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TESTING OF WEIGHING EQUIPMENT

NATIONAL BUREAU OF STANDARDS HANDBOOK H37

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NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS HANDBOOK H37

TESTING OF WEIGHING EQUIPMENT

By Ralph W. Smith

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PREFACE

This volume is one of a series of handbooks designed to present in compact form comprehensive information relative to weights and measures supervision, and describes various types of scales and weights, the principles of their operation, and methods for their inspection and test. Current editions of other handbooks of this series are Handbook H26, "Weights and Measures Administration," published in 1941 and superseding Handbook H11 of the same title, and Handbook H29, "Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices," published in 1942, and superseding several earlier publications issued under similar titles. Handbook H26 treats of the general aspects of the subject; Handbook H29 presents the codes of specifications, tolerances, and regulations for commercial weights and measures and weighing and measuring devices, adopted by the National Conference on Weights and Measures and recommended by the National Bureau of Standards for State promulgation.

It was originally planned that the third Handbook of the series would discuss methods of inspection and test for all of the various types of commercial weighing and measuring devices commonly encountered by the weights and measures official. The preparation of material has been so delayed that it is deemed inadvisable to withhold from publication the material already completed on weighing equipment pending the preparation of material on measuring equipment; accordingly the present publication, which deals only with weighing equipment, is being issued, to be followed, if and when practicable, by another publication dealing with the various types of commercial measures and measuring devices.

It is not the duty of a weights and measures officer to repair commercial equipment which he finds to be in faulty condition. Since this Handbook is intended primarily for use by weights and measures officers, it does not, therefore, enter the field of repairing weighing equipment, but is basically restricted to a discussion of methods of making those inspections and tests which the weights and measures officer must make in the discharge of his official duties. However, in the belief that an understanding of some of the fundamental principles of their operation is essential if intelligent tests are to be applied to weighing and measuring devices, there have been included brief discussions of these principles for the various types of apparatus treated; these discussions are elementary and are intended to give just enough information to fulfill the requirement stated.

In addition to the discussion of methods of inspection and tests, there are included for each of the fundamental types of scales, and for weights, outlines in which the several steps of the recommended test procedure are tabulated in their proper sequence. Of necessity, the treatment of the many kinds of commercial apparatus in use must be by general type only; that is, it is out of the question to mention each variation of the general type which may be manufactured. If the basic principles of each test are borne in mind, it is believed that no difficulty will be experienced in adapting the test routine to all equipment encountered. It is recognized that the equipment and testing methods which are recommended are not necessarily the only equipment and methods which may be used successfully; it is believed, however, that the recommendations given represent the preferred procedure.

Mention is made from time to time of "specifications" and "tolerances;" where some specific requirement of specifications or tolerances is cited, the reference is to the specifications and tolerances as published in National Bureau of Standards Handbook H29, previously referred to.

Technical words and phrases which are used are defined whenever definitions are considered necessary or advisable. It will be noted that in numerous instances use is made of expressions peculiar to or having a particular significance in weights and measures practice; where the weights and measures usage differs from the customary, scientific, or engineering usage, the difference is explained.

A schedule of weights and equipment recommended for use in the field testing of commercial scales and weights, is given as appendix I of this Handbook. Appendix II comprises weights and measures tables and equivalents. In appendix III will be found citations to other publications of the National Bureau of Standards and to some outside publications, containing information supplementary to that published in this Handbook and which will be helpful in developing full understanding of testing methods for weighing equipment.

Although, as previously stated, this Handbook has been prepared primarily for use by weights and measures officials of the States, counties, and cities, it is believed that much of the information presented will be of material assistance to persons employed by commercial and industrial establishments in the maintenance of weighing equipment.

LYMAN J. BRIGGS, Director.

CONTENTS

TESTING OF WEIGHING EQUIPMENT

A manual for State and local weights and measures officials, describing various types of commercial weighing equipment, the principles of their operation, and methods for their inspection and test.

By Ralph W. Smith

Chapter 1.—BASIC PRINCIPLES: MASS AND WEIGHT; LEVERAGE; EQUILIBRIUM

Mass and Weight.—The "mass" of a given body is the quantity of matter comprising it. The force exerted by gravity upon any body is proportional to the mass of the body. The "weight" of a given body is a measure of the force of gravity acting upon that body. What is commonly called a "standard weight" is really a standard mass of metal or other material, by comparison with which the masses of other bodies may be determined through measurements of their respective weights, or by means of which the values of forces may be measured. In our customary system, the "pound" is the unit for both mass and weight. The force of gravity acting upon the standard 1-pound mass, under standard conditions, is a standard 1-pound force.[1]

The actual gravitational force acting upon a given body varies with the location of the body; that is, this force is measurably less upon a mountain top than it is at sea level, other conditions remaining unchanged. Thus, even while the mass of a given body remains constant, its weight may be said to be variable, depending upon the location of the body. However, if the weight of the body is determined, directly or indirectly, by the use of

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[1] This definition of the unit of force sets up an "absolute" unit; that is, one which is invariable, regardless of location. Ordinarily, engineering measurements are made by the "gravitational" unit defined as the actual force of gravity acting upon a 1-pound mass in any particular location. As explained in the text immediately following, this latter unit varies slightly; the variation is so small, however, that it may be neglected in all ordinary work.

standard weights, the observed value of the weight of the body will not vary with the elevation (other conditions remaining unchanged) because the changed gravitational force will be applied both to the body being weighed and to the standard weights (or their equivalent), and the weight of the body in terms of the standard weights will be unchanged; in other words, a 1-pound standard weight will counterbalance the same mass or amount of a given commodity at sea level as on a mountain top.[2]

In commercial transactions involving quantity determinations, the fundamental consideration is usually to determine the mass or the amount of commodity; since these determinations are made, however, in terms of weight, as previously defined, the expression "weight" is loosely used to represent the amount of commodity. Thus, "5 pounds of iron" really is a mass of iron such that the force of gravity acting upon it is five times as great as the force of gravity acting upon a standard mass known as the "pound." But this iron would customarily be said to have a "weight" of 5 pounds rather than a "mass" of 5 pounds. On the other hand, there are times when the fundamental consideration in a weighing operation is to determine the amount of a force. It may be desired to determine a quantity of iron —as for a "sash weight," for instance—such that the force exerted by or upon this amount of iron will be five times that exerted by or upon a 1-pound standard weight. Although the actual quantity of iron would be the same in both cases, in the former case it was the mass, or the amount of commodity, and in the latter case it was the weight, or the "heaviness" of the commodity, which was of fundamental importance. These two viewpoints may readily be differentiated by observing the distinction between the terms "mass" and "weight"; however, since the units of mass and weight are identical in name, and since no purpose would be served in the procurement of commodity if the two were to be differentiated, the distinction between them may be considered of academic interest rather than of practical importance.

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[2] In this discussion, variations which result from changes in air density (which are commercially unimportant) have been disregarded. Moreover, the general question of air-buoyancy corrections, which are practically never made in connection with commercial weighing transactions, is not discussed herein; for information on this subject, reference should be made to other publications of the Bureau.

As used herein, the word "scales" means weighing scales, that is, instruments used for determining weight, and embraces all types from the simple equal-arm beam to the relatively complicated weighing machines developed within the last 30 or 40 years. But whether simple or complex, the scale is a mechanism for opposing an unknown force with a known counterforce and thus determining the desired weight.

The majority of commercial scales employ one or more levers in their construction. The importance of scale levers warrants a brief discussion of the principles of leverage and of an allied subject—equilibrium.

Leverage.—A lever may be defined as a rigid member that is capable of turning about an axis and in which are two or more other points where external forces may be applied; it is used for transmitting and modifying force and motion. The axis about which a lever turns is called the "fulcrum"; the two other essential points on the simple lever may be termed the "power"[3] and "load" points.

There are three classes of levers, called the first, second, and third, and illustrated diagramatically as A, B, and C, respectively, in figure 1, where F indicates the fulcrum, L the load point, and P the power point. In

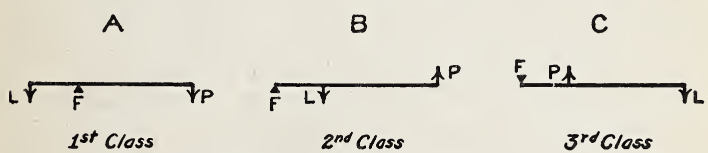

FIGURE 1.—*Classes of levers.*
F=Fulcrum.
L=Load point.
P=Power point.

a lever of the first class (A), the fulcrum is between the load and power points; in a lever of the second class (B), the load point is between the power point and the fulcrum; in a lever of the third class (C), the power point is between the load point and the fulcrum. Levers of the third class are rarely used in scale construction.

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[3] Throughout this publication the term "power" is used in its specialized scale sense as referring to the counterforce opposing the load; the term is not to be understood in its engineering sense of time rate of doing work.

Homely examples of levers of the different classes are: first class, pliers, seesaw, crowbar used as a pry, walking beam; second class, nut crackers, oar, pump handle when fulcrumed at end; third class, tweezers, sugar or fire tongs.

A lever may be used in scale construction for a variety of purposes. It may be used for the direct comparison of forces—as in the case of a simple equal-arm beam; it may be used to alter the amount of a force—as in the "multiplying" levers under a scale platform; it may be used merely to change the direction of application of a force, as from an upward to a downward direction—as in the reversing lever in a five-section railway track scale; it may be used merely to extend the point of application of a force—as the extension levers (used in tandem) sometimes employed between the platform levers and weighbeams of built-in scales; or it may have two or more of these functions.

The use of the lever to alter the amount of a force is a most important one in scale construction. The principles governing the multiplying power of a lever are simple, but should be well understood. The distance[4] from the fulcrum to the power point is called the "power arm" of the lever; the distance from the fulcrum to the load point is called the "load arm." The ratio between the length of the power arm and the length of the load arm is the "multiple," or the "ratio," of the lever.[5] For instance, if the power and load arms are equal, the ratio of the lever is 1:1 (read as "one to one"), its multiple is 1, or it is said to be an "equal-arm" or an "even" lever; if the power arm is five times as long as the load arm, the ratio of the lever is 5:1 (five to one), or its multiple is said to be 5. Any lever with a multiple greater than 1 is said to be a "multiplying" lever. (However, any lever with a multiple greater than 1 may also be considered to be a "reducing" lever; a given lever multiplies if the power point is considered to be the starting point of the consideration, and it reduces if consideration begins at the load point.)

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[4] In a scale lever, whenever the forces act along a line—as along the knife-edge of a pivot—this distance is measured at 90° to the line of action of the force, that is, perpendicular to the line of the knife-edge.

[5] It may be mentioned that the "multiple" of a lever is sometimes called by the physicist the "mechanical advantage" of the lever. Also, "multiple" is sometimes colloquially referred to as "count."

Thus if we assume three levers each of the same total length but of different class, and assign to the arms the distances indicated in the diagrams in figure 2, the lever

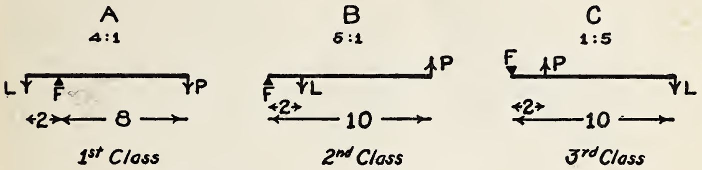

FIGURE 2.—*Arm lengths of levers.*
F=Fulcrum.
L=Load point.
P=Power point.

A has a ratio of 8:2 or 4:1; or its multiple is 4. Lever B, being fulcrumed at one end, has a longer power arm than lever A, and its ratio is 10:2 or 5:1; its multiple is 5. In lever C the power arm is shorter than the load arm, and the ratio is 2:10 or 1:5; its multiple is 1/5 or 0.2. This means that, disregarding friction and the weight of the levers, lever A would be in equilibrium with a load of 4 pounds at L and 1 pound at P (or with other loads in like proportion), lever B would be in equilibrium with 5 pounds at L and an upward force of 1 pound at P, and lever C would be in equilibrium with a load of 1 pound at L and an upward force of 5 pounds at P.

The law of the lever may be stated by saying that the power arm is to the load arm as the load is to the power, when the system is in equilibrium; or expressed as an equation:

$$\frac{\text{Power arm}}{\text{Load arm}} = \frac{\text{load}}{\text{power}}$$

or

Power arm multiplied by power=load arm multiplied by load.

When multiplying levers are connected, so that the power point of the first joins the load point of the second, the power point of the second joins the load point of the third, and so on, the multiple of the assembly is the product of the multiples of the individual levers. Thus, if a 4:1 and a 5:1 lever are so connected, the multiple of the assembly would be 20, the product of 4 and 5, the multiples of the two individual levers; in other words, considering the assembly as a whole, a power of 1 pound would counterbalance a load of 20 pounds. Such combinations of two levers of the first class, and of two levers, one of the first class and one of the second class, are illustrated

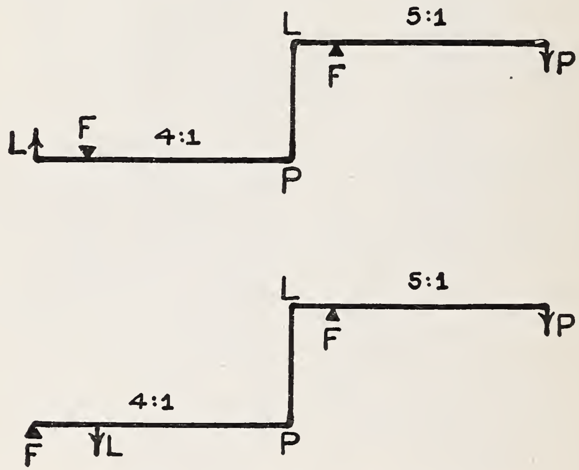

FIGURE 3.—*Combinations of levers.*
F=Fulcrum.
L=Load point.
P=Power point.

diagramatically in figure 3; in each case the multiple of the system is 20.

In scale construction, the multiples of the levers used are not always integral numbers; multiples such as 2.9, 3.4, 2⅔, 3⅓, etc., are not uncommon.

The multiple of a scale is the product of the multiples of the individual lever combinations comprising the scale, and is usually figured to the tip of the weighbeam, although on large scales and on scales having full-capacity weighbeams (that is, without counterpoise weights), the multiple to the butt of the weighbeam (that is, to the load pivot of the weighbeam) is frequently quoted. Scale multiples are more apt to be even figures than in the case of individual levers; portable platform scales usually have multiples of 100 or 200, whereas larger platform scales usually have multiples of 500, 1,000, or 2,000;[6] examples of the multiples of counter scales are 2, 4, 5, 20, 50, 53⅓, 66⅔.

When a scale is said to have a multiple of 100, or, as it is frequently expressed, a ratio of 100:1, it means that 1 pound at the tip of the weighbeam (where the counterpoise weights are applied) will counterpoise 100 pounds on the scale platform or other load-receiving element. A scale is always designed to have a lever system of a definite multiple. When the multiple of a scale with a counterpoise is not known, this may readily be found by first balancing the scale, then applying one unit of weight (as, for instance, 1 pound) at the tip of the weighbeam, and determining how many of the same weight units are required on the platform to restore the original condition of balance. For example, if 1 pound at the tip of the weighbeam counterpoises 200 pounds on the platform, the ratio is 200:1, or the multiple is 200.[7]

Equilibrium.—A body is said to be in equilibrium when the forces acting upon the body are balanced and do not change its state of motion. Three kinds of equilibrium are recognized—stable, unstable, and neutral; these are characterized by the result which follows a slight displacement of the body from its position when in equilibrium, and may best be described by citing examples. If a right cone resting on its base be tilted slightly and then released, it will return to its former position; as it rests on its base it is in "stable equilibrium." If this cone were to be inverted and balanced on its apex, or point, and then the base of the cone, which would be uppermost, were to be displaced sideways a slight amount, the cone would not return to its former position but would continue to move in the direction in which it had been

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[6] On modern railway track scales the butt multiple (multiple to the butt of the weighbeam) is usually 800 or 600, and the tip multiple (multiple to the tip of the weighbeam) 10,000 or 7,000, except on flexure plate scales, on which the multiples are considerably higher.

[7] The butt multiple can be determined as follows: With the scale in proper zero-load balance, apply a 1-pound weight to the load pivot of the weighbeam, and then reestablish a balance condition by means of the weighbeam poise; the resulting poise indication in pounds will be the desired butt multiple.

displaced; as it was balanced on its point the cone was in "unstable equilibrium." If this cone were resting on its side on a level table and were rolled along the table for a slight distance, it would neither return to its former position nor continue in motion, but would remain in its new position; as it rests on its side it is in "neutral equilibrium" with respect to displacement along the table top; although it is apparent that it is also in stable equilibrium with respect to displacement in a vertical plane, for if the point of the cone be raised slightly above the table top and be then released, the cone will return to its former position. Thus, in any given example, the criterion of the kind of equilibrium which prevails is the effect which follows a slight displacement around some line or point of support.

The "center of gravity" of a body is defined as the point through which the total weight of the body acts when the weight is considered as the resultant of the parallel forces of gravity upon all the particles of the body, no matter how the body may be turned about; from this it follows that the center of gravity is such a point that if the body could be suspended therefrom, it would remain at rest in any position. The position of the center of gravity of an object is determined by the distribution of the mass of the object. Assuming equal densities throughout, the centers of gravity of a sphere, a cylinder, a cube, etc. will be at the centers of the sphere, cylinder, cube, etc., respectively; if the object were so made, however, that the density were greater on one side than on the other, the center of gravity would lie somewhere between the center and surface toward the "heavy" side. In the case of bodies of irregular shape, the center of gravity may actually lie outside of the body itself; this may also be true in the case of certain bodies of regular shape as, for example, a ring.

The effect on the position of the center of gravity of an object or system which results from slight displacement of the object or system around a line or point of support, may also be considered as determining the kind of equilibrium which prevails. If displacement raises the center of gravity, the object or system is in stable equilibrium; if displacement lowers the center of gravity, the object is in unstable equilibrium; if displacement neither raises nor lowers the center of gravity, the object is in neutral equilibrium.

In the case of an object like the beam of an equal-arm balance, the position of the center of gravity with reference to the line of the fulcrum—that is, the axis of rotation of the beam or, specifically, the knife-edge of the fulcrum pivot—will determine the kind of equilibrium of the beam and also control in part the character of its oscillation and its sensitiveness. To have a condition of stable equilibrium, the beam fulcrum must be above the center of gravity; if, then, the fulcrum be lowered, as it approaches the height of the center of gravity the period of oscillation of the beam will increase, the speed of oscillation will decrease, and the beam will increase in sensitiveness. If the beam fulcrum be lowered to a point below the center of gravity, the beam will then be in unstable equilibrium or will be "accelerating," and will not oscillate at all.

These effects of a change in the fulcrum position may be demonstrated easily with a strip of wood. Select a strip relatively long and narrow. Try to balance this edgewise on a knife blade; the center of gravity is above the fulcrum line and the system will be unstable; even if a momentary balance is obtained, the slightest rotation will cause the strip to fall because it will continue to rotate in the direction of its initial displacement. Now cut a notch part way through the strip at its middle point (see fig. 4), but not extending quite to the center line, thus:

FIGURE 4.

and again try to balance the strip on the knife blade; the strip will be noticeably less "top-heavy" than before, but unstable equilibrium will still prevail, since the center of gravity is still somewhat above the fulcrum line. Cut the notch deeper a little at a time; a point will be reached where the strip will balance and oscillate slowly. The center of gravity is now slightly below the fulcrum line, and at this point it will be noticed that only slight pressure at the end of the strip will be required to depress it considerably. Continue to cut the notch deeper, thus lowering the center of gravity with respect to the fulcrum line. It will be noted that the period of vibration grows shorter, the swings more rapid, and the sensitiveness less, that is, greater pressure than before at the end of the strip will be necessary to cause the same angular displacement of the strip.

These facts are given consideration when scales are designed, and the manufacturer so places the fulcrum pivots of a beam that the desired results will be obtained. In order to provide a means for restoring the relation between the center of gravity of the weighbeam of a scale and the fulcrum knife-edge when the latter has been worn down as a result of use, and of thereby restoring in a measure the original sensitiveness of the scale, provision is frequently made for raising the center of gravity of the weighbeam by raising the balance-ball assembly.

Stable equilibrium must prevail if a scale weighbeam is to oscillate; a slow and even-swinging motion is preferred and this indicates the probability of relatively great sensitiveness. If unstable equilibrium prevails, the weighbeam will not oscillate and cannot be balanced, and is said to be "unstable" or "accelerating"; around what would otherwise be the balance position, an unstable weighbeam will rise or fall to its limiting stop and will remain either up or down. The remedy for an unstable weighbeam may be a lowering of its center of gravity with relation to the fulcrum line.

Chapter 2.—BASIC ELEMENTS: PIVOTS, KNIFE-EDGES, AND BEARINGS; THE SIMPLE BALANCE; THE STEELYARD; THE ROBERVAL BALANCE; THE COMPOUND LEVER SYSTEM; NOSE-IRONS; COUNTERPOISE WEIGHTS; GRADUATED WEIGH-BEAM BARS

Pivots, Knife-Edges, and Bearings.—In the discussion of leverage in the preceding chapter frequent reference has been made to the "fulcrum point," "load point," and "power point" of levers and weighbeams. It has been shown that the relative locations of these points fix the lengths of the arms of a lever or weighbeam and thus establish its multiplying power. It follows that these points must be definitely established if a lever or a system of levers is to be used as a part of a weighing device, and that they must remain fixed if the designed multiple is to be maintained.

Primitive weighing devices have been constructed with wooden levers in which the fulcrum, load, and power points were fixed by cords passing around or through the levers, the fulcrum cord being used to support the device, and the pans or hooks and the poises being attached to the other cords. Examples of this construction may still be seen in the so-called "Chinese" steelyards. Later, metal very largely replaced wood as a construction material for scale levers, and today most of the working parts of scales are of metal, cast iron, steel, brass, and certain aluminum alloys being the materials most commonly employed. In the ordinary present-day construction, hardened steel "pivots," each sharpened to a "knife-edge," are set into the lever at the load, power, and fulcrum points in such a way that the knife-edges will receive or transmit the forces or will support the lever and serve as the axis about which it tends to turn. These pivots are known, respectively, as the load, power, and fulcrum pivots of the lever. In a given lever the pivot knife-edges must be parallel. As long as the knife-edges remain fixed and sharp, each knife-edge receives or transmits force along a line definitely positioned with respect to the other knife-edges of the lever, and disregarding deflections, the multiple of the lever remains definite and constant.

Sometimes instead of being shaped to a knife-edge, a pivot is shaped to a point; such "point pivots" or "cone pivots" are made use of in certain cases where levers join at an angle or where a very flexible connection is needed, and are satisfactory where the transmitted forces are not too great.

Knife-edges or pivot points are always opposed by "bearings," suitably shaped for their particular service; surfaces of bearings opposing knife-edges may be plane (that is, flat), concave (that is, curved), or V-shaped, whereas those opposing pivot points are cupped or cone-shaped. The surface of the bearing designed to come in contact with a knife-edge or pivot point should be at least as hard as the opposing edge or point, so as to minimize any cutting or indenting effect.

Although steel is the customary material for pivots, agate is employed for this purpose in some precision balances. Agate is also used to a considerable extent for bearings in scales of small capacity.

Mention should also be made of a fairly recent development in commercial scale manufacture—the use of the so-called "flexure-plate" or "plate fulcrum" principle, wherein thin plates of steel, rigidly secured to the two cooperating members, replace the conventional pivots and bearings. In another type of construction, limited to scales of relatively small capacity, tightly stretched steel bands are utilized as a substitute for conventional pivots and bearings.

The Simple Balance.—The earliest form of weighing machine of which we have any record is the equal-arm balance with suspended pans—a type which is still used for a wide variety of weighings, ranging from commercial operations to scientific weighings of the highest precision.

This type of scale consists essentially of an equal-arm beam; means for supporting the beam fulcrum, either a pillar or a stirrup with a hook or ring; and two pans, one depending from each end of the beam. There may or may not be a pointer or indicator mounted on the beam to assist in determining the balance point. In ordinary weighing with this type of scale, commodity on one pan is counterpoised with weights of equal amount on the other pan, there being no multiplication of force in the system; such a scale has the obvious disadvantage that standard weights must be provided equal in value to the value of the commodity being weighed.

The Steelyard.—After the equal-arm balance, the next development in weighing devices was the unequal-arm beam, commonly known today as the steelyard. This development is ascribed to the Romans, and, as in the case of the simple balance, the type has survived to the present time. In this type, commodity on a hook or pan suspended from the short arm of the beam, is counterpoised by a much smaller amount of weight acting through the longer arm. By means of a movable weight, called a "poise," and graduations on the long arm of the beam, weight indications from zero to the capacity of the steelyard may be obtained with a single poise of relatively light weight. By utilizing two series of graduations on the beam and two poises, one small and one large, the same steelyard may be used for comparatively light and heavy weighings. When the weight of the poise is increased, heavier loads may be weighed, but the value of a given beam interval will be increased, and hence the precision with which the beam can be read will be proportionally reduced.

The simple balance and the steelyard are both examples of a lever of the first class. These simple types of weighing instruments served the needs of commercial weighing for many centuries before any further advances were made in scale design. They were inexpensive as well as simple to construct, for the comparatively light loads weighed they were portable and easy to use, and with the steelyard it was not necessary to have weights to the value of the loads to be weighed, giving this type an added factor of great convenience as compared with the simple balance.

The Roberval Balance.—In the seventeenth century a French mathematician named de Roberval devised a mechanical paradox which demonstrated an important new principle. Roberval's device consisted of a hinged parallelogram, each horizontal member being fulcrumed at the middle, and each vertical member having a bar rigidly attached at a right angle to it and projecting outwardly, as indicated diagrammatically in figure 5. With this device in equilibrium, equal weights (as *A* and *B* in

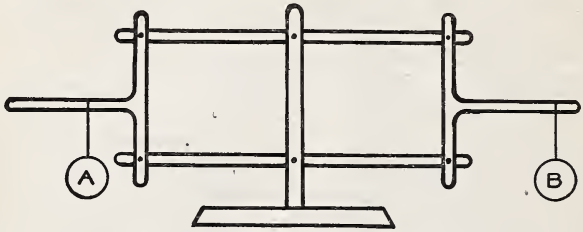

FIGURE 5.—*The Roberval principle.*
Diagrammatic sketch of the device by which the principle was originally demonstrated.

fig. 5) may be hung from any points along the projecting bars without disturbing the equilibrium of the device.

It was not long before the Roberval principle was applied to scales for commercial weighing. The adaptation of this principle to an equal-arm weighing device was accomplished by replacing the projecting bars of the original device with pans mounted above the vertical members of the parallelogram, thus providing the first example of "stabilized pans" with the load imposed above the weighing mechanism. The same principle was later applied to the unequal-arm type of scale. These two types are illustrated diagrammatically in figure 6. The essential condition in scales of the type illustrated is that

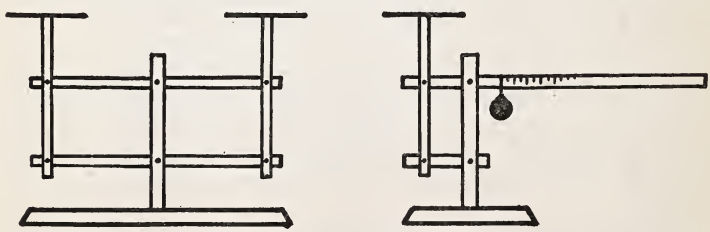

FIGURE 6.—*Application of the Roberval principle to weighing scales.*
Diagrammatic sketches of stabilized-pan scales of the simple equal-arm and unequal-arm types.

the members of the system form a parallelogram; that is, that the two upright members be parallel and that the other two members be parallel. If the parallelogram is not maintained, incorrect weighing results will be obtained whenever a load is not centered directly over the supporting upright member.

In commercial scales embodying the Roberval principle, the parts corresponding to the parts illustrated in the diagrams in Figure 6 are essentially as follows: The main lever, or the lever and graduated beam combined, correspond to the upper horizontal member in the diagrams; the support for the main-lever fulcrum corresponds to the central vertical member shown attached to the base; the stabilizing bar or link, or the check link, corresponds to the lower horizontal members shown in the diagrams, and in the commercial scale this is relatively light as compared with the upper member.

It may be well to mention at this point that the application of the principle of pan stabilization outlined above is not now confined to the simple lever designs described nor to the two simple types of scales mentioned, but is also applied to certain relatively complex equal-arm lever systems and to many compound-lever scales; also that in the more elaborate types of scales the stabilizing bar or check link is frequently located above the main levers rather than below them, in order to obtain certain advantages in the operation of this element, which need not be detailed here.

The Compound-Lever System.—In the "compound lever system" there are combined into one working unit two or more simple levers; the expression is more often used, and will be used in this discussion, as referring to systems of levers having multiples greater than 1.

The present development of the compound-lever principle in scale construction is an answer to the demand for a weighing machine capable of weighing bulky and heavy loads with speed and convenience. It would be neither a speedy nor convenient operation to weigh a wagon-load of hay or a truck-load of coal on an equal-arm type of scale or by means of a steelyard; the weighing is quickly and easily performed, however, on a multiplying-lever platform scale of suitable capacity. The original problem in this particular connection was to devise a scale that would weigh a loaded, horse-drawn vehicle; this problem was solved by the 4-, 5-, or 6-ton "wagon" scale. The advent of the motor truck, however, marked the beginning of a period of further development in scale construction, and the steady increase in the size and weight of trucks and in the amount of "pay load" they are designed to carry has necessitated a corresponding increase in the strength and weighing capacity of vehicle scales, until now 15- and 20-ton "motor-truck" scales are being generally installed for vehicle weighing, and motor-truck scales having capacities of 30, 40, and 50 tons are also available. A comparable development has also taken place in the field of railway-freight-car weighing; the 40- or 60-ton railway track scale has virtually disappeared, to be replaced by scales of capacities of 120 to 250 tons.

Considering the many centuries during which weighing devices have been in use, the development of the compound-lever scale has been comparatively recent. The principle of its operation is simple, however. As previously stated, it is a combination of simple multiplying levers so arranged that a load applied at one end of the system is counterpoised by a relatively small force applied at the other end of the system. For example, two 15:1

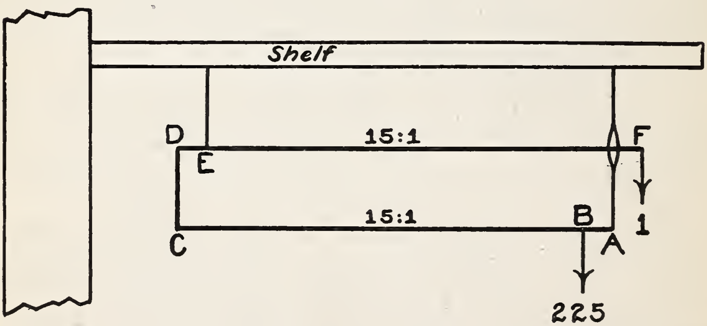

FIGURE 7.—*The "butchers meat beam."*

Diagrammatic sketch of the lever system.

A=Fulcrum of lower lever (second class).

B=Load point of lower lever and also of the system as a whole.

C=Power point of lower lever.

D=Load point of upper lever (first class).

E=Fulcrum of upper lever.

F=Power point of upper lever and also of the system as a whole.

levers may be mounted one above the other, and combined by connecting the power pivot of the lower one to the load pivot of the upper one to produce a multiple of 15×15, or 225, between the load pivot of the lower one and the power pivot of the upper one; in this arrangement a load of 225 pounds suspended from the load pivot of the lower lever would be counterpoised by a force of 1 pound applied at the power pivot of the upper lever. This is the general scheme of the type of commercial scale commonly known as a "butchers meat beam"; it is illustrated diagrammatically in figure 7, the multiples assumed above being indicated.

In a platform scale the compound-lever principle is the same, although the arrangement of parts is somewhat different. Here there is a group of levers known as the "platform levers" which support the platform and through which the force exerted by the load on the platform is transmitted (either directly or through one or more additional levers) to the last lever in the system, the "weighbeam" of the scale, where it is counterpoised by a relatively small force. Such a system typical of the "portable platform" type of scale is diagrammatically illustrated in figure 8. There are two platform levers, each one branched so that there are a fulcrum and a load point at each of the four corners of the platform; the effect is the same as though there were four separate levers. These two levers are spoken of as the "long" and the "short" levers; the former extends from A_1 and A_2 through O to C, and the latter extends from A_3 and A_4 to O. The four load arms, $A_1 B_1$, $A_2 B_2$, $A_3 B_3$, and $A_4 B_4$, are the same length, and the distance, measured perpendicular to the line of the fulcrum knife-edges, from each of the fulcrums A_3 and A_4 to the power pivot O of the short lever—the power arms of the short lever—is the same as the distance, measured as before, from the fulcrums A_1 and A_2 of the long lever to the point O, where the two levers are connected by means of a loop. Thus the multiple of each branch of the short lever is the same as the multiple of each branch of the long lever up to the point O; and by reason of the connection of the two, the extension OC of the long lever affects forces transmitted through the short lever in the same way and in the same proportion as it affects forces transmitted through the

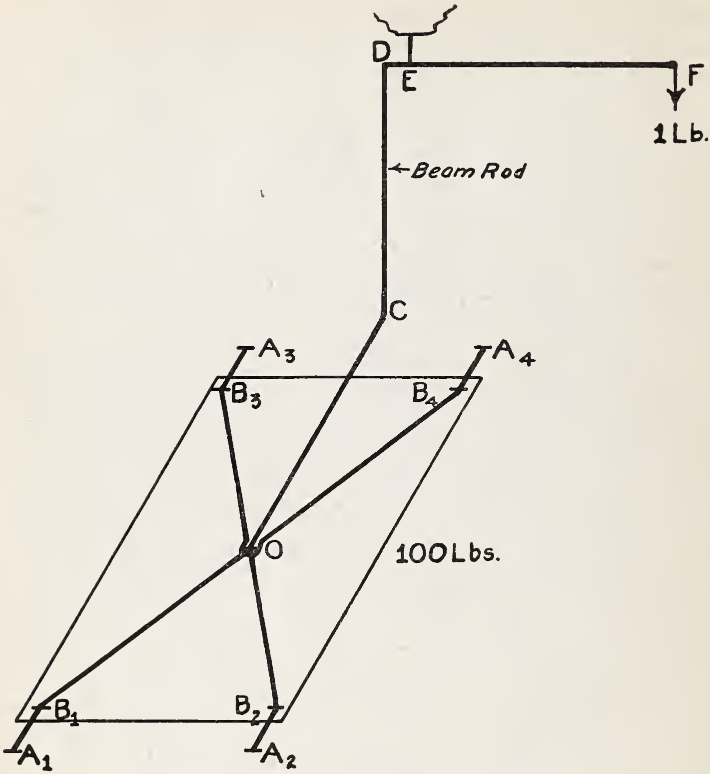

FIGURE 8.—*The "portable platform" scale.*

A_1, A_2=Fulcrums of long lever.
A_3, A_4=Fulcrums of short lever.
B_1, B_2=Load points of long lever.
B_3, B_4=Load points of short lever.
C=Power point of long lever.
D=Load point of weighbeam.
E=Fulcrum of weighbeam.
F=Power point of weighbeam and also of the system as a whole.
O=Power point of short lever and secondary load point of long lever.

The scale platform is indicated by light lines.

branched portion of the long lever. In the assembly, the result is the same as though the power arm of the short lever were lengthened by an amount equal to *OC* and joined the long lever at C. In other words, a given load applied at any one of the load points B_1, B_2, B_3, or B_4 is counterpoised by the same force at the point C.

It will be noted that the lever arrangement illustrated in figure 8 is of a different character from those illustrated in figure 3, page 6, and in figure 7, page 16. The multiple of the platform lever system shown in figure 8 is not the product of the multiples of each branch of the two levers, but is the multiple of any one branch traced from its fulcrum to the point C. As previously stated, it is only when levers are connected "in series," so to speak, with the power pivot of the first joining the load pivot of the second, the power pivot of the second joining the load pivot of the third, and so on, that the multiples of the separate levers are multiplied together to find the multiple of the system. Thus, reverting to figure 8, if we assume a scale multiple of 100, as shown, and if we assume that the weighbeam has a multiple of 10, the multiple of the platform lever system would be 100 divided by 10, or 10; and this would also be the multiple of each branch of the platform levers with respect to the point C. (It will be obvious that the beam rod merely transmits the force between the platform levers and the weighbeam and has no effect upon the multiplying power of the system.)

At this point it may be well to repeat that the effective length of a lever arm with a knife-edge fulcrum is the perpendicular distance from the line of the fulcrum knife-edge to the point of application of load or counterpoising force. Thus, the power arm of a lever like the long lever in a portable-platform-type scale, such as is discussed above, is not measured along the actual lever, but is measured as the perpendicular distance from fulcrum knife-edge to power knife-edge, as illustrated diagrammatically in figure 9.

The distinction between the so-called "straight" lever and the "pipe" lever will be brought out in the discussion of warehouse types of scales in chapter 4.[8]

Nose-irons.—In the manufacture of scale levers and weighbeams, these are designed to have certain multiples so that the combination, when assembled as a complete scale, will have a certain multiple. It is at times a matter

[8] See page 48.

of considerable difficulty to set the pivots in a lever so that the actual distances between the knife-edges will conform with sufficient exactness to the designed distances, so manufacturers have had recourse to the expedient of making the power pivots in one or more of the

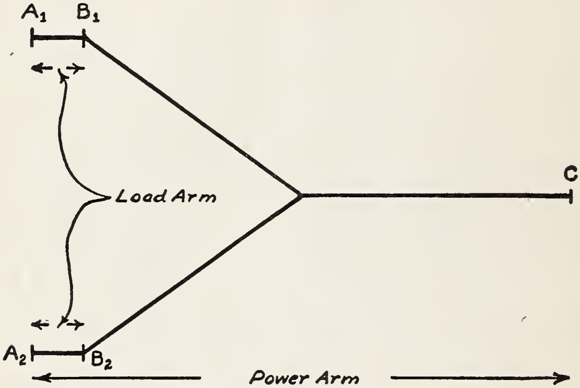

FIGURE 9.—*The "arms" of the long lever of a portable platform scale.*

A_1, A_2=Fulcrum knife-edges.
B_1, B_2=Load knife-edges.
C=Power knife-edge.

levers of the system, adjustable with respect to their distances from their respective fulcrums.[9] By means of these adjustments, slight inaccuracies in the setting of the pivots may be compensated for and the multiple of the lever or of the system be brought to the designed value.

The slidably mounted, manually adjustable pivot assembly just described is known as a "nose-iron." The nose-iron may be held in place by set screw and bolts, by clamping bolt alone, or by the differential action of a combination of two screws.

There may be mentioned briefly another matter to which scale designers also give consideration. This is what is called the "range of the pivots." This expression refers to the position in a lever of the fulcrum knife-edge relative to a line joining the load and power knife-edges.

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[9] In comparatively rare instances the load pivot of a lever may be designed to be adjustable with respect to its distance from the fulcrum pivot.

In figure 10 three kinds of ranging are illustrated diagrammatically for a lever of the first class, the letter *F* indicating the fulcrum pivot in each case. The first sketch (*A*) shows all three knife-edges in line; these

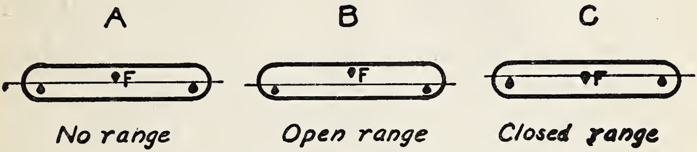

FIGURE 10.—*Range of pivots.*
Diagrammatic sketches of equal-arm levers to illustrate the three kinds of range.
F=Fulcrum.

pivots are said to have "no range," "neutral range," or "flat range." The second sketch (*B*) shows the fulcrum knife-edge above the line joining the other two; this is an example of "open range," and the amount by which the fulcrum knife-edge fails to reach the line joining the other two knife-edges is the "amount of the range," or the amount by which the pivots are "ranged." The third sketch (*C*) shows the fulcrum knife-edge below the line joining the other two knife-edges; this condition is known as "closed range," and the amount of the range is the amount by which the fulcrum knife-edge projects through the line joining the other two knife-edges.

The neutral condition is the theoretically ideal one, and in precision balances the beam is designed to realize this condition. In commercial scales, however, it is customary to design and construct most weighbeams and certain levers so that these will have closed range, the amount of the range depending upon the loads on the pivots and the resistance of the lever or weighbeam to deflection under such loads, being greater the greater the anticipated deflection. It is obvious that with closed range, deflection of the lever or weighbeam will cause the pivots to approach or to realize the neutral condition, or even to attain a condition of open range. Closed range in a lever or weighbeam also permits some wearing down of pivot knife-edges before a condition of open range, which it is desired to avoid, is reached.

It may be noted that levers and weighbeams of automatic-indicating scales, which are designed to assume various angular positions under differing conditions of loading of the scale, are normally designed with neutral range.

Counterpoise Weights.—With a scale made to a definite multiple, the weights which are to be used at the tip of the weighbeam, and which are known as "counterpoise" weights, may be made independently to certain predetermined values, with the assurance that when used with the scale they will give accurate results; in this way the necessity for "sealing," or putting into adjustment, particular weights for each individual scale is avoided, and the confusion and inaccuracies which otherwise would result in use through the mingling of weights belonging to similar scales of different multiples are eliminated.

The "counterpoise hanger" which, in many designs, is hung from the tip pivot of the weighbeam, serves primarily as a support for the counterpoise weights, but is also utilized as a receptacle for balancing material. The counterpoise weights designed for use on a hanger are relatively flat and are slotted to fit conveniently on the hanger around the hanger "stem."

If the multiple of a scale to the tip of the weighbeam (that is, to the knife-edge at the tip of the weighbeam) is 100, this means that 1 pound at this point will counterpoise 100 pounds on the load-receiving element. A counterpoise weight accurately sealed to 1 pound will therefore have a counterpoise value of 100 pounds on this scale, a 2-pound weight will have a counterpoise value of 200 pounds on the scale, and so on.

A counterpoise weight is required to be marked with two values: (1) the "nominal value"—that is, the designed actual mass of the weight; and (2) the "counterpoise value"—that is, the value in terms of load on the load-receiving element, which the weight represents when used on any scale having a multiple proper for the weight in question. Thus the 1-pound weight in the foregoing example would be marked 1 LB—100 LB, the 2-pound weight would be marked 2 LB—200 LB, etc.

The relation between the counterpoise value and the nominal value of a particular counterpoise weight, expressed as a ratio, is the ratio of the scale with which it is intended that the weight be used; in the foregoing example this is 100:1. Obviously, a counterpoise weight can have an actual counterpoise value agreeing with the marked counterpoise value only when it is used on a scale of the intended multiple. For example, a weight marked 2 LB—200 LB must be used only on a scale having a ratio of 100:1; if used on a scale with a multiple, for instance, of 1,000, the counterpoise value of the weight would be 2,000 pounds instead of 200 pounds as marked.

The so-called "bottle" and "hanger" weights perform functions similar to those of ordinary slotted counterpoise weights, but differ from the latter in the following particulars: The bottle weight is somewhat bottle-shaped; it is provided with a hook and is intended to be applied directly to a weighbeam loop (as is the counterpoise hanger) and not used in direct connection with a counterpoise hanger; it is ordinarily applied at the tip of a weighbeam, but in special scales is sometimes applied at the butt of a weighbeam. A hanger weight resembles a counterpoise hanger in general appearance, but of course has no receptacle for loose material and is sealed to a definite value; it is designed usually as the first of a series of counterpoise weights to be applied at the weighbeam tip, other weights of the set being slotted and being applied on the hanger weight as a support. Bottle and hanger weights should be marked as in the case of other counterpoise weights.

Graduated Weighbeam Bars.—Even though it is possible to do so, it is impracticable to have counterpoise weights for all of the desired weight indications on most commercial scales. The weighbeam of the scale is therefore graduated and fitted with a movable poise, from which combination, weight indications of various amounts may be obtained. The greatest value indicated on the graduated weighbeam should equal or exceed the value of the smallest counterpoise weight furnished with the scale, so that weight determinations from zero to the capacity of the scale may be made.

The poise on a weighbeam may be considered as a fixed force acting on the beam through a power arm of varying length. Let us assume a portable-platform-scale weighbeam graduated from 0 to 100 pounds, the poise placed in the zero position, and the scale "balanced," that is, in such condition that the weighbeam will oscillate about the midpoint of its permissible travel between the stops of the "trip loop," which surrounds the weighbeam near its tip. If the scale is properly adjusted, the poise may now be advanced to a position where the weighbeam reading is 100 pounds and in this position will counterpoise a load of 100 pounds on the platform; the actual weight of the poise is such that when advanced from the zero graduation to the 100-pound graduation on the weighbeam, the counterforce applied to the lever system is equal to that which would be applied by a 1-pound weight on the counterpoise hanger. By moving the poise only half as far, only half the former force would be applied and only half the former load would be counterpoised.

By making the poise heavier, the same force as before can be applied by displacing the poise a shorter distance from its zero position. On the scale cited in the foregoing example, another bar may be added to the weighbeam, and this may be fitted with a poise several times as heavy as the first one—for example, nine times as heavy; when this large poise is advanced from its zero position a distance equal to the travel of the small poise from the zero to the 100-pound graduations, it will counterpoise 900 pounds on the platform.[10] Such an arrangement eliminates the necessity for any counterpoise weights at all on a 1,000-pound scale; all weight indications from zero to 1,000 pounds can be obtained with the two poises. A scale so equipped is said to have a "full-capacity weighbeam"; that is, weighings up to the full capacity of the scale may be made on the weighbeam bars without the use of any loose counterpoise weights.

In a full-capacity weighbeam, the "main" bar—the one having the large poise—may have only a small number of

[10] The actual weight of a weighbeam poise may be computed as follows: Multiply the weighbeam capacity (in pounds) by the length (in inches) of the weighbeam power arm; divide the result by the product of the multiple at the tip of the weighbeam and the poise run (in inches); the result is the weight (in pounds) of the poise. The terms may be rearranged and the steps expressed as the formula

$$\text{poise weight} = \frac{\text{weighbeam capacity}}{\text{poise run}} \times \frac{\text{weighbeam power arm}}{\text{weighbeam tip multiple}}.$$

An alternative formula is

$$\text{poise weight} = \frac{\text{weighbeam capacity}}{\text{poise run}} \times \frac{\text{weighbeam load arm}}{\text{weighbeam butt multiple}}.$$

graduations; in this design the interval between these graduations corresponds to the capacity of the "fractional" bar—the one with the small poise. In order that the main poise may be definitely positioned at each of its several graduations, it is customarily provided with a pawl, or latch, which fits into notches cut into the weighbeam bar. Thus, in the example cited above, there would be a notch for the main poise at zero and at successive 100-pound positions.

Frequently, scale weighbeams have more than two graduated bars, but not all weighbeams having two or more bars are full-capacity weighbeams. Sometimes the fractional bar and poise of a full-capacity weighbeam are incorporated in the main poise. Some weighbeams on large scales are "type registering"; that is, they are so designed as to enable the operator to impress on a weigh ticket a record of the weight for which the main and fractional poises are set. Frequently the bar or bars of a weighbeam that is not a full-capacity weighbeam are provided with notches throughout their graduated lengths (such a bar is known as a "notched" bar) and are equipped with poises provided with pawls to engage the notches; or such a bar may be provided with a "hanging" poise, that is, one provided with a loop or hook equipped with a knife-edge element to engage the notches, and which hangs below the bar. A weighbeam bar without notches is known as a "smooth" bar.

Chapter 3.—AUTOMATIC WEIGHT INDICATION: AUTOMATIC-INDICATING SCALES; THE SPRING; THE PENDULUM; THE DASH POT; INDICATING MEANS

Automatic-Indicating Scales.—Just as the demands of trade for the unit weighing of large loads brought about the development of scales of large capacity, so the demands of trade for rapidity in weighing are primarily responsible for the development of the modern automatic-indicating type of scale.

Automatic indication of weight, in its simpler forms, has been known of for a long time, but the principle was not applied to commercial weighing machines immediately upon its discovery. When it was so applied, it was at first confined to weighing devices of small capacity; through the initiative of scale manufacturers, however, the application has been extended to embrace scales for practically all purposes and of all capacities.

Automatic-indicating scales must not be confused with scales which automatically weigh out successive amounts of commodity in drafts of predetermined weight, such as automatic grain hopper scales, automatic packaging scales, etc. The automatic-indicating scale is one "in which is embodied or to which is attached a self-acting mechanism, the capacity of which may be equal to or less than the nominal capacity of the scale, through the agency of which the indicated weights of loads of various magnitudes may be obtained."[11] The trade expression "full automatic" is applied to an automatic-indicating scale in which the capacity of the automatic-indicating mechanism equals the weighing capacity of the scale; the expression "semi automatic" may be used to distinguish scales in which the total weighing capacity exceeds the capacity of the automatic-indicating mechanism, this mechanism being operated in conjunction with one or more weighbeams, with enclosed, mechanically applied "unit" weights, with loose counterpoise weights, or with a combination of these.

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[11] Quoted from the definition adopted by the National Conference on Weights and Measures, paragraph A-2d of the code for scales.

To obtain automatic indication of weight when a load is applied to a scale, it is necessary that the "counterforce"—that is, the force required to counterpoise the load—be automatically applied or adjusted to the proper amount, and that suitable means be provided to indicate the value of the load. Designs have been worked out for electrical operation and control of beam scales, whereby the poise would automatically be set to the proper point on the beam when a load is applied; these systems have not been used to any great extent, however. Ordinarily the counterforce is supplied by one or more springs—usually of the cylindrical coiled or helical type—or by means of a modified lever known as a "pendulum."

Except in the simplest designs of automatic-indicating scales, the counterforce referred to above acts in combination with a lever system of one kind or another. Drawing a rough analogy between the automatic-indicating scale and the hand-operated beam scale, it may be said that the spring or pendulum mechanism, the indicator, and the reading face of the former correspond to the poise, graduated beam, and counterpoise weights of the latter; platform lever systems are employed in platform scales of either class.

The Spring.—"Elasticity" is that property of a body by which it is capable of recovering its original size and shape after it has been forcibly distorted. With reference to a given body, the "elastic limit" is the greatest stress (force per unit area) to which a body may be subjected without preventing its recovery of its original form after the distorting force has been released; if a stress in excess of the elastic limit is produced, an appreciable "set," or permanent deformation, will be caused. A "spring" may be defined as an elastic body or device; that is, one which, when released after having been forcibly distorted (its elastic limit not having been exceeded) will recover its original shape.

An important principle relative to elasticity, known as Hooke's law, may be stated for helical springs as follows: The extension of any spring is proportional to the stretching force. This law holds only within certain limits. The limiting stress at which Hooke's law remains true is known as the "proportional limit"; in other words, the proportional limit is the highest stress at which extension is proportional to stress. The proportional limit may be shown to differ from the elastic limit; in the case of certain materials these differences are considerable, although in the case of materials commonly used in the construction of springs, these differences are negligible.

The principle expressed in Hooke's law is the basis for the use of springs in scale construction to supply counterforce. For years such springs have been ordinarily made of steel, hardened to the proper point, and usually constructed of wire of circular cross section wound into a helix or cylindrical coil, that is, a coil of circular cross section and uniform diameter. Factors of importance in the design of such springs may be noted as follows: The extension under a given load will be greater the greater the number of turns, the greater the diameter of the coil, and the smaller the diameter of the wire. Another fact of importance when such springs are used in scale construction is, that they are affected by temperature; as the temperature is increased the spring grows "weaker" and will stretch a greater amount under a given load than at a lower temperature. Many of the more elaborate spring scales have been equipped with automatic, thermostatically controlled adjusting devices designed to compensate for the variations in the resistance or elasticity of the springs, resulting from changes in temperature.

Within the past few years special alloys have been developed as materials for spring manufacture, and special heat treatments and special designs for the springs have been worked out, such that for the practical purposes of scale construction, the elasticity of the resulting helical springs is essentially unaffected by temperature changes within the range of temperatures to which commercial weighing scales are normally subjected.

The Pendulum.—As used in scale construction, a "pendulum" is not primarily an oscillating member—as is the case in a clock pendulum—but is a modified lever of the first class, with the distinguishing and very useful characteristic of having, in effect, arms of variable effective length which automatically adjust themselves to counterpoise any load within the capacity range for which the pendulum is designed. It consists essentially of a lever having a comparatively large mass, known as the "pendulum weight" or "pendulum ball," secured at or near the free end of the long arm. The diagrammatic sketches shown in figure 11 illustrate the characteristics

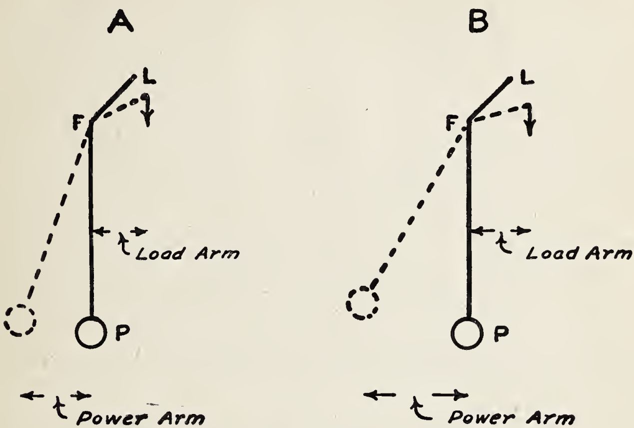

FIGURE 11.—*The pendulum as a counterforce.*
Diagrammatic sketches illustrating the varying "power" of a pendulum.

of the pendulum as used to supply the counterforce in an automatic-indicating scale. Referring to sketch *A*, if the pendulum is fulcrumed at *F*, a small load hung from *L* will cause the pendulum to rotate to a new position, as indicated by the dotted line, such that the weight of the pendulum ball acting through the power arm of the pendulum will just counterpoise the load acting through the load arm of the pendulum. If a larger load be hung from *L*, equilibrium will again be established, but with the pendulum in a new position, as indicated by the dotted outline in sketch *B*; the larger load is counterbalanced without any change in the weight of the pendulum ball, by reason of the new ratio between the power and load arms of the pendulum. For any position of *FP* between the vertical and the horizontal, the power arm of the pendulum increases as the pendulum ball is lifted.

The angles through which *FP* is displaced and the changes in the length of the power arm of the pendulum are not directly proportional to the loads applied. Moreover, considerations of scale design usually make it impracticable to apply the load to a pendulum through a straight extension from the fulcrum, such as is indicated by *FL* in figure 11. Accordingly, in ordinary scale practice a cam is mounted integral with the pendulum at a point near the fulcrum, and the load is applied through a flat, flexible, steel tape or ribbon operating over the curved surface of the cam. The curvature of the cam may or may not be circular, and the center of curvature may or may not lie in the line of the fulcrum of the pendulum. By controlling the curvature of the cam surface with respect to the fulcrum of the pendulum, it is possible to produce a pendulum scale in which throughout the weighing range of the scale, equal increments of load will cause equal increments of relative movement of the indicating elements connected to the pendulum. Cams are frequently made adjustable as to position in order to facilitate the adjustment for weighing accuracy of the assembled scale.

The amount of counterforce which a pendulum is capable of exerting depends upon the effective lengths of its load and power arms and upon the mass of the pendulum ball. Other factors remaining constant, the counterforce which may be exerted by a given pendulum will increase as the weight of the pendulum ball is increased, and as the distance of the pendulum ball from the fulcrum is increased. In scale construction provision is ordinarily made for changing the weight of a pendulum ball or for moving it up or down on its supporting arm, or for both, to facilitate the adjustment of the assembled scale for weighing accuracy.

The Dash Pot.—By reason of the very characteristic of the counterforce mechanism which makes the automatic-indicating scale possible—that is, its readiness to respond automatically, completely, and at once to changes, within the designed range, in the amount of platform load—this mechanism, and the indicating mechanism connected to it, tend to oscillate for an appreciable time after a load has been placed on the load-receiving element of the scale, before the parts come to rest in their final positions. This oscillation will continue for varying periods, depending upon a variety of factors, the amplitude of each succeeding "swing" of the mechanism being smaller, until finally the parts come to rest.

In order to reduce the amount of this oscillation so that weight indications may be obtained promptly, it is customary for all except the simple types of automatic-indicating scales to be equipped with devices to damp, or check, the oscillations. These devices are known as "dash pots."

In addition to limiting and damping the oscillation of the mechanism and thus bringing the reading elements quickly to rest so that readings may be precisely made, the dash pot performs another important function; this is to protect, or assist in protecting, the more or less delicate mechanism comprising the self-indicating portion of the scale, against the shock and possible damage or derangement incident to the sudden application or removal of a load.

The dash pot functions in its double capacity through the resistance which it offers to rapid movement of the scale mechanism; in other words, it operates as an effective brake. Dash pots are of two general kinds, liquid dash pots and air dash pots; the former are very much more widely used than the latter.

The type of liquid dash pot most commonly used comprises a hollow metal cylinder closed at one end, which is the liquid reservoir; and fitted within the cylinder a metal piston, usually provided with ports which are adjustable as to size. The piston adjustment makes it possible to control the resistance offered by the piston to movement in the liquid. The cylinder is fastened to the scale frame or housing and the piston is connected with an element of the automatic-indicating mechanism or of the lever system close to such mechanism. The resistance of the piston to travel in the liquid provides the necessary braking power to control the oscillation of the scale mechanism and to absorb some of the shock of loading impact.

The liquid used in these dash pots is usually a fairly light petroleum oil, although other liquids and mixtures have been utilized. The damping effect of a given dash pot may be increased or diminished by using a liquid of higher or lower viscosity. The selection of a suitable liquid for a dash pot of a particular design is governed to a considerable extent by the clearances around the piston, the area of the ports, the range of adjustment of the ports, the area of the piston, etc. Another important consideration is to obtain a liquid the viscosity of which will not be seriously affected by changes of temperature throughout the range likely to be met with in the use of the scale.

The air dash pot comprises a hollow cylinder, usually of brass, closed at one end (except that there may be a vent which may be fixed or adjustable as to size), and, fitted within the cylinder, a piston, usually of some self-lubricating material, such as a graphite composition. The operation of the air dash pot is similar to that of the liquid type.

Indicating Means.—The weight indications of an automatic-indicating scale are always read by means of some sort of indicator cooperating with a series of graduations. Either the indicator or the graduated member may be the movable element of the combination. The most rudimentary indicating system is illustrated in the "straight-face" spring scale, in which an indicator or pointer is attached to the lower end of a spring and, in conjunction with a straight, graduated scale, indicates directly, and without any multiplication, the elongation of the spring when loads are applied. There is a limit to the distance which the spring may be extended, and this limits the length of the graduated scale; the number of graduations per inch on the graduated scale is limited by the ability of an observer to distinguish the graduations; or expressed in another way, the value of each graduation in proportion to the capacity of the scale is limited by the ability of an observer to detect and read the value of slight changes in the position of the indicator. In consequence, the commercial straight-face spring scale is not susceptible of the precision of indication which may be obtained in other types of the same capacity.

To illustrate what is discussed in the preceding paragraph, assume a straight-face spring scale in which the capacity is 20 pounds and the length of the graduated scale is 4 inches. The pointer will travel 1 inch per 5 pounds of load. Assuming also that 20 graduations per inch represents the closest practicable spacing of the graduations, we arrive at ¼ pound as the minimum value for each graduation; that is, it will be impracticable to graduate this scale "finer" than to quarter pounds.

If in the preceding example it were possible to increase or magnify the travel of the indicator, indications corresponding to spring elongations caused by loads much smaller than quarter pounds could be read. This is exactly what is accomplished in the "dial" type of scale, which has a circular "reading face" with a series of graduations near its outer edge, and a long indicating pointer or indicator designed to make one or more revolutions of the dial. Mounted on the same shaft with the indicator is a small pinion which meshes with a straight rack which in turn is connected with the lower end of the spring. Thus the small vertical movement of the rack caused by a slight elongation of the spring is converted into a relatively large circular movement of the end, or "index," of the indicator. The multiplication of such an indicating system is governed by the number of teeth in the pinion and the length of the indicator; the accuracy of the indications of spring elongation depends principally upon the accuracy of the spacing of the teeth in the rack and pinion, the accuracy with which the indicator is balanced about its axis, the accuracy with which the graduations are spaced, and freedom from frictional effects.

Reverting to the example of a straight-face scale given above, a spring having the same characteristics as the one described could be employed in a dial scale to give weight indications of 1 ounce or ½ ounce with the same or even a greater spacing of graduations, by reason of the increase of indicator travel possible in the dial type.

Increase of indicator travel through the agency of a rack-and-pinion assembly and a long indicator is made use of not only in spring scales, but also in other types of automatic-indicating scales.

It may be mentioned that dial scales as well as automatic-indicating scales of other types are very frequently fitted with two reading faces, thus permitting the reading of the weight indications from opposite sides of the scale; depending upon the design, one or two indicators may be used on these scales.

A "fan" scale is so called because the indicator, in traveling from its position at zero load to its position at capacity load, describes a path shaped like an opened folding fan; that is, a sector of a circle. The application of load to such a scale causes the indicator arm, which is relatively long, to rotate on its axis and to pass across the graduated face; the total angular movement of the indicator between zero and capacity indications seldom exceeds 90 degrees and is usually considerably less than this.

A "cylinder," "drum," or "barrel" scale differs in one fundamental respect from most other types of automatic-indicating scales; in the cylinder scale the indicator is the fixed element and the graduated scale is the movable element, whereas in most other types the reverse is true. The graduations are on a "chart" mounted in the form of a cylinder over a light skeleton framework; in the customary construction this cylinder is mounted with its longitudinal axis horizontal, and is caused to revolve through 360 degrees through the medium of a rack-and-pinion assembly. The fixed indicator consists ordinarily of a fine "wire" (usually a thread) stretched horizontally across the face of the chart. Obviously, only a small portion of the surface of the cylinder is required for the single series of weight graduations; the reason for building a cylinder scale is to provide room for a plurality of series of value computations giving the money values for various weights at different prices per pound. A scale equipped with a price-computing chart is called a "computing" scale; this type will be discussed at a later point, in the chapter devoted to special scales.

Another type of automatic weight indication consists of the projection upon a ground glass screen of the image of a fixed indicator and of a portion of a movable graduated scale. The graduated scale is comparatively small and is attached to a pendulum mechanism; by means of an optical system and a source of light, the image of a portion of the graduations is magnified and projected on the screen, the portion of the graduations so reproduced depending upon the position of the graduated scale as determined by the load on the scale platform; by means of the fixed indicator, weight indications may be read. The reverse arrangement may also be employed, in which, by means of an optical system, the image of a movable indicator and of a fixed series of graduations is projected on a screen.

Automatic indication of weight may also be obtained by means of specially graduated pressure or deflection gages in combination with hydrostatic and other elements.

Chapter 4.—TYPES OF ORDINARY SCALES: BENCH OR COUNTER—EQUAL-ARM, UNEQUAL-ARM, PLATFORM; SUSPENDED; PORTABLE PLATFORM; WAREHOUSE; OVERHEAD; WAGON; MOTOR-TRUCK; RAILWAY TRACK

It is the purpose of this and the succeeding chapter to describe briefly the more usual types of ordinary and special scales which the weights and measures officer may encounter in the course of his official duties. In the present chapter, ordinary scales, as distinguished from special scales, have been classified on a "constructional" basis—that is, on the basis of their design and construction—and are treated under the following type designations: Bench or counter—embracing equal-arm, unequal-arm, and counter platform; suspended; portable platform; warehouse; overhead; wagon; motor-truck; railway track.[12]

Bench or Counter Types.—The classification of bench or counter scales embraces, in general, all scales which are especially adapted, on account of their compactness, light weight, moderate capacity, and arrangements of parts, for use upon a counter, table, or bench. The term "bench" is ordinarily applied to scales intended for industrial use, whereas the term "counter" is applied to scales intended for use in commercial establishments. Based upon their general design characteristics, these scales fall readily into three groups: Equal-arm scales, unequal-arm scales, and platform scales. These three groups are separately considered below under their respective headings.

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[12] The present National Conference code for scales classifies scales, for purposes of tolerance application, upon the following basis, the quoted material being paragraph A-2c of the scale code:

> Small-Capacity and Large-Capacity Scales.—The term "small capacity" shall be construed to include all scales of the bench (counter) and hanging types having nominal capacities of 400 pounds or less. Scales other than small-capacity scales are to be considered large-capacity scales. A vehicle scale is a large-capacity scale designed to be used to determine the weight of a motor truck or wagon, loaded or unloaded.

It is useful and convenient, however, for purposes of type identification, to continue to recognize the classification based on design and construction, as herein set forth.

Counter scales as a whole might also be subdivided into computing scales and noncomputing scales, the term "computing" referring to scales equipped with special charts which, in addition to indicating weight values, also indicate money values corresponding to different amounts of commodity for a series of unit prices. The computing charts, however, are essentially accessory to the weight-indicating elements of a scale, and, moreover, a computing scale may be of any one of the counter-scale types listed above or may not be a counter type at all. Therefore, notwithstanding the fact that the counter computing scale is encountered with great frequency in retail establishments, the consideration of computing scales with respect to their price-computing elements has been postponed to the succeeding chapter where special types of scales are discussed.

From the standpoint of similarity of capacity, type of indications, and character of use, many bench and counter scales and many "suspended" scales (or "hanging" scales, as they are frequently called) should be grouped together. Certain fundamental differences, however, in construction and test methods, dictate that these scales be separately considered under their respective type headings.

Equal-Arm Types.—Equal-arm scales—also known as "even-arm" and "even-balance" scales—are of two types, suspended-pan and stabilized-pan. The type in which the pans are suspended from the beam—usually known as a "balance"—is not well adapted to general commercial uses and will be met very infrequently. This type will occasionally be found in use for weighing commodities such as coffee, tea, spices, etc., at retail, and test samples, as of cream, and pharmacists occasionally employ an "analytical balance" in compounding prescriptions. The principal concern of the weights and measures official with these balances, however, is in connection with his own use of them in testing commercial counterpoise and other weights and his own standards.

The type of equal-arm scale in which the pans are supported above the beam and are stabilized by a linkage on the Roberval principle, will be found in general use in many lines of business and industry. These are commonly spoken of as "trip" scales. The simplest variety of this type is that with no side beam and no special indicators to show the condition of balance; loose weights must be provided with these scales in denominations down to the smallest value which it is desired to determine when using the scale. When such a scale is equipped with a "side bar" assembly—that is, a graduated weighbeam bar and poise—the side bar directly takes care of all weighings up to its capacity; loose weights are then required only in denominations corresponding to multiples of the capacity of the side bar, and by the combined use of side bar and weights, weight determinations may be made of all amounts up to the capacity of the scale.

Some equal-arm scales are provided with an indicating means to show the condition of balance; this may be a pointer mounted at right angles to the beam and cooperating with another pointer or with a graduated scale, or it may consist of two horizontal indicators the movements of which correspond to the movements of the two pans. There is also a type of equal-arm scale which employs a long upright pointer in combination with a bending or torsional element supplying a counterforce, and a small fan chart; when the scale is balanced the pointer coincides with the zero graduation, which is at the middle point on the chart; there may or may not be graduations on either side of the zero, and, if present, these may or may not have weight values assigned to them. This scale is commonly spoken of as an "over-and-under" scale, because the chart is frequently marked to show "under weight" on one side of the zero graduation and "over weight" on the other side; when the chart is so marked the scale should be so designed and constructed that the commodity pan will not be confused with the weight pan.

In another type, a semiautomatic equal-arm scale, there is incorporated a fan-shaped computing chart of ordinary design but of relatively small capacity, and loose weights in multiples of the chart capacity are provided. In this scale the automatic-indicating part of the assembly may be said to correspond in function to the side beam of the ordinary trip scale.

The majority of equal-arm scales are made on the "knife-edge" principle; that is, the beams or levers are fitted with pivots having knife-edges, the latter making contact with conventional bearings. In one type of scale, however, the "torsion" principle is employed, pivots and bearings being replaced by steel bands stretched tightly around skeleton frames clamped rigidly to the lever system; as either of the pans is depressed from the balance position, the fulcrum and end bands are twisted slightly and tend to return the beam and pans to their normal positions of balance.

Equal-arm scales with stabilized pans or "platters" are made in various capacities from 50 pounds on each pan down to the druggists' class A prescription scale with a capacity of one-half ounce on each pan. In the best grades of knife-edge scales, metal bearings may be replaced by bearings made of agate.

Unequal-Arm Types.—The unequal-arm type of scale as here classified and discussed, is a counter scale in which the principle of the unequal-arm lever is applied in one of its simplest forms. As found in ordinary commercial use, the unequal-arm scale is well standardized as to type. It has a single unequal-arm lever of the first class, the power end of which is the graduated weighbeam of the scale, and a single, stabilized load-receiving element which may be a plate, pan, platter, or scoop. The weighbeam may consist of a single bar or of two parallel bars, and in either case it may or may not employ counterpoise weights; if the scale is not designed for the use of counterpoise weights there will ordinarily be no pivot or loop at the tip of the weighbeam and, of course, no counterpoise hanger. The ratio of the lever is comparatively low, usually being of the order of 5:1. Scale capacities range from about 35 pounds to 1 pound.

Many automatic-indicating scales with fan charts resemble the unequal-arm scale in their lever systems, but while the principle is that of the unequal-arm lever, the lever is of the second instead of the first class; that is, the fulcrum is at one end of the lever instead of being between the load and power pivots. Other automatic-indicating scales with circular dials do conform in construction to the unequal-arm beam scale, the graduated beam of the latter being replaced by a mere lever arm connecting with an automatic-indicating head. These scales are not usually intended to be included when one speaks of "unequal-arm" scales.[13]

[13] These scales are, however, grouped with unequal-arm scales in the outline of test procedure given at the end of chapter 8, page 140.

The unequal-arm type lends itself readily to many modifications to meet the demands of specialized weighing service. Percentage scales, paper and textile sampling scales, testing scales, postal scales, and the like are frequently of this type; some of these will be discussed briefly in the succeeding chapter. The steelyard, which is a simple, suspended scale consisting essentially of a single unequal-arm beam, is classed as a "suspended" scale and is discussed under that heading.

Platform Types.—A "platform" scale is one in which the load-receiving element is a platform having four or more lines of support comprised in bearings which rest upon knife-edges in the levers. A bench or counter platform scale is a platform scale in which the weighbeam or other reading element is located at an elevation sufficiently low in relation to the weighing platform to be accessible and easily read when the scale is used upon a bench or counter.

With the exception of equal-arm and unequal-arm scales, the majority of scales intended for use on a bench or counter are platform scales. However, there are numerous automatic-indicating computing scales with compound lever systems which do not differ much in outward appearance from platform scales, but in which the platform or platter has a two-point support—that is, but two platform bearings—the platform being stabilized by means of a stabilizing linkage on the Roberval principle. This linkage is sometimes located at a considerable distance above the platform, in which case the scale is said to have an "overhead check"; in other cases it is below the platform level. By definition these scales are not "platform" scales because they do not have four platform bearings, and it is necessary that they be distinguished from platform scales because of certain special tolerance requirements applicable to this type.[14]

The ordinary counter-platform beam scale conforms in general principles of design to portable platform, warehouse, and wagon scales; that is, there is a lever system supporting the platform at four points and joined to the weighbeam through the medium of a vertical beam rod.

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[14] These stabilized-platform, automatic-indicating scales are grouped with "unequal-arm" scales in the outline of test procedure given at the end of chapter 8, page 140.

Counter platform beam scales sometimes have weighbeam fulcrum bearings and occasionally platform bearings of agate. The scales are self-contained, the weighbeam support, beam-rod pillar, and base being assembled as a unit and the working parts of the scale being supported by this framework. In the majority of cases a trig loop is provided, within which the beam oscillates. Weighbeams may have one or more graduated bars, and counterpoise weights may or may not be utilized. Frequently, but not always, there is a nose-iron at the tip end of the platform lever system. Suitable means are provided for checking the movement of the platform to prevent interference between platform and frame and displacement of the platform bearings from their pivots.

The capacities of bench and counter platform scales ordinarily lie between 50 and 300 pounds. Their ratios are greater than those of the unequal-arm scales previously discussed and less than those of portable platform scales, ratios of 66⅔:1, 53⅓:1, and 50:1 being common.

A modification of the ordinary counter platform scale which will frequently be encountered is one which is known as a "union" scale. In addition to the conventional platform, this scale embodies another small platform or a fork above the weighbeam, designed to accommodate a scoop; it is also characterized by absence of a trig loop. This scale is really a combination of a counter platform scale and an unequal-arm scale; forces caused by a load in the scoop are communicated directly to the weighbeam without assistance from the platform lever system. The multiple of the scoop part of the scale is much less than that of the platform part of the scale, these multiples usually being in the ratio of one to eight; this necessitates a double series of figures designating the values of the weighbeam graduations when a single-bar weighbeam is employed, and a double marking of the counterpoise values of counterpoise weights. The single-bar weighbeam is frequently graduated to 40 pounds by ¼-pound divisions with respect to the platform, and to 5 pounds by ½-ounce divisions with respect to the scoop; when the weighbeam has two bars, one is graduated with respect to the platform and the other with respect to the scoop. The total platform capacity is usually 240 pounds. The customary complement of counterpoise weights is one

"5–40" and two "10–80", the first figure of each of these combinations referring to the counterpoise value with respect to the scoop, the second to the counterpoise value with respect to the platform; the nominal values of these weights are, respectively, ¾ pounds and 1½ pounds, giving a "platform" multiple of 53⅓. Some union scales are made to a platform multiple of 66⅔, with a ratio of 1 to 10 between scoop and platform; in this case the nominal values of the counterpoise weights are the same as before, but their counterpoise values are 5–50 and 10–100, respectively.

Bench and counter platform automatic-indicating scales are made in a variety of styles. Scales of this class found in retail establishments are usually of the computing type. Industrial scales of this class are usually of the dial type and these are ordinarily graduated only in terms of weight, although special computations may also be shown; sometimes special provision is made to facilitate tare and net readings by means of a movable dial, a special indicator, etc. Auxiliary weighbeams, referred to as "tare" or "capacity" weighbeams, are common on this class of scale. Frequently the conventional platform is replaced by a special load-receiving element designed particularly to meet the demands of special weighing conditions or to accommodate specific articles being weighed. The type of scale, previously mentioned, in which the weight graduations are reflected onto a ground-glass screen is also met in the class of scales being here considered.

The capacities of counter platform automatic-indicating scales conform in general to the limits previously mentioned in connection with counter platform beam scales—50 to 300 pounds. The value of the minimum graduation on such scales intended for use in retail establishments is usually 1 ounce; on scales intended for industrial uses, the values of the minimum graduations range ordinarily from 2 to 8 ounces.

Suspended Types.—A suspended, or "hanging," scale is a self-contained scale which is designed to be suspended from an overhead support. There are many suspended scales which are used for the same purposes as counter scales and which are identical in some respects, such as capacity, character of indicating elements, etc., with some scales of the counter type. Again, certain suspended scales correspond in capacity and character of indications and use with scales of the portable platform and warehouse types. In other words, that group of scales classified as "suspended," overlaps, as it were, several other groups with respect particularly to capacity and use characteristics.

The simplest form of suspended automatic-indicating scale in commercial use is the straight-face spring scale. The limitations of this type as to precision of indication operate to restrict its satisfactory use to a very few fields of commercial weighing, such as, for example, small lots of fuel, ice, laundry, and coarse vegetables. These scales are made in capacities up to several hundred pounds.

As compared with the straight-face spring scale, the hanging spring scale of the dial type, by reason of its possibilities for greater precision of reading and of its greater freedom from frictional effects under ordinary conditions of use, is adapted for use in a wider range of commercial weighings. The dials on these scales range in diameter from 4 to 15 inches, or, on scales of special construction, the diameter may be as great as 30 inches; capacities range from 5 pounds to 5,000 pounds or more; the load-receiving element may be a hook, a pan or platter, a scoop, or a special element designed to accommodate commodities of a special character.

The pendulum type of automatic-indicating scale is also made as a hanging scale with circular dial; load-receiving elements are provided of various characters and sizes to accommodate a variety of commodities. Capacities are relatively small, ordinarily ranging from 50 to 150 pounds.

Cylinder computing scales (automatic-indicating) are occasionally designed to be suspended from an overhead support instead of being made in the more usual design as counter scales.

The simplest form of suspended beam scale which will be found in commercial use is the steelyard, and this will be encountered comparatively rarely except in the regions where cotton is weighed. The steelyard for weighing baled cotton is usually referred to as a "cotton beam" or, when used by a public weigher, as a "weighmasters' beam." Steelyards may have smooth or notched beams and are made in various capacities ranging from 125 to 2,500 pounds; the ordinary cotton beam has a capacity of 700 to 800 pounds, by 1-pound subdivisions. Steelyard poises are usually of the hanging type and readily detachable from the beam, the upper part of the poise which engages the beam being formed as a hook rather than as a loop, as is the case with hanging poises on counter types of scales; the usual weight of the poise for use on cotton beams is 16 pounds, although on various types of steelyards poise weights may range from 1 to 64 pounds. Cotton beams are usually suspended from a portable wooden "frame" equipped with a device known as a "downhaul"; this device is similar in principle of operation to the drop lever on certain portable scales, and permits the lowering of the steelyard so that a bale of cotton may be engaged by the "hooks" which constitute the load-receiving element, and the subsequent raising of the steelyard and its load to the weighing position.

The "crane" scale, designed to be interposed between the hook of a crane and the load being handled, will be found in some industrial or material-handling plants. These may be either beam or automatic-indicating scales. On the beam type the leverage system and beam arrangement are similar to those of the "butchers' meat beam," but the capacities are much higher, ranging from 2,500 pounds to 60,000 pounds. The automatic-indicating type of crane scale may be a simple spring scale of the dial type, or it may comprise a lever system connected with an automatic-indicating head.

Portable Platform Types.—The platform scale designed to rest on the floor and to be readily movable from place to place is ordinarily spoken of as a "portable platform" or "portable" scale; as designating a type, these expressions are never applied to counter or bench scales or to scales designed to be installed more or less permanently in one location. Accordingly, the portable scale is normally characterized by a tall pillar, bringing the beam, graduated face, or other indicating element up to a height convenient for reading when the scale rests on the floor; moreover, these scales are frequently equipped with wheels to facilitate movement of the scale from place to place. In order to prevent unnecessary wear on the working parts and protect them from damage during movements of the scale or when loads are applied to the platform, there is frequently incorporated a relieving device (on beam scales) or a locking device (on automatic-indicating scales). On a beam scale the relieving device is usually an arrangement whereby the weighbeam fulcrum loop may be lowered, thus permitting the platform lever system to drop clear of the platform bearings and the platform to rest on the frame; the mechanism is controlled by a lever above the beam shelf; a scale so equipped is known as a "drop-lever" scale. Sometimes the relieving mechanism is controlled by a pedal adjacent to the foot of the pillar, in which case the scale is said to be equipped with a "foot lever." A relieving device may also consist of a mechanism whereby supporting members can be thrust upward against the underside of the platform, thus preventing the transmission of forces from the platform to the lever system. On an automatic-indicating scale the locking device is an arrangement for preventing the communication of forces from the platform to the automatic-indicating mechanism by bringing into action between these elements a rigidly supported member which will carry the forces from the platform, and by so locking in position certain elements of the indicating mechanism as to prevent motion of its parts; the device may be operated by turning a handle protruding from the pillar or in some similar manner. In certain cases the operation of the locking device also automatically controls the motion of "locking feet" which, when the scale is in condition for weighing, descend beneath the platform and anchor the scale in position.

Special platforms may be designed to adapt the scales to particular uses, as, for example, the weighing of barrels, filled sacks, pipe, or bars of metal, or the combined sacking and weighing of commodities. Sometimes a portable scale will be built with a raised platform in combination with a very short pillar, so that the weighbeam is below the level of the platform; such scales are used for the weighing of articles of large area, such as sheets of metal, mattresses, and the like.

In the case of beam scales, the weighbeams may have one or more graduated bars—sometimes as many as seven—and the weighbeam may be "full capacity," or counterpoise or "bottle" weights may be utilized; weighbeams may be notched or smooth, and may be mounted below the shelf—being supported by a "loop"—or above the shelf—being supported by a "stand"; a trig loop is always provided. Single-bar weighbeams and the principal fractional bars of full-capacity weighbeams are usually graduated to 50 pounds by ¼-pound subdivisions on 500-pound scales, to 100 pounds by ½-pound subdivisions on scales having capacities of 1,000 to 3,000 or 4,000 pounds, and to 200 pounds by 1-pound subdivisions on larger scales up to 10,000-pound capacity. In portable beam scales of the lower capacities the ratio is uniformly 100:1; in scales of larger capacities the ratio is frequently 200:1.

There are also specially constructed portable beam scales having a capacity of 400 pounds and weighbeams graduated to 2 or 3 pounds by fractional-ounce or decimal-pound subdivisions, which are designed for particularly accurate weighing of expensive commodities and for check-weighing purposes. The ratio on these scales may be less than 100:1; 66⅔:1 is a ratio frequently employed.

General-purpose automatic-indicating scales of the portable type have dials or other indicating means which are ordinarily graduated to one one-thousandth or less of their capacity; that is, there are usually not more than 1,000 subdivisions. The value of one subdivision may be from 1 ounce to 5 pounds; the capacity of the automatic-indicating portion of the scale may be from 50 to 1,000 pounds. A weighbeam having one or two graduated bars may also be incorporated in the scale, bringing the nominal capacity of the scale to one and one-half times (or more) the capacity of the automatic-indicating elements.

Attachments similar to the automatic-indicating portion of the over-and-under counter scale previously described, may also be obtained for installation on portable scales of the beam type, being designed either wholly as "balance indicators" or as such indicators in combination with a small range of automatic weight indication on either side of the "zero graduation."

A modification of the ordinary portable scale that is frequently met with is the person-weighing scale, or "person weigher." These scales may be either beam or automatic-indicating, they may or may not be coin-operated, and they are characterized by small platforms (about 10 by 14 inches) and tall pillars; the capacity is usually 300 pounds and the beam scales usually have full-capacity beams with the fractional bar graduated to ¼-pound subdivisions.

Warehouse Types. (*Self-contained and built-in*) (*Including discussion of features common to all built-in types.*)—The expression "warehouse scale" is here used to embrace all types of platform scales not otherwise defined which are primarily designed to be installed in a fixed position inside a building.[15]

Warehouse scales may be broadly divided into two main groups, "self-contained" and "built-in." Scales of the smaller capacities are of the self-contained type; that is, the scale is designed to be completely assembled as a unit within the frame supplied with the scale, and this is then to be set into the floor so that the scale platform will be flush with the floor. These scales are also known as "floor" scales.

It is not uncommon to encounter a self-contained warehouse scale in use resting on the floor—like a portable scale without wheels. If the floor is level and provides a solid support for the scale, and if the height of the platform—10 or 12 inches above the floor—is not conducive to abuse of the scale during the application of loads to the platform, satisfactory service in such a position may be anticipated.

Warehouse scales of the larger capacities are of the built-in type; that is, the framing must be built into proper position, and the supports for the levers and weighbeam must be separately positioned; the responsibility for doing this and for assembling the various parts so that levers will be level, connections plumb, and all parts in proper relation to each other, rests upon the scale erector and not directly upon the manufacturer. In one variation of the built-in type, sometimes designated as a "fulcrum stand" type, the main-lever fulcrum stands are properly spaced by means of tie rods supplied by the manufacturer.

There are numerous elements of general design and

[15] The use of the word "dormant," to distinguish this general type of scale, is to be discouraged, as is also the use for the same purpose of the expression "built-in." The expression "built-in" is better reserved for use as a qualifying phrase in opposition to "self-contained."

construction which are common to built-in warehouse scales and to wagon, motor-truck, and railway track scales (all of which are likewise built-in); these will be discussed briefly at this point.

The lever system may be composed of "straight" levers, or may include one or more "torsion" levers, the latter also being referred to as "pipe" or "T" levers. A straight lever is ordinarily a single, straight, flanged lever with one fulcrum pivot, one main load pivot, and one power pivot; there may be a secondary load pivot to receive the

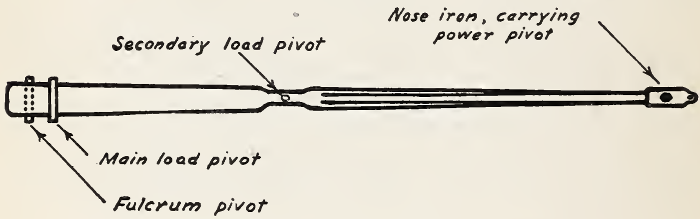

FIGURE 12.—*A "straight" scale lever.*
Diagrammatic sketch of a typical "long" lever of a wagon scale.

forces transmitted from the power pivot of some other lever in the assembly. A straight lever of one form is illustrated diagrammatically in figure 12.

The distinguishing characteristics of the torsion lever are a straight pipe-shaped member, at or near each end of which is mounted a "pipe head"—a member in which are mounted a fulcrum pivot and a load pivot—and to which is attached, usually at a right angle, an extension arm carrying at its tip end the power pivot of the lever. A torsion lever of one form is illustrated diagrammatically in figure 13. Sometimes the extension arm is attached at the extreme end of the pipe, but more often it lies between the two pipe heads containing the fulcrum and load pivots, in which case it may be midway between them—as illustrated in figure 13—or it may be closer to one than to the other.

In some designs of torsion levers "structural shapes" (such as channels or H- or I-beams) replace the customary pipe portion of the lever and are used as well for the extension arms, suitable butt and tip castings containing the pivots being attached to these members.

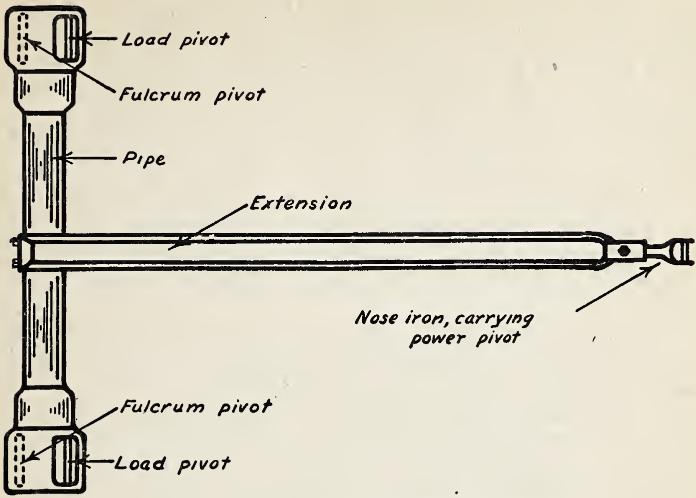

FIGURE 13.—*A "pipe" or "torsion" lever.*
Diagrammatic sketch of a typical lever.

Nose-irons are provided on certain levers for the purpose of equalizing the multiples of coordinate levers and of adjusting the multiple of the system as a whole so as to produce the desired multiple for the entire scale.

The main levers—that is, those directly receiving the platform load—may connect directly with the weighbeam or indicating head through a vertical rod connection called a "beam rod" (as in many warehouse and wagon types), or the forces may be transmitted from the main levers through one or more "extension" levers and/or a "shelf" lever. Extension levers, when they are included in the original design of the platform lever system, and shelf levers, are multiplying levers; when extension levers are utilized merely to extend the system so that the weighbeam or indicating head may be mounted at a greater distance from the platform than contemplated by the original design, they are usually "even" levers (ratio 1:1), and if of the straight-lever type these must, of course, be used in pairs, in order to maintain the initial direction of the force. A shelf lever is a lever ordinarily of low multiple, usually mounted just below the beam shelf or support for the indicating head; the shelf lever may, however, be mounted beneath the floor, and this is sometimes done for the purpose of utilizing the shelf lever as a weighbeam "extension" lever to permit mounting of the beam at a somewhat greater distance from the platform than would otherwise be practicable without the employment of additional levers. When a shelf lever is used in its normal position above the level of the main levers, the vertical rod connection between the platform lever system and the shelf lever is known as the "steelyard rod," and the connection between the shelf lever and the weighbeam is known as the "beam rod."

When the platform is provided with bearing feet which rest directly on the knife-edges of the load pivots of the main levers, this type of construction is known as the "rigid bearing" type. When load loops, or other linkages from the bearing blocks (which rest on the load knife-edges) extend downwardly and when, through suitable members, the platform is joined with these loops or linkages at their bottoms so that, in effect, the platform hangs from the load pivots instead of resting upon them, this type of construction is known as the "suspension bearing" type. In the simpler designs of suspension bearings, freedom of motion in only one direction is provided for; in the more elaborate designs, suspension bearings are intended to permit motion of the platform in any direction in a horizontal plane without introducing relative lateral or longitudinal movement between bearing surfaces and knife-edges. There is another design of platform suspension in which the platform is suspended from upwardly extending members which rest on the knife-edges; in this construction all of the flexible linkage is actually above the knife-edges, but this design contemplates freedom of platform motion similar to that provided by the other form of suspension bearing. In another type of construction known as the "ball check" type, steel balls rest in iron cups directly above rigid bearing feet, and similar cups are fastened to the under side of the weighbridge supporting the platform; the platform is thus supported by the balls, and when the platform is displaced slightly in any horizontal direction, the action of the balls in their cups tends to restore the platform to its original position. This construction is designed to permit, and at the same time limit, lateral movement of the platform without disturbing the relative positions of knife-edges and bearings. In a different design, small rollers are utilized for the same purpose, the rollers being mounted in sets at right angles to each other to permit lateral platform motion in two directions.

Checking devices of various designs (in addition to the ball checks and roller checks discussed above) are used to limit or even to prevent lateral platform motion; these are known as "check rods," "bumper checks," "transverse checks," "longitudinal checks," "stay plates," or "stay rods," depending upon their particular design or location. These devices may be rods with an eye at either end fitted somewhat loosely over pins or lugs, they may consist of two separate "bumper" elements mounted or adjusted with a small gap between them, they may consist of single adjustable "bumper" elements designed to contact directly with the framing, or, if the device is a stay plate or rod, this is rigidly secured to both frame and platform supports and serves not only to limit but to prevent horizontal platform motion.

Framing may be wood or steel or a combination of both, and concrete may or may not be used for foundation and side walls. The "pits" in which scales are mounted range all the way from a shallow opening beneath the floor just large enough to contain the lever system of a warehouse scale, to a deep concrete pit for a vehicle scale or a railway track scale, which is waterproofed, lighted, drained, ventilated, and heated, and which is roomy enough to permit an inspector to walk freely about and examine thoroughly all parts of the installation.

Weight-indicating elements may be weighbeams or automatic-indicating assemblies, or a combination of the two. Weighbeams may be single or multiple-bar, they may or may not be full-capacity, and they may or may not be registering. The ordinary type-registering weighbeam is a full-capacity weighbeam which has a row of type figures on the under side of the main bar; the fractional bar is incorporated in the main poise and is also provided with type figures; a slot is provided in the poise for the insertion of a card or "ticket," and by the operation of a hand lever a record of the weight indication corresponding to any notch position of the main and fractional poises may be printed or cut into the ticket; means are provided for conveniently shifting the position of the ticket for the proper entry thereon of gross and tare weights. Special type-registering weighbeams are also made in which the weighbeam capacity is only a small proportion of the nominal capacity of the scale, being equivalent to the value of the smallest counterpoise weight furnished; the weighbeam has type figures as in the regular type-registering beam and in addition there are type figures and a type-registering device on the counterpoise hanger stem, thus permitting the recording of the combined indication of weighbeam and counterpoise weights. Another type of registering weighbeam utilizes a pin mechanism for perforating or puncturing a specially printed weight ticket in such a manner as to record the weight indications of the scale.

Automatic-indicating elements may be of any of the usual types already discussed, and, as stated previously, these may be in combination with one or more graduated bars. Also, scales with automatic-indicating heads are frequently equipped with one or more unit weights which in principle of counterforce application correspond to ordinary counterpoise weights; these unit weights, however, are contained within the "cabinet" housing the automatic-indicating elements and their accessories, and are intended to be successively applied or removed by manipulation, from the outside of the cabinet, of an operating lever, wheel, or other means; when one or more unit weights have been applied there is automatically shown on the reading face an indication of the value which they represent. Unit weights, when utilized, are normally supplied in denominations corresponding to the capacity of the reading face; that is, on a scale having a reading face capacity of 1,000 pounds, for example, each unit weight would represent 1,000 pounds.

Automatic-indicating attachments may be connected to warehouse, wagon, or motor-truck scales of the beam type; a familiar example of this is the unit in which the weight indications are projected upon a ground-glass screen. Balance indicators similar to those made for use on portable scales are also designed for installation on beam scales of large capacity. There have also been developed a "printing" scale in which the counterforce is automatically applied—as in the case of an automatic-indicating scale—but in which a printing mechanism is substituted for the conventional weight-indicating element, and printing attachments designed to be employed in conjunction with automatic-indicating scales. There are also automatic weighing and recording attachments designed to be installed on a beam scale, or substituted for a weighbeam outfit whereby the weights of loads may be recorded on individual cards or successively on a paper tape; this attachment is particularly intended for use on track scales for the weighing of railway cars in motion, the design being such that, by means of one or more "trips" located adjacent to the weighrail, a moving car may automatically actuate the printing mechanism.

Reverting now to the consideration of warehouse scales alone, it may be said that these range in capacity from 500 to 40,000 pounds. Self-contained types of 500 and 600 pounds capacity, very similar to the ordinary portable scale, may occasionally be found set into the floor. True warehouse types ranging in capacity from 750 pounds upward are made in considerable variety. Minimum weighbeam graduations range from ½ to 2½ pounds; reading face capacities of automatic-indicating scales range from 250 pounds by ¼-pound subdivisions to 10,000 pounds (or more) by 10-pound (or greater) subdivisions; when an automatic-indicating scale has an auxiliary beam, the minimum graduations thereon are usually equivalent in value to the minimum reading face graduations, but may be less; the values of unit weights used in combination with an automatic-indicating head range from 250 pounds upward; platform sizes range from about 36 by 36 inches to about 22 by 9 feet.

Overhead Types.—Overhead scales are scales which normally are permanently installed in one location and which have a raised or overhead lever system.

A simple form of overhead scale is the "butchers' meat beam," which has already been described insofar as its lever system is concerned; when used for weighing sides of meat this scale is equipped with a hook as the load-receiving element. Without other essential change, the hook of this scale may be replaced by a hanging pan or platform, thus adapting the scale to the weighing of a wide variety of commodities. Such a scale is usually equipped with a full-capacity weighbeam having two graduated bars. On meat beams the nominal capacity is frequently 600 pounds; scales of this type designed for weighing other commodities may have capacities and minimum graduations considerably less than those of meat beams.

In overhead scales equipped with regular platforms, a conventional or modified system of levers is mounted overhead and connected by means of the necessary extension and reversing levers and vertical steelyard and beam rods with a conventional weighbeam assembly or automatic-indicating head mounted in a position convenient for observation. The lever system may be suspended from an overhead framework supported by pillars resting on the floor, in which case the entire scale is self-contained and movable, although usually it is permanently installed with a shallow pit below the platform and the platform flush with the floor level; or the lever system may be suspended directly from the ceiling or other overhead structural members of the building. One of the principal reasons for an overhead mounting of the lever system is to protect knife-edges and bearings from the corrosive effects to which they might be exposed were the levers in their conventional position beneath the platform; this type of installation will therefore be found where excessive moisture or other corroding agents are present immediately adjacent to the weighing platform, as in creameries, abattoirs, etc.

Another reason for an overhead lever system is that this is particularly adaptable to a scale in which the load-receiving element must be overhead, as, for instance, an "overhead track" scale for weighing dressed meat moving along an overhead rail; in such a scale the load-receiving element is a cut-out section of the overhead rail, onto which and from which the roller carrying the meat may pass directly; this arrangement is also adaptable for use with a monorail traveling crane. Hoppers and tanks for the weighing of grain or liquids may also in some cases be conveniently suspended from a raised lever system. The capacities of these scales vary, depending upon the particular uses for which they are designed, and range ordinarily from 1,500 pounds upward.

Wagon Types.[16] (*Including "livestock" and "dump" scales*).—The wagon scale is designed primarily for the weighing of horse-drawn vehicles as distinguished from motor trucks. The design of the scale contemplates that loads will be distributed fairly evenly over the four vehicle wheels. The lever system of a wagon scale conforms in general arrangement of parts to the lever system of a warehouse scale.

Wagon scales are normally installed in the ground, and the platforms are frequently unprotected from the weather. When located alongside a building the weighbeam or other indicating element is usually mounted inside the building; when located elsewhere, the indicating elements are protected from the weather by a "beam box." Platforms are almost invariably of wood. Beam scales outnumber automatic-indicating scales, and weighbeams are now usually of the full-capacity type.

Wagon scales of the so-called "pitless" type are designed for temporary installation. These scales might be said to be semi-self-contained; they have shallow-type levers and supports, so as to reduce to a minimum the depth of the assembled frame and lever system; they may be set on top of the ground or in a shallow pit. The absence of proper foundations is conducive to unsatisfactory weighing results in probably the majority of "installations" of pitless scales.

The capacities of wagon scales range ordinarily from 5 to 10 tons (4-ton scales were made at one time), minimum weighbeam graduations range from 1 to 5 pounds; the ratio of the scale (at the weighbeam tip) may be 333⅓ to 1, 500 to 1, 666⅔ to 1, or 1, 000 to 1, the last-mentioned ratio being the most common; platform sizes normally range from 14 by 8 feet to 22 by 10 feet.

A "livestock" scale is a scale having a "rack", or high fence, built on the platform and enclosing it so that livestock may conveniently be kept on the platform during the weighing operation; a gate is provided at one or both ends of the rack. Stock scales may be designed for the weighing of drafts ranging from a single animal to a railway car load of animals—being adaptations of warehouse, wagon, motor-truck, or railway track scales; the

[16] See p. 47 to 53, inclusive, for a discussion of features common to built-in scales.

stock scale which is a wagon type with the addition of a stock rack, probably outnumbers the other forms.

Another modification, originally of the wagon scale but now also of the motor-truck scale, is known as a "dump" scale; the name is derived from the fact that the platform or a portion thereof may be tilted while a loaded vehicle is in place, and the load dumped from the tail gate into a receiving bin beneath the platform. The lever system is arranged to permit the placing of the tilting mechanism, the movement of the platform parts, and the unobstructed flow of commodity from the vehicle to the receiving bin. These dump scales are usually found in country elevators as "receiving scales" for grain; they range in capacity from 6 to 15 tons.

Motor-Truck Types.[17]—The motor-truck scale is designed primarily for the weighing of motor trucks. The design contemplates that loads will largely be concentrated over the rear axle of the vehicle; accordingly the scale levers and other elements are made more rugged than similar parts in a wagon scale of equivalent nominal capacity, so that the scale will give accurate indications when a large percentage of the capacity load is concentrated on two vehicle wheels, and so that it will withstand and be relatively unaffected by the impacts incident to truck movement across the platform.

While the lever system of a torsion-lever motor-truck scale may not differ in general appearance from the lever system of a wagon scale of the same type, the lever system of a straight-lever motor-truck scale ordinarily differs from that of a wagon scale and closely resembles the lever system of a straight-lever railway track scale. In a typical two-section, straight-lever, motor-truck scale installation, there will be found two pairs of main levers —one pair at each end of the scale, mounted parallel with the transverse axis of the platform—two end extension levers—mounted at right angles to the main levers—and a transverse extension lever. In general aspects this design is similar to that of a two-section railway track scale. Four-section motor-truck scales, with lever systems similar to those of four-section railway track scales, are coming into use in installations with platform lengths in

[17] See p. 47 to 53, inclusive, for a discussion of features common to built-in scales.

excess of 40 feet. The motor-truck scale usually has stands for the main-lever fulcrum bearings, suspension main load bearings (in the straight-lever type), a rugged "weighbridge"—the girders and other structural members directly supporting the platform—a comparatively deep pit, and a substantial concerete foundation. Motor-truck scales may be of the beam type or of the automatic-indicating type, and when of the former they are usually equipped with full-capacity weighbeams; they range in capacity from 10 to 50 tons; platform sizes normally range from 16 by 8 feet to 60 by 10 feet.

Railway Track Types.[18]—Railway track scales are, as the name indicates, scales for weighing railway cars, and are ordinarily installed in railway yards, or on trackage in or about an industrial plant. The "weighrails", or "live rails", are a cut-out section of railway track suitably mounted on the weighing mechanism. The installation may or may not provide "dead rails" for the movement of traffic across the scale without the communication of forces to the weighing mechanism.

The lever system of a railway track scale is made up of "sections," each section comprising one or two "main" levers (depending upon whether they are torsion or straight levers) and the appropriate "extension" levers to transmit forces to the weighbeam either directly or through other extension levers; extension levers are referred to as "end," "middle," and "transverse," according to their positions in the lever train. Formerly it was common to build these scales with as many as six or eight sections, but for some time the tendency has been toward fewer sections; for a number of years the four-section scale has been more or less the standard, while recently the two-section scale is gradually coming into use. The lever systems of a four-section, "knife-edge," railway track scale with straight-lever and torsion-lever systems, respectively, are shown diagrammatically in figures 14 and 15.

An entirely different principle of design is utilized in the "flexure-plate", or "plate fulcrum", type of scale. This is a two-section scale in which the conventional pivots and bearings are replaced by steel plates which are rigidly

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[18] See p. 47 to 53, inclusive, for a discussion of features common to built-in scales.

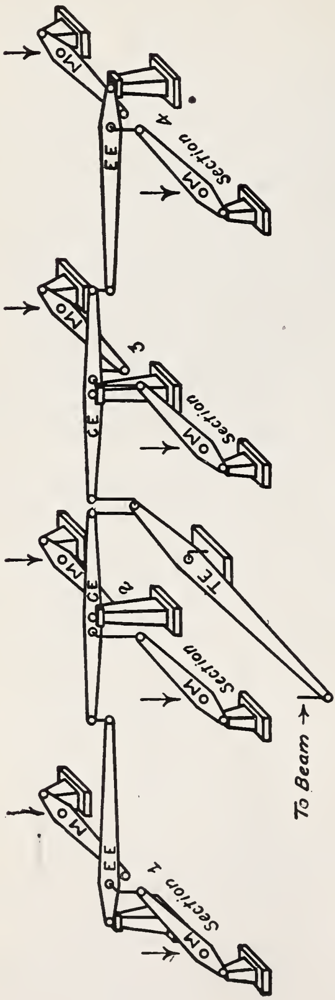

FIGURE 14.—*A "straight-lever" railway track scale.*

Diagrammatic sketch of the lever system of a four-section scale.

M=Main lever.
EE=End extension lever.
CE=Center extension lever.
TE=Transverse extension lever.
There are two main levers for each section.

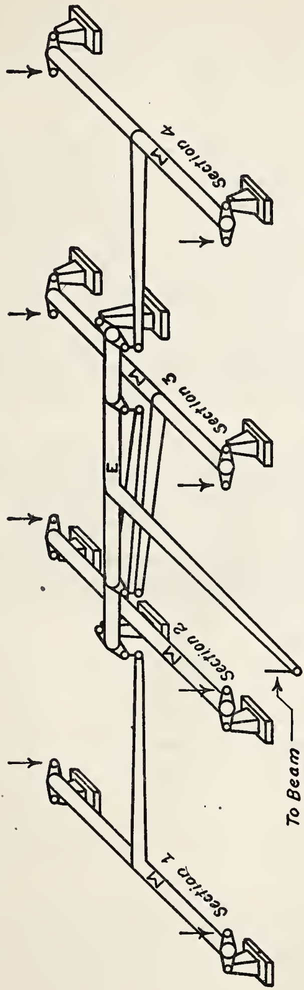

FIGURE 15.—A *"pipe-lever" railway track scale.*
Diagrammatic sketch of the lever system of a four-section scale.
M=Main lever.
E=Extension lever.

secured in place. Thus at the fulcrum of a lever, one edge of the plate is fastened to the lever and the other edge is fastened to a support corresponding to the fulcrum-bearing support in a knife-edge scale; at the load point of a main lever, one edge of the plate is fastened to the lever and the other edge is fastened to the weighbridge support; at the power points of a pair of main levers, one edge of each power plate is fastened to its main lever and the other edge of each such plate is fastened to a block, the other side of the block being fastened to one edge of the load plate of the end extension lever; and so on throughout the scale. The design is such that the plates are always stressed in compression. The plates are so formed that the centrally-positioned web is relatively thin and will flex sufficiently to accommodate the angular motion of the levers incident to scale operation; the thicknesses of the plate webs used throughout a scale will vary, being greatest in the main levers and smallest in the weighbeam.

Railway track scales normally range in nominal capacity from 100 to 250 tons; the length of weighrail on a modern scale usually lies between 50 and 62 feet; on registering weighbeams the value of the minimum graduation is regularly 20 pounds, whereas on nonregistering weighbeams the minimum graduations may have values of 10, 20, or 50 pounds.

Chapter 5.—TYPES OF SPECIAL SCALES: COMPUTING; POSTAGE AND PARCEL POST; COUNTING; PREDETERMINED-WEIGHT; PREDETERMINED-VOLUME; PREDETERMINED-CHARACTER-OF-LOAD; MISCELLANEOUS

Any scale assembly which performs some service in addition to weighing, or which is designed for some special, restricted use, may be considered to be a "special" scale. Some of the more common types of special scales found in commercial use are discussed briefly in this chapter; reference will also be made to some types which are not strictly commercial and which the official will rarely be called upon to examine, but which present interesting variations from conventional design; occasionally a type which has previously been discussed will again be mentioned.

Computing Scales.—The weights and measures official will encounter the money-value or price computing scale more often than any other type of special scale. These scales are usually referred to merely as "computing scales." Moreover, in ordinary usage it is customary to limit the term "computing scale" to mean only a money-value computing scale designed for use in the retail sale of commodities, nothwithstanding the fact that in its broad sense the term "computing" might reasonably be applied to any scale which is capable of indicating the result of some computation in addition to indicating weight. Scales other than the restricted class of "computing scales" just defined, but which nevertheless indicate the results of certain computations, are usually known by special names descriptive of their intended use, such as counting scales, grain testers, parcel-post scales, and the like.

Among the earliest varieties of computing scales were scales of the beam type in which the multiple of a portion of the weighbeam assembly was adjustable to correspond to different prices per pound. Another early variety of counter computing scale had a broad, reversible weighbeam with a series of weight graduations at the top, and below a number of series of value graduations corresponding to certain unit prices per pound, both weight and value indications being read from the index of the poise. Very few of these early scales are now in use, but the principle of the broad beam with its weight and value graduations is still utilized in certain types of small, unequal-arm, counter scales having capacities of a few pounds. For some years practically all of the computing scales of larger capacities have been of the automatic-indicating variety.

For the most part, computing scales have fan or cylinder charts. The weighing mechanisms of these scales do not differ from those of noncomputing scales; in fact, many computing and noncomputing scales of the fan-chart type are identical throughout with the single exception of the chart, which in the first case contains both weight and value graduations, and in the second case contains only the weight graduations. In the latter case the chart is frequently cut down to a size just sufficient to accommodate the weight graduations. Cylinder scales are always computing scales; there would be no useful purpose served in building a cylinder scale just to show a single series of weight graduations. Usually in the fan chart the weight graduations are at the top along the wide edge of the chart, and the several series of value graduations corresponding to the various unit prices for which the chart is designed are arranged below, the series for the highest unit price being at the top; however, there is at least one scale in which the position of the chart is reversed, the wide edge carrying the weight graduations being mounted at the bottom. In the cylinder chart the weight graduations appear at the middle or at the end of the chart, the value graduations being ordinarily arranged with the series for the lowest unit price at the left of the chart as viewed from the dealer's side of the scale. Both fan and cylinder scales usually indicate only weight on the customers' side of the scale, although at least one model of cylinder computing scale has been marketed, in which the customers' side of the scale discloses a duplicate of the full range of price computations shown on the dealers' side of the scale.

Manufacturers of computing scales have numerous charts suitable for each type of scale manufactured, the chart differences being in the range and selection of the unit prices. Cylinder scales are customarily made in capacities of 24 or 30 pounds, and without auxiliary weighbeams, being fully automatic. Fan scales are made in a variety of capacities and frequently have auxiliary weighbeams, chart capacities ranging from 1 to 20 pounds, and the weighbeam capacities being from one to several times the chart capacity. Fan charts are sometimes utilized with equal-arm scales, the chart capacity representing only a small proportion of the nominal capacity of the scale, and loose weights being utilized in combination with the chart indications for loads exceeding the chart capacity. There are also counter platform scales with weighing capacities in excess of 100 pounds which utilize a fan chart, a weighbeam, and counterpoise weights.

Postage and Parcel-Post Scales.—Scales designed for the determination of postage charges are not ordinarily tested by the weights and measures official. However, they constitute a variation of the value-computing type, and deserve mention for one distinctive feature: Instead of being designed to indicate proportionate money values for all weights within their weighing range—as in the case of the ordinary commercial computing scale—they indicate money values representing postal charges for certain fixed weight ranges. For example, the postage charges on first class mail matter advance on an ounce basis, and on parcel-post packages they advance on a pound basis; for a letter weighing just over 1 ounce the postage is the same as for one weighing 2 ounces, and for a package weighing just over a given pound the parcel-post charge is the same as for a package weighing the next higher pound. Thus, for a given rate, the charge indicated by a parcel-post scale will be the same throughout the range from 1 pound to the next; on a "letter" scale the first-class postage charges will be the same throughout the range from 1 ounce to the next. On a parcel-post scale postage rates per parcel-post zone correspond to prices per pound on the commercial computing scale. Similarly, on a postage or mailing scale intended for weighing other than parcel-post matter, postage rates per class of mail matter—first class, second class, third class, air mail—correspond to commercial computing scale prices per pound. The value chart on a postage scale, then, does not have a series of value graduations like those on a commercial computing scale, but shows instead for each postage rate a single postage value for each "weight zone."

Counting Scales.—Counting scales may be of the beam type or may embody an automatic-indicating mechanism. Their purpose is to count articles of relatively small weight and size, and this is accomplished by utilizing the known ratio between certain parts of the scale mechanism. For example, if the ratio of a scale to the tip of the weighbeam is 100 to 1, one article—such as a bolt, nut, small machine part, etc.—applied at the tip of the weighbeam will counterpoise 100 such articles on the load-receiving element of the scale; if it were desired to count out 1,000 such articles, 10 of them could be applied at the tip of the weighbeam, and the load-receiving element of the scale could then be loaded with similar articles until equilibrium was established. Counting scales are equipped with small, convenient receptacles to receive the small counted number of articles which will counterpoise the articles which the scale is to "count"; frequently a second receptacle is provided, having a ratio to the small receptacle different from that of the principal load-receiving element—as 20 to 1, for instance. Sometimes the support for the small receptacle is mounted like a weighbeam poise, so that the ratio to the load-receiving element may be varied; in this case the bar on which the support is moved is graduated, and the support may be set for counting out a predetermined odd number of articles, or the number of articles in a given lot may be determined. Counting scales are usually designed so that conventional weighings may be made when desired. The sensitiveness of the scale determines how light an individual article may be if a number of these are to be counted accurately; the more sensitive the scale the lighter the article which can be accurately counted. It follows that the sensitiveness of the scale also determines the degree of accuracy of the count of articles which weigh less than the minimum weight of articles accurately counted; for instance, if a given scale is just able to count accurately—that is, to the nearest 1—articles weighing as little as one-tenth ounce, it will count articles weighing one-hundredth ounce each with a precision such that the count will be accurate to the nearest 10.

Predetermined-Weight Scales.—The predetermined-weight scale is particularly designed for weighing out drafts of uniform weight value; and, in the case of some types, such a scale is also very well adapted to the check weighing of packages of the same nominal weight. Usually these scales are not suitable for general weighing operations.

The automatic grain hopper scale and the platform scale which is "back balanced," are examples of true predetermined weight scales. The former is designed for use in grain elevators, and is constructed to receive into a small garner a continuous flow of grain from an elevator leg, to discharge from the garner into the scale hopper until a predetermined weight of grain has entered the hopper, to shut off the flow from the garner, to dump the contents of the hopper, to register the dump on a counter, to restart the flow from the garner, and so on as a repeating cycle as long as grain is supplied. Continuous weighing is thus accomplished by means of a succession of drafts of uniform weight value, the object being to determine the total weight of the grain passed through the scale. There are also modifications of this type of scale designed for sacking uniform drafts of flour, grain, and similar commodities, in which each cycle of operation must be started by the operator. These scales may also be adapted for weighing liquids and a variety of free-flowing dry commodities, and in the smaller capacities are more or less widely used for filling cartons and sacks, being generically known as "packaging scales." The scales may be set for the desired weight per discharge by means of loose weights or weighbeam poise.

When a scale is said to be "back-balanced" a certain amount, this means that it is thrown out of balance sufficiently so that when weights in the stated amount are placed on the load-receiving element, a condition of balance is established. This out-of-balance condition corresponds to the condition which exists when a weighbeam poise is moved out from zero or when counterpoise weights are in place; in the scale described as a back-balanced type, however, it is frequently impossible to establish a zero-load balance because the range of movement of the "balancing" element is insufficient for this, and the scale must be balanced with weights on the load-receiving element. Obviously, such scales are intended for use in weighing out or packing drafts of commodity of predetermined weight value. An automatic-indicating element with a small range of indication may be incorporated in such a scale; this element may be simply a balance indicator, in which case the chart with which the indicator cooperates will have a single "zero" graduation, indicating conformance with the load for which the scale is set; or the element may be a weight-indicating device, in which case the chart may have tolerance lines on one or both sides of the zero graduation for the guidance of the operator, these showing the limits permissible for deviation from the true packing weight, or it may have a series of weight graduations on one or on both sides of the zero graduation. This is the same type of semiautomatic indication as is found in the equal-arm scale with the over-and-under indicator, described in the preceding chapter.

Another common type of packing scale is an adaptation of the ordinary beam scale, having a self-locking poise. This type may be used for general weighing, although the poise-locking feature which recommends it as a packing scale militates against its use for general weighing purposes. Ordinary beam scales are not infrequently adapted for use as packing scales by equipping them with special counterpoise weights whose counterpoise values correspond with the weights which it is desired to pack; for instance, flour-packing scales may have counterpoise weights with counterpoise values of 12¼ pounds, 24½ pounds, 49 pounds, etc.

Predetermined-Volume Scales. — For determining weight per unit volume, special scales have been developed in which a measured volume of the commodity is weighed and the result indicated in terms of the weight per unit desired. A common example of this type of scale is the "bucket grain tester." In this tester a small steelyard-type weighing device is equipped with a bucket having a known capacity—usually 1 or 2 quarts dry measure—and with a weighbeam graduated to indicate pounds per bushel; the weighbeam may also be graduated to show the actual weight of the grain in the bucket, the ratio between these values and the weights per bushel being the same as that between the volume of the bucket and the volume of a stricken bushel; the weighbeam may also have a third series of graduations, these being in terms of percent, to be used in determining the percentage of clean grain. For this last-mentioned use the predetermined-volume feature of the scale is not used; the poise is set at the 100 percent graduation, grain is placed in the bucket until equilibrium is established, the grain is removed and cleaned, the clean grain is replaced in the bucket, the poise is moved back until equilibrium is restored, and the percentage of clean grain is read off directly. Scales for a similar purpose and graduated in a similar manner are also commonly made in the unequal-arm type with stabilized plates; these are frequently known as "seed testers," and usually have "cups" of smaller capacities than the "buckets" discussed above.

Another special predetermined volume scale is one designed for determining the weight per gallon of ice cream. A cup of standard volume is utilized on the same principle as in the case of the grain or seed tester. These scales are also arranged so that by comparing the weight of a measured volume of the ice cream "mix" before whipping with the weight of the same volume of the finished product, the percentage of "overrun," or "swell," may be directly read on the scale.

Predetermined-Charter-of-Load Scales.—Many examples could be cited of scales which are designed to receive only loads of certain restricted characters, either for direct weighing or for determining certain characteristics of the article or sample weighed. A few of these will be described briefly and some others will merely be mentioned.

The "cream-test" scale is variously designed to receive from 1 to 12 "cream-test bottles" of the type used in the Babcock test for butterfat content of cream. The scale is balanced with the empty bottle or bottles in place, after which 9-gram or 18-gram charges of cream are weighed into each bottle. These scales are usually of the equal-arm type without weighbeams, a 9-gram or 18-gram weight being used first on one pan and then on the other for weighing out the samples; the balancing means on these scales usually have a considerable range, to accommodate bottles of varying weight, and the balancing adjustment is made particularly accessible and convenient to use because the scale must, of necessity, be rebalanced each time it is reloaded with empty bottles.

"Wheel-load weighers" are compact, portable scales specially designed for determining the wheel loads and axle loads of vehicles. They are designed with the platform raised only a few inches above the surface on which the weigher rests and with an inclined approach so that a pair of vehicle wheels may easily be driven onto the platforms of a pair of weighers suitably placed on a street or highway.

A "hopper" or "tank" scale is utilized for the weighing in loose form of free-running commodities such as grain, sand, coal, liquids, etc. Such a scale is essentially a platform scale in which the platform has been replaced by, or has been cut away to receive, a hopper or a tank. Thus a small-capacity hopper may be mounted on the lever system of a portable scale or a self-contained warehouse scale, and hoppers and tanks of larger capacity may be mounted on levers which in design and arrangement resemble those of built-in platform scales of similar capacities. The hopper or the tank is usually mounted above the lever system, although this element is sometimes hung from an overhead lever system.

Hoppers or tanks are usually round or square in cross section and mounted vertically, although cylindrical tanks for liquids are at times mounted horizontally; they may be made of wood or metal; the bottoms of hoppers intended for dry commodities are sloped toward the discharge opening at a considerable angle so that the material will all flow out when it is desired to empty the hopper; the frame directly supporting the hopper may be of wood or steel; hopper scales are not ordinarily equipped with full-capacity weighbeams, but utilize counterpoise weights.

Hopper scales for grain weighing are usually rated in terms of bushels, the weight equivalent of the "bushel" being taken as 60 pounds, the standard weight of a bushel of wheat; on this basis, capacities range from 40 to 2,500 bushels (2,400 to 150,000 pounds) ; minimum weighbeam graduations range from ½ to 5 pounds. Tank scales may be rated by gallons of tank capacity or by pounds of weighing capacity, and these values may lie anywhere within a considerable range.

"Egg-grading" scales have load-receiving elements shaped to receive a single egg. These scales may indicate merely that the eggs weighed are within one or another of several weight ranges, corresponding to the weight requirements of the grading rules in force.

Railway track scales, person weighers, and cotton beams, discussed in the preceding chapter, are, strictly speaking, also in the class of scales designed to receive only loads of special character. Many special testing machines, some of which resemble weighing scales, have been developed for testing specific materials for specific characteristics, as cement briquettes, paper, and yarn for tensile strength, structural materials for physical properties under tension and compression, machine parts and other articles for balance, various materials for moisture content, various materials for classification or uniformity of processing or manufacture, and so on in wide variety. The majority of such machines are not true weighing instruments but are primarily force-measuring instruments.

Miscellaneous.—Frequently the specialization in a particular scale consists of some minor modification only; this is the case in some of the scales already noted. Other examples of this are special charts, dials, or weighbeams graduated to read in bushels, gallons, yards, etc. of specific commodities upon the basis of a standard weight per bushel, gallon, yard, etc., where the weighings involve all of the commodity in question and the scale gives results directly in terms of the desired unit. Again, a scale for use in compounding, furnace charging, etc., may be devoid of weight indications; weighbeams or charts may be ungraduated so that proportions may be kept secret from workmen using the scale, poises on a beam scale being set by template or by use of weights applied to the load-receiving element, and markers being positioned on the reading face of an automatic-indicating scale in the same manner; or those portions of the indicating elements which contain the weight graduations may be partially covered by a locked shield, only enough being exposed to enable the workmen to tell when the desired condition of balance or coincidence has been reached. On the other hand, many special scales involve radical departures from conventional design and appearance, as in the case of many testing machines and scales for special industrial uses, such as have already been mentioned. This is also true in the case of such special weighing devices as those designed for continuous weighing, in which material being weighed passes over the scale on a continuously moving belt, and the scale integrates or totalizes the weight of the material which has passed across it.

Chapter 6.—ELEMENTS OF SCALE PERFORMANCE: ADJUSTMENT AND REPAIR OF SCALES; CONDITIONS AFFECTING SCALE PERFORMANCE—SENSITIVENESS, ACCURACY

It is the purpose of this chapter to discuss briefly and in general terms, some of the more common elements which affect the performance of scales, so as to suggest possible sources of trouble and methods of correcting it, when inspection or test discloses that a scale is not functioning as it should. The limits of this publication will not permit the inclusion of detailed instructions as to methods of adjustment or repair. Such instructions for particular makes of scales may frequently be found in the publications of scale manufacturers; it is also suggested that much valuable information along this line may be gained from personal discussion with experienced scale service men, repair men, and erectors.

Adjustment and Repair of Scales.[19]—It is not to be presumed that the weights and measures official is expected regularly to undertake the repairs and adjustments which are discussed below. The inexperienced official will do well to leave such work severely alone, and confine his mechanical activities strictly to his statutory duty of (1) determining whether or not the scales which he examines conform to the legal requirements of construction and performance as laid down in his specifications and tolerances, and (2) sealing, rejecting, or condemning these scales according to the results of his examination. The experienced official may do likewise if he so chooses, and in refusing to go beyond the strict "letter" of his statute he is undoubtedly within his legal rights. But when the official becomes competent to make minor adjustments and even slight repairs, it is believed that there are times when he should do so, and that if he fails to do so, he is failing to render to his community the full measure of service that may reasonably be expected of him.

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[19] This subject is more fully discussed in National Bureau of Standards Handbook H26, Weights and Measures Administration, chapter 19, pages 114-117.

The amount and character of such work to be undertaken by the official will depend not only upon his ability to do the work well, but upon a variety of circumstances not the least important of which is the availability of commercial service agencies upon which the scale owner may call. Assuredly, the official should never attempt anything along this line unless he thoroughly understands the problem and feels entirely competent to handle it. With these conditions met, however, considerations of the time and money loss to the scale owner if a commercial agency must be employed, the time and expense of a return trip by the official to make a retest, and similar factors, will guide the official in reaching his decision.

But whether or not adjustment or repair is ever undertaken by the official, he should strive to perfect himself along mechanical lines and familiarize himself with all of the conditions which affect scale performance, so that when he finds a scale inaccurate or otherwise out of proper weighing condition, he may be in a position intelligently to suggest to the owner the probable causes of the trouble, the steps to be taken for its correction, and the precautions to be observed to prevent its recurrence. This is a service which the official should always render when it is possible for him to do so, and until he can do so, he can not be considered to be fully qualified to carry on his work with the highest degree of usefulness to his community.

Conditions Affecting Scale Performance.—There are several factors which enter into proper scale performance, and these are so interrelated that it is somewhat difficult to separate them. We may, however, for purposes of discussion, group these under the two general heads of sensitiveness and accuracy, and then proceed to a consideration of those influences which are conducive or deterimental to satisfactory performance with respect to these characteristics.

Sensitiveness.—The sensitiveness of a scale may be said to be its response to relatively small increments of load. The smaller the amount of added load necessary to cause a perceptible change in the indication of a scale, the more "sensitive" the scale is said to be; conversely, if it is necessary to add a relatively large amount of load in order to bring about a perceptible change of indication, the scale is said to be relatively "insensitive." In a theoretically perfect scale, any increment of load, however small, would change the indication of the scale; as a practical matter, however, there is a limiting value for the load increment to which a scale will respond with a change of indication. Moreover, even when changes of indication do take place, these must be of a certain magnitude before they become perceptible to an observer. The sensitiveness of a commercial scale assembly, therefore, is dependent upon the inherent ability of the weighing mechanism to respond to small increments of load and the ability of the indicating means to make apparent to an observer the responses of the mechanism. If either the weighing mechanism or the indicating means is seriously "insensitive," refinement of the other element will not produce a sensitive assembly.

In the case of an automatic-indicating scale, the weight value of any applied load (within the automatic-indicating range of the scale) is supposed to be accurately and automatically indicated; hence, if such a scale is "insensitive" in that it fails accurately to respond to small increments of load, the observed condition is reasonably construed as "inaccuracy" rather than as lack of sensitiveness, and accordingly the specifications do not set up any criterion of sensitiveness for automatic-indicating scales. In the case of nonautomatic-indicating scales, however, the performance with respect to sensitiveness can readily be separated from the performance with respect to accuracy, and the specifications for such sales do set up definite requirements for sensitiveness. "Sensitiveness" being a general and indefinite term, susceptible of various interpretations, and it being desired to have a definite measure of this characteristic, the term "sensibility reciprocal" has been adopted and defined in such a way that specification requirements in terms of sensibility reciprocal have a very definite meaning for various types of commercial scales, and may be uniformly applied. For the sake of ease and brevity of expression, the term "sensibility reciprocal" is now generally read and written as "SR." Further reference to SR will be found in the instructions for testing various types of scales, appearing later in this publication.[20]

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[20] See p. 127.

While suitable sensitiveness is an essential characteristic of a correct weighing machine, all scales are not equally sensitive—nor should they be; there is such a condition as a scale being too sensitive to be well adapted to a particular use. Increased sensitiveness in a scale of a particular type is often accompanied by increased refinement and delicacy of parts, by increased initial cost of the scale, and by decreased rapidity of weighing. Sensitiveness requirements, therefore, should not be unreasonably severe, because unnecessary demands in this direction may militate against sturdiness of construction, long life, low first cost, low maintenance cost, and rapidity of weighing.

Failure of a new scale to meet sensitiveness requirements may be caused by improper design, improper construction, improper adjustment, improper assembly or installation, or a combination of these factors. In the case of the product of a well-established manufacturer, faulty design and poor construction are not to be anticipated. However, it will be appropriate to mention some of the more common points of good design and construction, including, for completeness, numerous points which have no direct relation to sensitiveness: Parts should be of such strength and rigidity that they will not be liable to breakage and that troublesome deflections will not develop under capacity loads; provision should be made to prevent frictional effects wherever possible by providing suitable clearances around live parts—as between frame and levers and platform, around pivots, etc.—and, by means of hardened antifriction points and plates, to reduce these effects to a minimum where a moving part is or may be in contact with some other part; knife-edges and bearing surfaces should be suitably hardened; knife-edges should be straight and sharp; bearing surfaces should be smooth and so designed or protected as to minimize the accumulation of foreign matter adjacent to a pivot; checking means should be provided so that during ordinary operation the parts—especially the platform—will not tend to become displaced in such a manner as to introduce frictional effects; the security of adjustable elements and of adjusting material should be insured; the fit and alinement of parts should be good throughout; materials should have been selected throughout for permanence and wearing qualities and for their special fitness for the services demanded of them; simplicity of design and construction should not be sacrificed for complexity unless something worth-while is gained; ease of operation, ease and precision of reading, and freedom from characteristics which might facilitate the perpetration of fraud in commercial use should be realized; the surface treatment of parts should be such as will minimize deterioration in use; in general, careful workmanship should be in evidence throughout the entire scale. It may also be mentioned that the reliable manufacturer will see to it that the factory assembly of his product is carefully performed, that the scales or their essential elements are tested before shipment, that the packing for shipment is such as to minimize the probability of damage in transit, and that all necessary instructions for unpacking and setting up or installing his scales are furnished to the purchaser.

Proceeding to a consideration of the other senstiveness factors noted in connection with new scales, it may be said relative to improper adjustment that means for controlling sensitiveness, such as a balance-ball assembly which may be raised or lowered, should be secured in position, but that displacement may take place in shipment; such displacement can readily be corrected. Improper assembly or installation may be responsible for a variety of frictional conditions which will adversely affect the sensitiveness of a scale, and these may be discovered by inspection, after which the procedure for their elimination will be obvious.

In the case of an old scale there must be considered, in addition to the factors just mentioned, two important causes of reduced sensitiveness—wear or deterioration of the working parts of the scale, and binding conditions resulting from improper maintenance. As in the case of frictional conditions in a new scale, it may be discovered by inspection whether or not these causes are operating; if worn or corroded parts are found, these may be repaired or replaced, or the scale may be discarded as having outlived its usefulness; if binding conditions are found, it should be a simple matter to relieve them and take steps to prevent or retard their subsequent development.

The principal parts whose wear causes reduced sensitiveness are pivots, bearings, and antifriction elements. When pivot knife-edges or points become rounded as a result of normal wear, corrosion, or excessive relative movement of knife-edges and their bearings, sensitiveness is reduced because friction is increased and, particularly in the case of a weighbeam, because the alinement of the knife-edges and the relation between center of gravity and fulcrum knife-edge are changed; cut and worn bearing surfaces also increase friction and reduce sensitiveness, as do worn or roughened antifriction plates and caps, and flattened antifriction points. Worn pivots and worn bearings should be reconditioned or renewed, but this work should only be undertaken by a competent mechanic; some types of antifriction plates may be readily replaced, but the repair or replacement of antifriction points is in the same class as the repair of pivots and should not be undertaken by the inexperienced. Where adjustable means for controlling sensitiveness are provided, temporary improvement can frequently be effected by raising the center of gravity of the weighbeam and thus "forcing" a more sensitive condition.

Binding conditions are common in scales which are not properly maintained, and, of course, the causes of binds should be located and removed. In a beam scale the character of the weighbeam action is a very good index of the sensitiveness.[21] If the scale is in good condition and free from binds, the weighbeam may be balanced so that it will oscillate, or swing up and back, with a free, slow, and even motion, and there will be only a slight "damping"; that is, there will be only a slight decrease in amplitude of successive swings; or in other words, on each successive upward or downward swing, the weighbeam will travel almost as far as it did on its previous swing in that direction. If the weighbeam swings relatively fast, the sensitiveness is probably low; if there is pronounced damping, this is evidence of the presence of friction; if the weighbeam oscillates with short, rapid swings, with a "springy," "jerky," or "lamb's-tail" motion, this is an almost certain indication of a direct bind against some live member of the mechanism—that

[21] See p. 107 for instruction as to method of handling a beam when making observations.

is, some member designed to be free to move in the course of the operation of weighing.

Binding conditions will result from a variety of causes: The accumulation of dirt or other foreign material under or around levers, pivots, or beam rods, and between platform and frame or pit-wall coping; the displacement of a part from its designed position—as from bending or loosening of supporting bolts or the deformation of a connecting link—causing this to come into contact with another part; weakness of foundation, anchorage, or supports, causing rubbing or contact of parts, particularly under heavy loads. The remedies for these conditions are obvious.

Accuracy.—A good scale should not only be susceptible of giving accurate indications of weight, but it should maintain its accuracy and adjustment under reasonable conditions of use and should reliably repeat its indications. Since a correct starting point, or zero-load condition, is essential for accurate weighing, a scale which will not retain its zero-load balance within reasonable limits is not a reliable or proper instrument. It is frequently difficult to locate the cause for shifts of zero-load balance, but in general these are probably caused by (1) changes in the relative positions of parts, principally knife-edges and bearings, during manipulation of the scale, induced by poor design or faulty construction, or (2) failure of certain elements of the mechanism to return to their initial positions after displacement, induced by poor design, faulty construction, excessive friction, or hysteresis. As here used, "hysteresis" may be defined as a lagging in the return to original position, of a mechanical system (such as a system of levers) or of an elastic body (such as a spring) after displacement or distortion and the subsequent removal of the force causing the displacement or distortion. Hysteresis may be reduced in the mechanical system by a general refinement of fits with resulting reduction of backlash and lost motion in linkage, and elimination of points of loose connection wherever practicable; hysteresis in properly constructed springs used in scale construction is slight, especially if the distortion is of short duration, and usually the spring will "recover" fully after a short interval of time.

In connection with this consideration of the stability of the zero-load balance condition of a scale, it should be noted that when a scale is equipped with a relieving or locking device, designed to provide a means for protecting the working parts of the scale during the application of loads or the movement of the scale, repeated operation of this device should not materially affect the zero-load balance condition. Likewise, the repeated application or removal of unit weights, or the reversal or interchange of parts designed to be reversible or interchangeable in the course of normal use, should not materially affect the zero-load balance condition of a scale.

The same factors which affect the ability of a scale to maintain its zero-load balance are apt to affect its ability accurately to repeat its indications upon repeated applications of the same load. In commercial operation, where zero-load balance is not checked between successive weighing operations, inconsistency of indications for applied loads of equal amounts may be caused by a shifting of zero-load balance, poor "repeatability," or—and this is most likely—to a combination of the two. It should be unnecessary to state that in a good scale, the performance with respect to both of these characteristics will be of a high order.

Any new scale should leave the hands of the manufacturer in first-class condition, but this is not invariably the case; moreover, damage or derangement may occur during shipment; again, a scale may have been improperly assembled or installed. Even new scales, therefore, should always be tested after installation in the location where they are to be used. If a new scale gives inaccurate results on test, it should first be ascertained whether the trouble is caused by damaged or missing parts or by improper assembly or installation, every effort being made to locate trouble of this character. Damaged parts may be a steel ribbon or tape which has been bent, kinked, or twisted, a bearing which has been cracked, a chipped or crushed knife-edge, exposed parts (such as the linkage beneath an equal-arm counter scale) which have been bent or otherwise damaged, an indicator which has been bent so as to be rubbing on the reading face. Missing parts may be an agate or steel bearing, a poise locking screw, an antifriction plate, an essential screw or bolt. As examples of improper assembly or installation there may be mentioned failure to remove all of the packing material from some of the delicate parts of the mechanism of an automatic-indicating scale, failure to remove foreign material which may be adhering to the inner surface of a ribbon or to the surface of the cam which contacts it, reversal of the position of some part when this is put in place (as end-for-end reversal of a beam rod), mounting of a scale on a counter having insecure supports, installing a built-in scale on insecure foundations, with insufficient clearances around platform or other moving parts, with levers out of level or with connections out of plumb.

If it be demonstrated that the mechanism is in good condition and that there are no faults of assembly or installation, then, and only then, should attention be directed to the adjustable features of the scale. One or more nose-irons will be found on the levers of many scales. The nose-iron should have been properly set and locked in position, and this position should have been clearly and permanently marked, by the manufacturer. However, it is possible for a nose-iron to become loosened in shipment; moreover, totally incompetent scale erectors have been known to assume that the nose-iron on a scale lever is provided for the purpose of readily plumbing connections, and to move a nose-iron for this purpose; an examination of the marks showing the factory position would reveal such conditions. If found loose or displaced, the nose-iron should be set back as nearly as possible to the factory position, and then by repeated tests its proper position should be established and it should be securely locked in this position. But as previously stated, unless a nose-iron is actually loose, or is obviously out of its proper position, the movement of this part should never be attempted until it has been conclusively demonstrated that the source of trouble does not lie elsewhere.

There are a number of other elements, improper adjustment of which may cause inaccuracies in new scales; also, readjustment of these elements may sometimes be necessary after a scale has been in use for some time, even though the original adjustment was properly made. A spring used to supply the counterforce is usually adjustable for effective length; a shortening of the effective length of such a spring will "stiffen" the spring and cause the scale to indicate less than formerly on a given load, and, of course, the opposite effect is produced if the spring be lengthened. Where a pendulum is employed to supply the counterforce, lowering the pendulum bob or ball causes a decrease in the indication, and raising the bob causes an increase in the indication, for a given load. In automatic-indicating scales, adjustable cams are utilized to harmonize the indications at half and full capacity; on cylinder or drum types of this class, small "chart-balancing weights," mounted on the arms of the chart frame, are similarly used for the one-quarter and three-quarter capacity points. On certain counter types, adjustments of the stabilizing linkage may be made to control errors resulting solely from changes in the position of the load on the load-receiving element of the scale. One or more of these elements may be out of adjustment, and not infrequently a combination of several different adjustments is necessary to correct errors found in a scale. With respect to these adjustable elements the same caution should always be observed as has already been noted in relation to nose-irons; that is, their adjustment should never be altered unless and until it has been conclusively demonstarted that faulty adjustment of the elements in question is responsible for the errors found.

Scales which have been in use for some time may be expected occasionally to develop errors primarily as a result of such use. Under certain conditions, dull or rounded knife-edges may introduce changes in the effective multiples of the levers in which they are mounted; one or more loose pivots will, of course, result in great uncertainty in the multiple of a lever. Knife-edges may have become chipped or pivots broken. If pivots have been renewed or reconditioned by an unskilled workman, the multiple of the lever may have been changed. To correct these conditions, a lever may successfully be reconditioned and the original multiple restored, provided that such work be undertaken in a scale factory or shop or by a competent mechanic provided with suitable mechanical equipment.

Yielding supports may allow some of the live parts of a scale to settle under load into contact with some other part, so that all of the forces are not transmitted to the weighbeam or other indicating means, in which case the scale indications will be less than they should be; an accumulation of foreign matter under levers, under platform, or elsewhere, and also certain binding conditions, may produce the same result. Yielding supports, settling of foundations, deflection of parts, or other causes may produce out-of-level or out-of-plumb conditions which will seriously affect the accuracy of weighing results. To correct these conditions, structural repair should be made to strengthen supports, foundations, etc.; loosened parts should be secured in proper position; foreign material should be cleaned away and binds eliminated; levers should be realined so that they will be level, and connections should be plumbed; weak members of the assembly should be replaced with members in which the effects of deflections under conditions of use will be negligible.

Weighbeam poises may have been made heavy, or may have become heavy from the lodgment within them of foreign material such as dust, kernels of grain, water, etc.; in these cases their indications will be too small. On the other hand, weighbeam poises may have become light from loss of material through wear, from the loss of the locking screw, or from the dropping out of insecurely positioned adjusting material, or material may have been intentionally removed from them; in these cases the indications of the poise will be too great. Because of rough usage, the shoulder or stop on the weighbeam bar, designed to define the zero position of the poise, may have become battered, and the poise itself may have become dented, so that when in normal manner the poise is pushed as far back as it will go it will rest a considerable distance behind its proper zero position; if the scale is balanced with the poise in this position, there will be a constant error resulting from this cause alone every time the poise is used in a weighing, this error being equal to the weighbeam value corresponding to the distance of the poise behind the zero graduation. The correction of these conditions in the field may or may not be practicable. Foreign material which has accumulated in a poise from natural or accidental causes may readily be removed, and this removal will frequently restore the poise to its proper weight. However, if adjusting material must be added to or removed from a poise, this will involve a complete resealing of the poise, including repeated zero-load balancing and testing; the secure attachment of material added, and the avoidance of interference of such material with poise movement, are also of prime importance. Slight battering of the shoulder of the beam may be corrected by careful peening and subsequent dressing of the drawn-out surface so as to position the poise correctly at zero; if this condition is serious, however, only shop or factory repair, or replacement of the weighbeam or bar is to be recommended.

The notches of a weighbeam, or the pawl of a poise, may have become so worn that the poise will not be correctly positioned or that it will not be definitely positioned; the same effect may result from an accumulation of foreign material in the notches. On a smooth bar, the reading edge of the poise may be so defaced, or the graduations on the bar may be so indistinct or otherwise poorly defined, that accurate settings of the poise can not be made. The reading face of an automatic-indicating scale may be so defaced that the indications can not be read with accuracy at certain points. The liquid in a dash pot may not be at the proper height, or it may not be of the proper consistency, having become thickened as a result of evaporation or the accretion of foreign material; foreign material may also collect at the bottom of the dash pot as sediment in sufficient amount to interfere with the operation of the scale. Wear on cooperating parts such as those of a rack-and-pinion assembly may reach serious proportions. Cleaning of parts and replacement of dash-pot liquid may conveniently be done in the field; minor repairs and the replacement of worn or defaced parts may be made in the ordinary scale shop and frequently in the field; regraduation of weighbeam or chart, recutting of weighbeam notches, correction of worn teeth in racks and pinions, and similar jobs should only be undertaken in the specially-equipped shop or in the scale factory.

When a scale is used with counterpoise weights which are too light, the scale indications will be too great, and when the weights are too heavy, the scale indications will be too small. The subject of weights used with commercial scales is discussed in detail in chapter 9 of this publication, to which reference should be made.

Instances will be found in which intentionally or inadvertently, the operator of a scale has done something to the mechanism, or has added some attachment, or has removed some part, as a result of which there are errors in the weight indications. Familiarity with standard construction and experience in ascribing probable causes to observed errors must be relied upon in these cases to locate the exact source of the trouble.

Chapter 7.—INSPECTION OF COMMERCIAL SCALES: COMPLIANCE WITH SPECIFICATIONS; CONDITION OF WORKING PARTS; EFFECTS OF EXTERNAL CONDITIONS; SUITABILITY OF EQUIPMENT IN USE

The preceding chapter necessarily contained much information along the line of inspection, and should be read in connection with the present discussion. Reference should also be made to the discussion of the inspection of commercial devices, appearing in National Bureau of Standards Handbook H26.[22] In Handbook H26 four purposes of inspection are enumerated:

1. To insure compliance with specifications.
2. To insure that working parts are in proper condition.
3. To diagnose troubles.
4. To discover external conditions which might have unfavorable effects.

Items 2 and 3 are overlapping, in that there will be no troubles to diagnose if all of the scale parts are as they should be; in what follows, the treatment of these items will, therefore, be combined under the heading of item 2.

Compliance with Specifications.—A "correct" scale is defined as one which meets two sets of requirements, (1) the specifications, including the SR requirements, and (2) the tolerances, which are applicable to it. If a scale fails in either respect it is "incorrect"; that is, it is incorrect if it fails to meet one or more of the requirements of the specifications or if it is not sufficiently sensitive, just as much as it is incorrect if the weight indications are in error in excess of the prescribed tolerances. The importance of and the necessity for inspection to determine compliance with applicable specifications is, therefore, at once apparent.

The application and classification of specifications are discussed in National Bureau of Standards Handbook

[22] Chapter 15, p. 110-115.

H29,[23] and reference should be made to that discussion. The distinction between retroactive and nonretroactive requirements should be kept in mind, and the general category of commercial devices to which the nonretroactive requirements do not apply should be carefully distinguished. Care must also be exercised to locate all of the specifications which apply to a particular scale.

When examining commercial devices, the weights and measures official should always have available for reference his official book of specifications. The new or inexperienced official should run through the printed specifications which are applicable, every time he examines a scale, checking the compliance of the scale under examination with each requirement; the number of requirements applicable to a particular scale may be rather large, and the suggested procedure is the only method of insuring that nothing has been forgotten. It is only the experienced official who thoroughly knows his specifications, who may trust to his memory in such matters, and even then it is advisable to refer to the book from time to time as a precautionary measure, particularly when examining a new make or type of device. Of course, the experienced official will readily recognize many scales as of a type and make which he has previously examined and found satisfactory with respect to specification requirements, and any scale being examined for the second or subsequent time, following original approval, may be presumed to be in compliance with the specifications unless it has been modified or has deteriorated since the previous inspection.

The preceding paragraph refers to jurisdictions in which a State type-approval law is not in effect. Where State type-approval is in force, equipment marked to show such approval carries the assurance of the manufacturer that specification requirements were met when the equipment left his hands.

When inspection for compliance with specifications discloses grounds for rejection of a scale, it is frequently unnecessary to make any test at all, or in any event to

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[23] See National Bureau of Standards Handbook H29, Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices, p. 2-5. The codes published in this Handbook are those adopted by the National Conference on Weights and Measures and recommended by the National Bureau of Standards for State promulgation.

make more than a "skeleton" test. There will be instances, however, in which it is desired to obtain complete information on the performance of a scale in the condition in which it was being used commercially; this might readily be the case were any court action, involving the scale in question, in contemplation.

Condition of Working Parts.—Before the regular test of a scale is undertaken, it is proper and advisable for the official to assure himself that the working parts of the scale are in condition to function as intended. This preliminary inspection may be complete, embracing all of the elements of the scale mechanism, or it may be partial, embracing only the more important or readily accessible elements; usually the partial inspection will be sufficient unless or until some trouble develops, indicating the desirability of a more thorough inspection to disclose the causes of the difficulty encountered.

There are listed below some of the more important items of inspection with respect to common types of scales. When special types of scales are encountered, it will be necessary to give such attention to their special features as circumstances and the experience of the inspector dictate. Although the list of items for "preliminary inspection" appears somewhat formidable, the preliminary inspection of any particular scale will ordinarily require only a few minutes on the part of the experienced official, who will quickly acquire the habit of checking the necessary points almost automatically and the ability to do this almost "at a glance." In the case of "inspection following unsatisfactory test results," the thoroughness of such an inspection will be dictated by circumstances in any given instance, and it is not contemplated that a complete examination of all of the parts of a scale will often be required.

PRELIMINARY INSPECTION

For general freedom from binding conditions.—

Examine for clearances:

Around platform of built-in scales (3/8 inch to 3/4 inch)

Around stock rack of livestock scales. (Rack must be mounted on the platform. Check for possible binds between gates and approaches.)

Around platform, and between platform and frame of self-contained scales.

See that:

Platforms are free to move a limited amount,[24] and will return to normal position after displacement.

Foreign material has not accumulated beneath counter scales.

Stabilizing links are free.

Open side of the hook of the counterpoise stem faces away from the trig loop.

Weighbeam pivots are centered in loops, weighbeam is balanced, and beam action indicates general sensitiveness.

For general cleanliness.—

See that there is an absence of:

Dirt in weighbeam notches.

Dirt in weighbeam loops.

Rust, oil, gummy deposits, etc., on weighbeam pivots.

Dirt or other foreign material on load-receiving element—platform, platter, scoop, pan, etc.—and on counterpoise weights.[25]

For general operating conditions.—

Examine for:

Rocking of platform, especially on warehouse and portable types. (Rocking may be caused by warped platform, bearing feet of improper length, displaced or missing bearing plates, or "steels," lever fulcrum loops of uneven length, worn or sagging supports for lever fulcrum loops, improper height of lever knife-edges.

Tightness of bolts securing weighbeam pillar and shelf and other exposed structural parts.

Centering of weighbeam—front to back—in trig loop. (If weighbeam tends to work to front or back of trig loop, the support for the weighbeam

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[24] Except in the case of a large-capacity scale in which the platform is checked with rigidly attached stay plates.

[25] See also chapter 9, for additional discussion on the inspection of counterpoise weights.

fulcrum may be loose or twisted, the weighbeam fulcrum loop may be deformed, the weighbeam may be bent, the weighbeam fulcrum pivot may be bent or improperly inserted.

Battered zero stop on weighbeam.

Battered weighbeam poise or deformed reading edge or other index of weighbeam poise. (When poise is pushed as far as it will slide in the zero direction on the weighbeam, a correct "zero" indication should be given.)

Worn notches on weighbeam.

Defaced graduation marks or figures on weighbeam or reading face.

Security of balancing material. (Any opening in the counterpoise hanger cup should be closed, and the cover should be fixed firmly in place.)

Agreement between weighbeam or reading face indications on dealer's and customers' sides of scale.

Suitability of openings in chart housing to insure readability of indications at all times.

Suitability of any attachments, extended platforms, special load receptacles.

Suitability of counterpoise weights in use. (Weights should be marked to correspond with the multiple of the scale. Weights should be available in such denominations and amount as to permit readings on all loads up to, but not exceeding, the nominal capacity of the scale. Improperly marked, broken, patched, and extra weights should be removed from service.)

See that:

Poises on notched weighbeams are equipped with pawls which fit the weighbeam notches. (Badly worn pawls should be renewed.)

Springs on spring-controlled weighbeam poise pawls are strong enough to seat the pawl properly in the weighbeam notches.

Dash pots on automatic-indicating scales are in proper adjustment. (When any load is applied, the indicator should swing from three to seven times before coming to rest; that is, it should swing not less than once beyond and once behind its final rest point before coming to rest, and the number of such swings should not be more than seven.)

Give consideration to:

Probability or evidence of fraudulent manipulation. (Plugged or drilled counterpoise weights, filed weighbeam notches, serious out-of-balance conditions, attachments, opportunities for introducing frictional effects at will.)

INSPECTION FOLLOWING UNSATISFACTORY TEST RESULTS.

Examine such of the following elements as might tend to produce the unsatisfactory results observed:

Pivots: For tightness and alinement, and for sharpness and cleanliness of knife-edges.

Loops and other bearings: For smoothness of bearing surfaces, cleanliness, and alinement with opposing knife-edges.

Nose-irons: For evidence of movement from factory sealing positions.

Antifriction points: For sharpness and cleanliness.

Antifriction plates, caps, and other surfaces: For smoothness and cleanliness.

Levers: For alinement and level.

Connections: For vertical alinement.

Moving parts: For evidence of friction with adjacent parts. (Observe particularly clearances under and around levers and around pivots, beam rods, steelyard rods, loops, shackles, links, etc.)

Cooperating parts, such as rack-and-pinion assemblies: For cleanliness, smoothness, and evidence of excessive wear or deformation.

Supporting members, such as lever stands, eye bolts, timbers, foundations, etc.: For security of positioning and evidence of deformation. (To check possibility of the yielding or settling of members or supports under load, compare appearances when the scale is not loaded and when it is loaded.)

Linkages, connections, etc.: For cleanliness, freedom of movement, and absence of deformation or other damage.

Dash pots: For frictional effects; in hydraulic dash pots, for an accumulation of sediment, and for proper height of liquid. (The piston must remain submerged in the liquid at all times.)

Weighbeam poises: For lost locking screws or other missing parts and for presence of foreign material within the poise.

Adjustable elements: For insecurity of positioning.

Steelyard or beam rods: For freedom of hook engagements, and for end-for-end reversal. (If one end of a beam rod is equipped with a bearing, this should engage the tip knife-edge of the lever system and the end with the hook should engage the load loop of the weighbeam.)

Steel tapes or ribbons: For kinks, bends, roughness, adhering foreign matter, etc.

Surfaces over which steel tapes operate: For roughness, deformation, adhering foreign matter, etc.

Effects of External Conditions.—The official should be alert in the search for any conditions external to the weighing apparatus itself which may be conducive to inaccurate or otherwise unsatisfactory weighing results or to the perpetration of fraud. In this field of inspection, experience, well-developed powers of observation, a modicum of imagination, and the ability to deduce probable results from observed or probable external conditions are requisites for success. The conditions with which the official is faced in the case of a particular scale at a particular time may, and frequently will, differ in one or more respects from those existing in the cases of every other examination which the official is called upon to make. It is out of the question to do more in this discussion than to suggest a few typical examples of factors to which attention should be given; the official must thoughtfully analyze each set of circumstances as he finds it, relying upon his own ability to reach the proper conclusions in each instance.

One general comment should be made relative to the character of inspection under consideration: The conclusions of the official will more often than not find their expression as recommendations rather than as orders; that is, the unsatisfactory external conditions with respect to which the official feels that he should make known his objections will very frequently be of such a nature that they violate no specification and do not constitute competent grounds for rejection or condemnation of the apparatus affected or for definite official orders to or legal action directed against the owner or user of the apparatus. In numerous instances the only remedy lies in obtaining the voluntary cooperation of the responsible persons in the correction or elimination of the objectionable conditions.

Below are listed some of the considerations which should receive the attention of the official when making inspections with respect to conditions external to a scale.

Give consideration to:

Suitability of position of movable scales or of installation of built-in scales. (For protection from damage, abuse, and excessive unnecessary wear of parts, for visibility of indications to operators and other interested persons, for freedom from disturbing air currents above or below the platform, for freedom from vibrations, etc.)

Suitability of illumination to insure readability of indications.

Character of pits in which built-in scales are installed. (Accessibility of parts for cleaning, drainage and ventilation to reduce corrosion, etc.)

Protection from rain, snow, etc. (Roof or shed over scale, weather strips around exposed platforms, provision for diversion of surface water, etc.)

Protection of scale mechanism from corrosive effects resulting from the weighing of certain commodities, such as hides, salt, lime, etc.

Suitability of Equipment in Use.—In concluding this discussion of the inspection of commercial scales, mention may be made of a factor which has a great deal to do with the usefulness of a scale in service, and with which the official should be familiar in order that he can be of maximum help to scale owners and operators in his jurisdiction. Many of the facts in relation to this factor upon which the official can base his recommendations will come to his attention incident to his inspection of scales, and it seems appropriate, therefore, to discuss the matter at this point.

The factor referred to is the suitability of the design of a scale for the particular purpose for which it is being used or for which it is about to be procured. Many scale owners have not made the best choice when selecting the types for their weighing equipment, and weighing conditions can frequently be greatly improved if some changes are made; moreover, when the advice of the official is sought by a prospective purchaser of weighing equipment, the official should be able to make constructive recommendations based on sound principles of scale selection. There is quoted below a discussion of this subject by F. S. Holbrook,[26] published in 1929 in National Bureau of Standards Miscellaneous Publication M85, under the title "Judging the Suitability of Use of Commercial Weighing and Measuring Equipment."

Experience in the enforcement of weights and measures laws has amply demonstrated the necessity of the application of * * * specifications and tolerances * * * and there can be no question of the wisdom of purchasing commercial apparatus in compliance therewith.

It is to be recognized, however, that the whole problem of the procurement of satisfactory apparatus in various commercial uses will not necessarily have been solved, even after satisfactory codes of specifications and tolerances for commercial apparatus have been promulgated and are enforced in a given jurisdiction, valuable and necessary as this procedure may be. The painstaking official is sure to find that ideal conditions are not to be attained by these steps alone—that along with the above other precautions are to be observed. One of these may be stated as the securing of a proper relation between the piece of equipment employed and the use to which it is put—the efficiency of utilization of apparatus —to the end that the best results may be obtained and the best conditions exist in all varieties of commercial transactions.

Individual weights and measures officials in striving to obtain the ideal condition in this respect in their jurisdictions have naturally come to recognize the important part which the principle involved plays in their work. However, the subject has, it seems, been but little emphasized in official publications usually in their

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[26] At the time of the publication of the material cited, Mr. Holbrook was Co-Chief of the Division of Weights and Measures of the National Bureau of Standards and Secretary of the National Conference on Weights and Measures.

hands. What information has been available along these lines has been in the catalogues or other publications of manufacturers of weighing and measuring devices. In relation to these, in general, we may state that it is no part of our purpose in what follows to disparage them as a source of useful information. That some of these publications contain material of value is not to be gainsaid. Certainly, in so far as his own product is concerned, the manufacturer is in an excellent position to recommend specific types for particular needs. Such suggestions deserve and should receive the careful attention of the official and of the purchaser.

It is obvious, however, that manufacturers' catalogues will almost necessarily confine their discussions to one kind and make of apparatus; they will not have occasion to present the whole subject in its broader and more general aspects. Moreover, since these publications naturally have as their primary or underlying purpose the sale of specific products, it may reasonably be supposed that the official has often discounted the contents thereof to some extent in the not unnatural belief that the suggestions advanced can hardly be wholly unprejudiced ones. Therefore such an article as this seems none the less necessary. Likewise, there have not been available to the ordinary purchaser any general constructive suggestions which he has recognized as being unbiased, for the source mentioned above is likely to be discounted in this case as in the other. Again an official presentation of the underlying principles may serve a useful purpose.

Proceeding to this presentation, it may first be observed that the purchaser of commercial apparatus will not have taken sufficient precautions if he merely selects a piece of apparatus in compliance with the code applicable to devices of the character of the one purchased, failing to give attention to any additional considerations. Likewise, the weights and measures official will not be exercising proper and efficient supervision over the apparatus in commercial use if he merely inspects and tests apparatus and seals or condemns it solely because it complies or does not comply with the specifications and tolerances applicable to it, at the same time neglecting to examine into the conditions surrounding its use. For while it is to be taken for granted that every piece of apparatus complying with proper specifications and tolerances is, in general, a proper one, it by no means follows that every such piece of apparatus is efficient, or even satisfactory, for every use.

But little consideration will be necessary to indicate the truth of this postulate. Few would be found to defend practices such as attempting, in commercial transactions, to determine the weight of a ton of coal on a railroad track scale, of 50 pounds of fertilizer on an autotruck scale, of 10 pounds of sugar on a portable platform scale, of 5 grains of an expensive or potent drug, to be used in compounding a prescription, on a counter scale, or of 50 milligrams of a radium salt even on a prescription scale. Nor would this be on account of the fact that the railroad track scale, the autotruck scale, the portable platform scale, the counter scale, and the prescription scale were not, in themselves, entirely satisfactory weighing machines. Each might well be of excellent design and construction, and in proper condition. It would rather be because each scale was employed in a use for which it was not designed and constructed and for which it was entirely unsuited. And yet, while it is undoubtedly uncommon, it has not been by any means unknown for scales to be misused in ways not unlike those mentioned.

It is, in short, essential that the purchaser of apparatus and the weights and measures official, in buying or in examining, respectively, apparatus intended for a certain use or being put to a certain use, should each satisfy himself that the piece of apparatus selected or employed is well designed for that particular use. Failure to observe these precautions may result in the owner receiving unsatisfactory service, and the amounts of commodity entering into commercial transactions being seriously inaccurate, even when due care is being exercised to secure the best results capable of being produced by the apparatus employed.

To be sure the weights and measures official will often not be in a position to condemn apparatus in use even though he may consider that it is not ideally suited to the use for which it is employed, nor is it even desirable that he have such broad powers. However, if serious inaccuracies are resulting, his authority will doubtless be found sufficient to correct conditions either directly by proceeding against the apparatus itself, or indirectly, but perhaps not less effectively, by proceeding against the amounts of commodities determined. Also, even in cases where mandatory action is not indicated, he can furnish valuable service by assisting a prospective purchaser to make a wise selection on the one hand, or by pointing out the inefficiencies in the case of apparatus in use on the other.

In these cases the official will naturally take care to give general advice only, covering such points as accuracy desirable, preferable capacity of device, whether one or more devices will probably be needed, etc., leaving to the purchaser in every case the decision as to the merits of similar products of the different makers. Also, when the various devices under consideration all comply with the specifications and tolerances in force, it will, we believe, be much the wiser course for the official to refrain from differentiating between devices designed upon different principles but intended for identical uses. In other words, considerations such as convenience, speed of operation, durability, etc., should be evaluated by the purchaser. We have in mind the undesirability of comparison of the relative merits of beam scales and automatic scales, spring scales and pendulum scales, piston-type and visible-type liquid-measuring devices, and meters, etc.—such matters as these should be left to the salesmen for presentation. The purchaser should inform himself along these lines and draw his own conclusions without the interposition of the official. Failure on the part of the official to observe this precaution is likely to lead him into serious difficulty even when his motives are above reproach.

Contrary to the practice in this country, which will be described later, some foreign countries adopt the practice of officially placing restrictions upon the type of apparatus allowable for particular uses. To mention one specific example, in England the regulations corresponding to our specifications and tolerances provide for three classes of "beam scales" (defined as equal-arm weighing instruments, the pans of which are below the beam), namely, classes

A, B. and C. To each of these classes are applied independent requirements as to sensitiveness and accuracy. "Special trades" are then tabulated and the class or classes of scale required to be used in these trades are noted. Under such conditions the purchaser of a scale, by being restricted in his choice, is guided as to the type to be selected.

In this country we have few such restrictions as these, and if a proper enforcement of law can be procured without them it would be our judgment that under conditions as they exist in this country it is best to allow the purchaser the greatest freedom of choice. It has always been considered that were the attempt to be made to lay down particular requirements for the kinds of apparatus to be put to various uses, the task of the weights and measures official would be greatly complicated—perhaps the majority of the weights and measures offices as at present constituted would find it impossible adequately to enforce the requirements. For these reasons the specifications and tolerances usually adopted here are general in their character, they are drawn broadly to cover devices of certain general types, and they do not generally attempt to define or restrict the uses to which apparatus may be put.[27] Thus the selection of equipment here is more untrammeled than in England, but for this reason a purchaser should, both on his own account and for the protection of those with whom he deals, feel more, rather than less, obligated properly to select apparatus satisfactory and adequate for the use to which it is to be put.

In any event even were the attempt to be made to require specific types for particular uses this object would probably best be accomplished in this country by rule and regulation promulgated by the individual offices rather than by specifications and tolerances designed for national acceptance. This is for two reasons: First, the manner of use of apparatus is, under our system of law, the prerogative of the States, and they should be left entire freedom to work out these details in the manner which seems to them best. Second, the specifications and tolerances are not only guides for the weights and measures official in the enforcement of law but they also serve the very important purpose of advising the manufacturer of weighing and measuring devices as to what apparatus will be satisfactory in many of our far-flung jurisdictions. The approval of type by the Board of Trade appears to subordinate this purpose in England. As we understand it, their specifications may be said to serve as general guides only; each design produced by each maker is considered on its individual merits, and must be approved before it is put on the market for commercial use. Since we do not have any Federal approval of type of apparatus—and State approval in relatively few jurisdictions—the specifications and tolerances must become primarily the sole reliance of the manufacturer in judging whether his product will be satisfactory. They should, therefore, be prepared in the form which will be of most use to the manufacturer.

It seems, then, best that they be not complicated by specifications concerning the particular uses to which specific types may be put.

[27] There are several minor exceptions to this general statement.

For after all the manufacturer of the apparatus is not, perhaps, primarily concerned with this—certainly in most cases he can not be held generally responsible for the use in which a device which he produces may be employed. When he produces apparatus complying with the specifications and tolerances he fulfills the only duty to which he can be held strictly to account. He will, and usually does, when practicable, go further than this; to secure customer satisfaction, he will endeavor to see to it that the purchaser secures apparatus nicely fitted to his particular needs. But since he will often not be fully advised as to the condition under which the apparatus is to be used, and since, in any event, a manufacturer will practically be obliged to sell the particular device ordered, the onus of securing a device properly fitted to the particular need must, in the final analysis, be borne by the purchaser.

One further word may be added in regard to the character of the requirements contained in the specifications and tolerances. We feel that the principal object to be attained by specifications and tolerances is to eliminate from commercial use generally unsatisfactory commercial types. The desirable concomitant is to secure in place of the discarded apparatus constantly improving types. This latter condition will be most effectively secured not by hedging the manufacturer about with specific and restrictive specifications, but rather by allowing his initiative the fullest play. The specifications and tolerances have, therefore, been designed to inform the manufacturer in general language of the fundamental considerations believed to be vital to the construction of proper apparatus, and of some forms of construction found by experience not to result in accuracy, dependability, or fair dealing in the field. Within these broad limits the manufacturer has been left the greatest latitude possible in the working out of his designs.

In the above, attention has been invited to the importance of careful analysis in arriving at a decision as to the suitability of apparatus for particular purposes. In the remainder a few general principles will be given and a few examples cited to assist in describing the nature of this analysis. These will not by any means cover the field, but they may serve as examples of the proper method of attack.

In the first place, a general comment may be made on the relation of price of commodity and accuracy of determination. It is almost universally accepted as being good business practice to consider that required accuracy of weighing is roughly proportional to the value of the commodity sold. In wholesale dealings this may be illustrated by the fact that the Interstate Commerce Commission regulations provide that claims may be filed against railroad companies in the case of wheat in carload lots if the discrepancy found is greater than ⅛ percent; in the case of coal, a discrepancy eight times as great, or 1 percent, is allowable. This is doubtless due, at least in part, to the fact that the latter is a very much cheaper commodity than the former. This is further indicated by the fact that the tolerances recommended by that body for grain scales and for general purpose scales are 0.1 percent and 0.2 percent, respectively. While this principle does not seem entirely consistent at first glance—an error of 1 percent or 1 cent on the dollar would seem to be of equal importance in the case of a purchase of a certain numbers of dollars' worth of any commodity—nevertheless, it is doubtless a reasonable and also a necessary commercial practice since, as a rule, in wholesale transactions at least, the higher the price of a commodity the smaller will be the margin upon which it is handled, and thus there is probably a legitimate need for higher accuracy of determination of quantity in the case of the higher priced commodities.

In retail sales of commodities it is doubtless not generally true that the margin is smaller in the case of the higher priced commodities. At retail, however, attention will often be focused on the shortage per purchase and the resulting discrepancy in terms of value. Let us consider in these terms, for the sake of illustration, a shortage of one-half ounce on a purchase of various food commodities procurable at grocery stores or delicatessens.

Commodity	Ordinary price per pound	Supposed error	Resulting overcharge per purchase
	Cents	Ounce	Cents
Potatoes	4	½	0.125
Sugar	7		.22
Rice	10		.31
Spinach	15		.47
Domestic cheese	32		1.0
Butter	55		1.7
Boiled ham	80		2.5
Tea	100		3.1
Shelled nuts	125		3.9
Chocolates	150		4.7

We believe that in the minds of the great majority the error on the lower-priced commodity will seem a less serious matter than the same error in the higher range of the table, and the conclusion will be that the latter should be somewhat more accurately weighed than the former. While we have no quarrel with this conclusion, nevertheless we should not allow it to influence us to disregard any unjustifiable errors in commercial transactions, be the value of the commodity involved great or small.

Therefore, one of the things to be kept in mind in the selection of a piece of apparatus is the value of the commodities which are to be bought or sold, and the general criterion to be applied is that the higher the value of the commodity the greater the accuracy which should be sought.

In buying weighing apparatus for a particular purpose two important factors are to be borne in mind; one is the weights of the heaviest and of the lightest drafts which must be handled, and the other, the required percentage accuracy in the weights of the commodity—or of the highest priced of the several commodities—to be weighed. From these figures two things can be determined: First, whether one device will suffice or whether more than one must be procured, for a scale with a large enough capacity to weigh the heaviest draft may not weigh the lighter drafts within the required accuracy; and, second, the best type and capacity of the device or devices. In general, the scale purchased should be of a capacity only moderately in excess of the heaviest draft to be weighed in practice—perhaps the nearest higher capacity ordinarily marketed. It is believed to be a mistake to procure a scale of a very much greater capacity than will be needed in the normal course of business, since required sensitiveness and accuracy will often be sacrificed thereby. Again, for the same reason, a scale should not be used in weighing loads which are too small a fraction of its capacity. It will be found to be good economy to make the investment in additional apparatus when such apparatus is indicated to be necessary.

Much the same considerations govern in the case of a widely different kind of apparatus, namely, glass graduates. In the case of cylindrical graduates, about the same absolute accuracy can be obtained at each graduation and each graduation is subject to almost the same error. The reason is that the original placing of the graduation and the accuracy with which any measured quantity can be brought into coincidence with the graduation are functions of vertical displacement from the correct position of the surface of the liquid rather than of the volume measured. The result is that the percentage accuracy is almost exactly proportional to the quantity being measured. For instance, in the case of a cylindrical graduate of 4-ounce capacity having a diameter of 0.6 inch, a maximum error of measurement of about 15 minims would not be excessive at any graduation which is itself in error by the full amount of the tolerance allowed. This would be an error of 0.8 percent on a measured quantity equal to the capacity of the graduate. On a measured quantity of one-half ounce, however, were the same absolute error to be made, the percentage error would be 6.4 percent of the measured quantity. The advisability of not using a cylindrical graduate at too small a percentage of its capacity, and the desirability of supplying several sizes when quantities varying considerably in amount are regularly to be measured, is obvious. It is considerations such as these which have induced the National Bureau of Standards to make the recommendation to glassware manufacturers that approximately the first 10 percent of the capacity of precision cylinders be left ungraduated.

In selecting a scale a factor which at first glance may be considered a minor matter, namely, the value of the minimum graduation, will be found to be of considerable importance when the requirements of the specifications are carefully analyzed. It will be discovered that a reduction in value of the minimum graduations on the beam or reading face, results in many instances in a reduction in the values of the minimum tolerance and of the sensibility reciprocal demanded by the specifications, the two latter values being directly dependent on the former. This is a reasonable demand, since a scale with a small minimum graduation holds itself out as being capable of giving more accurate results than a scale not so finely graduated; and this representation should be fulfilled. Therefore it is provided that the minimum tolerance on a used platform scale of the beam type shall in no case be less than the value of one of the minimum graduations on the beam; likewise the maximum sensibility reciprocal is the value of two of these graduations. Similarly it is provided that the minimum tolerance on an automatic-indicating counter scale or on a spring scale, not new, shall in no case be less than one-fourth of the minimum graduation on the reading face or dial.

Now the smaller the tolerance and the sensibility reciprocal, the greater the refinement of parts necessary, to construct a scale of the required accuracy and sensitiveness. Also it will be found more difficult to maintain the scale in conformity with the more rigid requirements. In spite of this there should be no hesitation on the part of the purchaser to procure a scale having a sufficient sensitiveness and accuracy to enable him satisfactorily to weigh the smallest amount of the most expensive commodity normally to be weighed. On the other hand, the considerations indicate that he will be wise not to select a scale which is more finely graduated than is necessary.

We have seen that it is often advisible to furnish more than one device when the amounts of commodity to be weighed differ greatly. In the case cited in the preceding paragraph, if commodities differing widely in price and quality are to be weighed, the wisest course of all might well be to procure two devices of the same capacity, one to be of higher accuracy and more sensitive than the other, and perhaps of greater general refinement. The first will be kept in the best possible condition by reserving it for the commodities of high price and quality; the other can be utilized to perform the rougher work. Many merchants have recognized the benefits accruing from such a procedure and have put it into effect with excellent results. The specifications for prescription scales and balances, providing as they do for class A and class B scales, specifically recognize the desirability of this principle in the case of prescription work.

Another example of proper selection somewhat analogous to the above involves the factor of the ability to perform certain operations within tolerances or the ability to indicate with certain accuracies in the case of devices other than scales. Thus, there is incorporated in one or two of the codes of specifications a principle which may be stated as follows: Apparatus must be so designed and constructed that it will successfully perform those operations which it purports to be able to perform, within the tolerance provided for such operations. For instance, if a liquid-measuring device has a graduation representing the first pint, quart, or half gallon, then such a device obviously holds itself out as capable of delivering a pint, or quart, or one-half gallon of liquid within the tolerance allowable on such a delivery—2 cubic inches—and consequently it is required that it be susceptible of being so operated. However, if 1 gallon is the first graduation, then it will be satisfactory if it is susceptible of being operated within the tolerance on this amount—3 cubic inches. If in the ordinary course of business it is to be expected that amounts less than 1 gallon will rarely or never be called for, then for the sake of obtaining the larger minimum tolerance it would seem to be good judgment to pick a device which does not purport to deliver less than this amount. A sale of a smaller quantity could be made, if occasion should arise, by the utilization of an inexpensive liquid measure.

As a final example of the character of factors important in the selection of a piece of equipment—in this case conditions of installation are also involved—we will briefly discuss a meter intended for use in a filling station retailing gasoline. In this case the most prominent factors in the mind of the purchaser will probably be accuracy and speed of service to automobiles; the latter factor will probably be considered by the purchaser as synonymous with maximum delivery rate. How are these to be evaluated?

More than one size of meter can be secured for this service having different maximum and minimum rates; also the maximum rate can be made to vary over a considerable range of values according to installation conditions. In deciding upon the proper maximum rate (the supposed speed factor) it should be borne in mind that dependability of delivery at all delivery rates (the accuracy factor) is ordinarily more readily obtained when there is not too great a range between the maximum and minimum rates, and that in effect only the former can be varied, since the specifications dictate that the minimum rate may in no case be considered to be greater than 7 gallons per minute. Another consideration involving accuracy versus speed is that it is difficult to stop the indicator accurately at the desired amount when it is moving very rapidly over the dial as the result of a high delivery rate; thus, the flow may be stopped too soon, requiring a "cracking" of the delivery valve to bring the indicator to the proper point, or it may not be stopped soon enough, with a resulting overdelivery. Finally, in case gasoline is furnished too fast to a car, spillage, resulting not only in shortage in the delivery but also in tending to customer dissatisfaction and constituting a fire hazard, is the very probable result.

It has also been suggested above that speed of delivery to cars and maximum delivery rate are not necessarily synonymous ideas. Anomalous as this statement may sound, it is true that the one may not always follow the other. In the development of this idea it may be said that it is probable that few cars will take gasoline much faster than 20 gallons per minute and that investigations seem to indicate that for many of them a slower rate of delivery than this must be employed. Now difficulty will probably be encountered in the slowing down of the delivery to just the proper speed in each case by the expedient of a partial closing of the delivery valve. Thus when some valve closure is indicated by experience to be necessary it is probable that to be on the safe side the operator will be inclined to close the valve somewhat more than is necessary. In delivery to some cars, then, a high delivery rate may result in a slower delivery than would result from a slower rate.

From the above it will be apparent that a careful analysis of the various factors involved will be well repaid. In this instance it may convince the purchaser that too high a delivery rate may not only result in incorrect deliveries and other disadvantages but that it may even defeat its own purpose and not actually result in a greater speed of delivery to the average car served.

General Conclusions.—A few general conclusions may be adduced from the above discussion, as follows:

A user should not procure weighing or measuring apparatus of a considerably larger size or capacity than is required to meet his needs. In doing so he will usually be sacrificing sensitiveness and accuracy and thus unnecessarily increasing the percentage errors of his determinations.

It is inadvisable to provide only one piece of apparatus to be used over an unjustifiably large range, and especially at too small a percentage of its total size or capacity, when two or more pieces will increase the accuracy of determination. To do so is ordinarily poor economy.

A low-grade and inaccurate type of apparatus should never be employed when it is indicated that a better and more accurate type is advisable. Conversely, it is uneconomical to procure an unnecessarily high-grade piece of apparatus to do work which could be satisfactorily handled by something of a lower and less expensive grade. Often two devices will be the proper solution.

A buyer should first familiarize himself with the specifications and tolerances applicable to the character of a device to be purchased and determine the various factors of importance in connection with the work which the apparatus to be procured will be required to perform. With all these facts in mind he should analyze the various features of the available apparatus and purchase only when he has assured himself that the proper type of device has been found.

Finally, it is felt that there can be no better advice in closing than the following comment. Never purchase a piece of apparatus for commercial use without a guaranty from the seller that in case the weights and measures official refuses to approve it a new and satisfactory-piece of apparatus will be furnished, the original purchase price refunded, or other satisfactory adjustment made. This guaranty will, we believe, be given by the seller in almost every case without hesitation; and it seems reasonable to demand it, since the seller should certainly be in a better position than the buyer to judge as to the compliance of the piece of apparatus with the official requirements.

Chapter 8.—TESTING OF COMMERCIAL SCALES: TESTING EQUIPMENT; BALANCE CONDITION OF A SCALE; ADJUSTMENT OF ZERO-LOAD BALANCE CONDITION; TESTING; CENTER-LOAD ACCURACY TEST; SHIFT TEST; TEST FOR SENSITIVENESS (SR TEST); TEST OF MANUALLY REMOVABLE WEIGHTS; APPLICATION OF TOLERANCES; OUTLINES OF TEST PROCEDURE; APPROVAL, REJECTION, AND CONDEMNATION

Testing Equipment.—Proper testing equipment is obviously a prerequisite to the proper testing of scales. For a general discussion of weights and measures standards and equipment reference should be made to National Bureau of Standards Handbook H26, chapter 14, p. 83 to 91; for a schedule of weights and measures standards and equipment recommended for weights and measures offices and field use, reference should be made to the same publication, appendix III, p. 281 to 292. For ease of reference, there are repeated in this publication, in appendix I, p. 161 to 162, the recommendations given in Handbook H26 for weights and equipment "for field use."

By "proper" testing equipment is meant equipment suitably designed, sufficiently accurate, and adequate in amount. It is probable that equipment provided for testing purposes most often fails of being proper with respect to the last-mentioned condition—adequacy of amount—and this shortcoming is especially noticeable in connection with the testing of large-capacity scales. In this particular relation, reference should be made to National Bureau of Standards Miscellaneous Publication M104, "Testing Equipment for Large-Capacity Scales for the Use of Weights and Measures Officials"; in that publication the necessity for specialized equipment for the purpose in question is discussed in some detail, and some typical equipments already in successful use by weights and measures officials are described and illustrated. Later equipments of this character are described and illustrated in the Reports of the Twenty-fourth, Twenty-fifth, Twenty-sixth, Twenty-eighth, and Thirty-first National Conferences on Weights and Measures, NBS Miscellaneous Publications M129, M156, M157, M161, and M170, respectively. The Vehicle-Scale Testing Unit of the National Bureau of Standards is illustrated and described in the Report of the Twenty-seventh National Conference, NBS Miscellaneous Publication M159.

However, it is not to be understood that inadequacy of equipment is by any means confined to apparatus for the testing of large-capacity scales; it is frequently observed in the equipment provided for the testing of the most ordinary classes of commercial apparatus of small and moderate capacities.

The needs of the case may be stated briefly as follows:

1. Standard weights should be provided:
   (a) In suitable denominations to permit of (1) the direct testing with test weights of all desired intervals, and (2) the application of the prescribed tolerances and SR requirements.
   (b) In sufficient quantity to permit of testing, with standard weights, up to the capacity of the scale (or up to the point of maximum loading in use) on all scales up to 10,000 pounds capacity.
2. Special weights and/or equipment should be provided for testing many special kinds of scales—such as, for instance, prescription and jewelers scales (weights adjusted to special tolerance), hanging scales (means for applying weights), and wagon and motor-truck scales (weights of large denomination and mechanical means for handling them).
3. Balances of suitable capacities and sensitiveness should be provided for the testing of all loose weights used on the scales tested.
4. Simple tools should be provided to permit of the making of those adjustments which it is proper for the inspector to make.

A number of general matters, directly connected or indirectly associated with the testing of scales, have been discussed in National Bureau of Standards Handbook H26, Weights and Measures Administration; particularly chapters 16, 17, 18, and 19 of that publication, p. 97 to 117, should be read in connection with the present discussion. The following extract from chapter 16 of Handbook H26[28] contains material so directly relevant as to justify its inclusion here.

Since the purpose of testing is to learn how the device under test will perform in service, a test should extend further than a study of performance under a set of more or less ideal conditions; it should be carried to the point of establishing the probability, at least, of the performance of the device under average conditions of use. The official will, therefore, try in his test to approximate service conditions of operation, and any method of use which may reasonably be employed in service may, with propriety, be duplicated in the test.

In general, it may be said that the official should not base his conclusion on the acceptability of performance, upon single observations under the different conditions or at the different stages of his test. Check observations should always be made if practicable, and if groups of several observations can be made the average of these will probably represent much more nearly the actual conditions than any one series of individual observations.

Another point which should be very strongly stressed is that for the efficient conduct of tests, the loads of known weights which the official applies to scales must approach as nearly as practicable to the capacities of the scales; and as scales are built stronger and larger to accommodate the increasing loads of automobile trucks, so the amount of the test load applied by the testing official must grow steadily greater. Where not so many years ago the official considered it unnecessary to have more than 1,000 pounds of weights for testing large scales, he is today confronted with the necessity of providing 10 to 20 times that amount and of devising means for quickly and efficiently transporting and handling these large loads.

It should also be remembered that in the case of numerous types of devices, a determination of the sensitivity of the device is an essential part of its test, since inaccuracies will inevitably result from the use of devices not having a proper degree of sensitiveness. For certain classes of scales a simple method of determining whether or not the device is acceptable in this respect is possible by close definition of the expression "sensibility reciprocal" or "SR," and expressing the requirements in terms of this characteristic. In the case of other classes of apparatus also, the factor of sensitiveness has received careful consideration.

During the progress of a test a constant effort should be made to eliminate the effect of outside influences lest a result be ascribed to imperfection in the device which is really caused by some condition entirely outside the device itself. Thus, for example, the effects of wind upon a platform scale * * * might seriously

[28] Pages 117-119.

prejudice the test results of the official who is not alert to the possibilities along these lines.

The official should also be cautioned against "jumping at conclusions" before he has made a careful analysis of the test results and of any other facts which may have a bearing upon the performance of the device under test; likewise it should be emphasized that data as nearly complete as practicable should be at hand before the analysis is undertaken or the conclusion drawn. There is no question, for example, but what many a nose iron, many a pendulum ball, and many a spring on weighing scales * * * have been adjusted to force a correct indication when the real cause of the inaccuracy lay elsewhere; and the unfortunate part of it is that such adjustments are almost never effective for more than a very short time, because the real source of the trouble, which was uncorrected, still persists, and the effects will probably grow more pronounced as time goes on. The old adage to the effect that the wise physician treats the cause and not the sympton may well be borne in mind in this connection. In short, the adjustable features of a weighing or measuring device should never be made use of to correct its indications except as a last resort and when it has been demonstrated beyond question that their improper adjustment is the real cause of the inaccuracies revealed by the test.

The careful official will record the results of his test for two reasons: First, so that he may have the data at hand to study the performance of the device which has developed inaccuracies and determine the reasons therefor. Second, so that he may have a complete record for his files of the work which he has done and of the performance of the devices which he has examined; such a record may prove invaluable at some future time.

Balance Condition of a Scale.—The condition of zero-load balance of a scale—that is, the balance condition with no load on the load-receiving element—is of primary importance in a test. If a scale is out of balance at zero, the balance error is reflected as a fixed error in every observation made; for example, if a scale is balanced 1 ounce fast at zero, the amount of the load required to produce any scale indication in excess of 1 ounce will be 1 ounce less than would be required if the scale were in correct zero-load balance. Before a test is started, therefore, it is essential that the scale be in correct balance at zero load,[29] that is, that it correctly gives a weight indication of zero when there is no load on the platform, plate, or other load-receiving element.

A lever scale of the nonautomatic-indicating type not having an indicator and a graduated scale or arc is correctly balanced when the weighbeam comes to rest at, or oscillates through approximately equal arcs above and

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[29] For the special case of scales designed to be "back balanced" a certain amount, see page 148; for cream-test scales, see page 149.

below, the center of the trig loop when one is provided; or a position midway between other stops when these are provided; or a horizontal position when no trig loop or other stops are provided.

A scale of the nonautomatic-indicating type having an indicator and a graduated scale or arc is correctly balanced when the indicator comes to rest at, or oscillates through progressively smaller arcs about, a definite and clear zero graduation.

A scale of the automatic-indicating type—that is, one having a reading face—is correctly balanced when the indicator comes to rest at a definite and clear zero graduation.

On a beam scale provided with a trig loop, the following procedure is recommended for determining the correct balance condition, either at zero or under load: Release the weighbeam without impulse at either the bottom or the top of the trig loop, allowing it freely to rise or descend, as the case may be, and noting how far it travels on its first swing. If the beam just fails to touch the bar of the trig loop opposite to its starting point the scale is in correct balance condition; if the beam touches the bar, or if it fails by any considerable amount to reach the bar, the balance condition is not correct.[30] By adjusting the zero-load balance until, when the weighbeam reaches the highest or lowest point of its initial swing, the gap between the weighbeam and the upper or lower bar of the trig loop is very small—that is, until just a narrow streak of light can be seen between them—the balance condition is definitely established in a way which can be duplicated with exactness on subsequent observations; moreover this method may be used with a minimum loss of time, since usually it is necessary to observe only the first swing of the weighbeam. A weighbeam so balanced should eventually come to rest just halfway between the upper and lower bars of the trig loop.

Theoretically it should make no difference whether the weighbeam is allowed to rise or to descend in this balancing operation; practically, however, there may be a slight difference even on a scale in good condition, and the difference will be greater the greater the friction

[30] This assumes the absence of frictional effects. See succeeding paragraph.

present; accordingly a uniform procedure should be followed throughout a particular test. As a matter of fact, it is advisable to adopt a standard procedure to be followed in all tests; it is believed that the release of the beam at the bottom of the trig loop will be found to be the more satisfactory alternative.[31]

The release of the weighbeam without impulse is of importance in this procedure. Some variety of "stroking the weighbeam" is adaptable to any beam scale test. By the stroking method, to release the weighbeam at the bottom of the trig loop the fingers are rested on top of the beam, holding it at its lowest position, and then with a stroking motion and only a light pressure the fingers are "dragged" across the weighbeam downwardly and toward the tip of the beam; or the weighbeam may be held down by a light finger pressure at its tip—on the "goose neck" or "arrow tip"—and stroked by gently dragging the fingers straight downward; or the weighbeam may be held down by a slight upward pressure below the butt of the weighbeam and stroked at this point with a gentle upward motion. (To release the weighbeam at the top of the trig loop the procedure is, obviously, the reverse of that just outlined.)

Before a balance observation is begun on a weighbeam having a counterpoise or a counterbalance hanger, any swinging of these hangers should be stopped, because a swinging hanger will prevent a smooth and even weighbeam motion.

It will sometimes be found that a slight amount of foreign matter will have formed a sticky deposit on a bar of the trig loop, some of which may have been transferred to the weighbeam at the point where contact is made between the weighbeam and the bar. This may cause the weighbeam to hang or stick in its lowest or highest position; sometimes an appreciable force is required to dis-

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[31] There may be times when it is desirable to determine as accurately as may be, the existing errors on a scale in which the frictional effects increase as the load increases. On such a scale, if the balancing method described is followed, the scale will erroneously appear to have multiplying minus errors as compared with the true errors. In this case the scale should be so balanced both at zero and under load that when the weighbeam is successively released at the bottom and at the top of the trig loop, it will fail by equal amounts in the two instances to reach the opposite limit of travel on its first swing, thus being balanced as nearly as practicable at the center of the trig loop. The adaptation of this procedure to a scale not equipped with a weighbeam and trig loop will be obvious from the instructions for balancing such scales, as given later in the text.

lodge the weighbeam. Such a condition will make it impossible to obtain a proper balance by the stroking method described above; the remedy is to clear away the deposit on the bar and weighbeam so that there may be a clean metal-to-metal contact. An excess of paint on the bars of the trig loop may cause the same trouble, in which case cleaning is again the remedy. With a steel trig loop and a steel weighbeam (as on some large-capacity scales), slight magnetization may cause the same apparent sticking effect; here the remedy is demagnetization or, as a temporary expedient, the attachment to bar or weighbeam of a thin strip of nonmagnetic material—a single thickness of paper will often be sufficient.

On a beam scale not equipped with a trig loop but having some other form of weighbeam stop, the weighbeam may be handled during a balancing observation in the same manner as has been described above; that is, by using the stroking method.

On the unequal-arm type of scale not equipped with a trig loop or other weighbeam stops, the same method may be used except that the criterion is not the clearance between the weighbeam and its upper stop (since there are no weighbeam stops), but is the clearance between the "stop" elements below the load-receiving element. This clearance cannot ordinarily be conveniently observed directly; however, this is unnecessary since the same result is obtained by observing the weighbeam at the end of its swing—it should just fail to indicate a "bump." It should be noted that if this method is used on this type of scale the resulting position of rest of the weighbeam will be approximately horizontal—as it should be—if the specification requirement for equal weighbeam play above and below the horizontal is met.

On a trip scale—equal arm, with stabilized pans—not equipped with some form of balance indicator, it will ordinarily be convenient to observe directly the clearance between the "stop" elements below at least one of the pans. The stroking method of balance observation may be applied by depressing the pan opposite to the one below which the stop elements are to be observed, holding it momentarily in its lowest position by a slight finger pressure, and then releasing it by dragging the fingers away with a downward motion, noting that on the downward swing of the other pan the stop elements just fail to come into contact. A scale balanced by this method will come to rest with the lever system horizontal and the pans on a level with each other (which is proper "balance" condition for this type of scale) if the scale is mounted in a level position, if the stop elements are so positioned that the pans have equal travel above and below the position at which they are on a level with each other, and if the scale is otherwise in good condition.

On such unequal-arm and equal-arm scales as are discussed in the two preceding paragraphs, there may be a difference when making balance observations depending, in the case of the unequal-arm scale, upon whether the weighbeam is released at the lower or upper limits of its travel (as previously noted under the discussion of weighbeams with trig loops) and, in the case of the trip scale, depending upon which pan is released at the lower limit of its travel. Whatever practice is followed for zero-load balance should be followed throughout the test.

In this general connection it may be mentioned that at times very insensitive, "sluggish," scales, probably having a large amount of friction, will be found in service, and that if one of these scales has been balanced as accurately as possible so that the beam or pans will come to rest midway between the limiting stops, the scale may, and in all probability will, appear to be seriously slow on zero-load balance when the balance is observed according to the method which has been outlined above. This is because additional load is required to overcome the sluggishness or the friction and cause the movement of weighbeam or pans contemplated by the method in question. In order properly to report the zero-load balance condition on such a scale it would be reasonable to check this by releasing the weighbeam successively at the bottom and at the top—or, on a trip scale, by releasing at the bottom first one pan and then the other—and noting in each case the amount by which the element under observation clears the stop; if the clearance is the same in each case the zero-load balance condition may be said to be as good as can be obtained. Of course, a seriously insensitive scale, or one in which serious frictional effects are present, should not be permitted to remain in commercial use.

When the balance condition of a beam scale is such that the weighbeam "bumps" on its first swing after release at the lower limit of its travel, the scale is said "to be too high in balance," "to be balanced too high," "to be balanced fast (or quick)," or "to be plus (or fast) on balance"; if the balance condition is such that the beam does not rise as high as it should, "low," "slow," and "minus" would be substituted, respectively, for "high," "fast" and "plus" in the quoted expressions.

On an automatic-indicating scale, coincidence between the index of the indicator and a graduation line, corresponds to the "balance condition" of a beam scale. Similarly, on a scale provided with an indicator and a graduation line or other reference point, or with two indicators, for the purpose of defining the proper balance condition, coincidence between the appropriate parts is the criterion of correct balance. True coincidence can be obtained only when the two coöperating elements are suitably shaped and dimensioned, as when the index of the indicator and the graduation line are of the same width, and when the ends of the two indicators are of the same shape and size; if these conditions are not met, the parts should be brought into such relation that the narrower member is positioned centrally with respect to the wider one.

Another important consideration in connection with the reading of various types of indicating elements is the possible effect of parallax. In certain combinations of indicating elements, as, for example, a pointer which moves across a graduated chart, or a chart which revolves behind a fixed indicator, for any given position of the two elements of the combination there will be an apparent displacement of their relative positions when they are viewed from certain different angles, and the magnitude of this effect will be greater the greater the separation or clearance between the two elements. The indications of these combinations should be observed from a position directly opposite the indicator; that is, the line of sight should pass through the indicator and be perpendicular to the chart. To assist the observer to position his eye correctly when reading its indications, a scale may be equipped with a "knife-blade" indicator, an auxiliary "sighting" wire, or other similar means.

When a scale is equipped with a relieving or locking device or with unit weights, if repeated operation of the relieving or locking device or repeated application and removal of unit weights results in changes of zero-load balance of any considerable magnitude, the scale may properly be rejected for instability of the zero-load balance condition. Such action is also justified if for any other reason a scale will not "hold its zero balance" within reasonable limits. The value of the minimum tolerance applicable to a scale has been suggested as a maximum allowance for permissible zero-load "balance shift," but no limiting value has been adopted by the National Conference nor has any such value been generally agreed upon by the scale industry.

It is a safe assumption that some means for balancing have been provided by the manufacturer in virtually every type of scale which will be encountered except the straight-face spring scale; and by an amendment to the National Conference specifications adopted several years ago, balancing means are now required on all scales, so that on new scales even the exception noted should not apply.

Adjustment of Zero-Load Balance Condition.—Zero-load balance adjustments are, in general, accomplished in one or both of two ways: (1) By increasing or decreasing the amount of balancing material—usually shot, or lead in some other form—contained in the receptacle provided; and (2) by operating some adjustable element such as a balancing ball or screw. On automatic-indicating scales of the pendulum type, slight changes of balance may be effected by changing the height of the leveling feet supporting the scale, but such an adjustment should never be carried to the extent of throwing the scale out of level sufficiently for this condition to be apparent on the level-indicating means mounted on the scale.

Receptacles for balancing material will be found as follows: (1) Beneath the weight plate of equal-arm stabilized-platform scales, access being had by unscrewing the weight plate, (2) beneath the pan of unequal-arm scales, access being had by unscrewing the pan or removing a cap or cover plate, (3) in the counterpoise cup, access being had through a hole in the cover or by unscrewing the cup from the stem, (4) in an enlargement of the butt end of the main lever on some automatic-indicating counter scales, access being had by removal of a cover plate, (5) at the tip end of the beam of a bucket grain tester.

Balance balls may be manually or mechanically operated, in the latter case usually by means of a screw driver. These may be found on almost any type of scale except simple spring scales, frequently in combination with some receptacle for loose balancing material; where both are provided, the latter is used for effecting relatively large changes of balance, final adjustment being accomplished by means of the balance ball. On scales with weighbeams, the balance ball is usually located near the butt of the weighbeam.

Balancing screws may operate to control the height of a pendulum or spring assembly and thus effect changes in zero balance. These are sometimes protected by a plate or door which must be removed or opened to provide access to the balancing screw.

The position of the indicator on a dial spring scale may be directly adjustable, the adjustment being secured by a small screw. Steelyards may be balanced by means of small weights attached near the tip of the weighbeam.

Large-capacity beam scales are sometimes equipped with a "counterbalance" hanger suspended from the butt of the beam for effecting relatively large changes of balance; provision may be made for receiving loose balancing material in the cup of the hanger, and one or more counterbalance weights may be employed on the counterbalance hanger.

A careful examination of any ordinary or special scale will usually disclose the means provided for effecting zero-load balance changes. In any case of doubt, the official may with entire propriety call upon the owner or operator of the scale to put it in proper zero-load balance condition.

A scale is considered to be "accurate" when its weight indications correspond, within the limits of the applicable tolerances, to the values of applied loads. A scale that is out of balance at zero load in an amount exceeding the minimum tolerance applicable to the scale, is obviously not in condition to satisfy the requirements for an accurate scale, and, for purposes of weights and measures administration, such a scale should be considered to be inaccurate as found. The ease with which the zero-load balance condition of most scales may be adjusted may tend to minimize in the mind of the official inspector the importance of this condition. But this very ease of adjustment, and the ease with which the balance condition of a scale may be checked by the user, make inexcusable any failure on the part of the operator to keep his scale in reasonably good zero-load balance condition at all times. It must be remembered that in the large majority of commercial weighings—that is, except when an actual tare weighing of container or vehicle immediately precedes or follows the weighing involving the commodity contained therein—any zero-load balance error is transferred to every commodity weight determined, and that zero-load balance errors may result in very considerable errors on commodity weights. It should be clear that the penalty for the use of an inaccurate scale is incurred just as surely by the user of an out-of-balance scale as by the user of a scale inaccurate in other particulars.

Testing.—There are four principal parts to the test of a scale, although all of these are not applicable to the test of every scale. These parts are as follows: (1) The center-load (or distributed-load) accuracy test, made with increasing loads centered on the load-receiving element (or uniformly distributed over it) and sometimes including, in the case of an automatic-indicating scale, a test with decreasing loads, (2) the shift test, made with off-center loads under certain prescribed conditions of off-center loading, (3) the test for sensitiveness, and (4) the test of any manually removable weights used with the scale.

Center-Load Accuracy Test.—The center-load (or distributed-load) accuracy test is made to develop the performance characteristics of the assembled scale when loads are reasonably centered on or evenly distributed over the load-receiving elements, with particular reference to the correctness of the ratio of the lever system (in the case of a scale employing manually removable weights), and of the indications of each bar of the weighbeam and of any automatic-indicating elements or unit weights which may be employed. The test made with decreasing loads on automatic-indicating scales, is made for the double purpose of developing the performance characteristics of the scale under this possible method of use, and of judging the refinement of manufacture, freedom from lost motion, and absence of excessive effects of mechanical hysteresis; for routine testing of scales not subjected to decreasing loading in the course of normal usage the decreasing-load test is ordinarily omitted.

In making the center-load accuracy test it is ordinarily advisable to keep the load reasonably well centered or evenly distributed on the pan or platform of the scale at all times so as to avoid introducing errors resulting solely from an off-center position of the load; these latter errors will be determined in the shift test, and if carelessly introduced in the center-load accuracy test they may prove confusing to the inspector and may mask the sort of errors which the center-load accuracy test is particularly designed to develop—that is, errors in the ratio of the lever system, in the weights of weighbeam poises, and in the adjustment of the element automatically supplying a counterforce.

It has already been indicated that the test should be carried up to the nominal capacity of the scale or to a point corresponding to the maximum loads weighed on the scale. In this connection there arises the question of the number of intermediate points throughout this range at which observations should be made. In general it is true that the greater the number of test points the better the test; and for a theoretically complete test, observations should be made at every graduation of reading face or weighbeam, and at very closely spaced intervals when determining the ratio errors. As a practical matter, however, this is out of the question except for an extended laboratory study or when very special conditions demand exceptionally extensive test data.

For ordinary testing it will be sufficient if there are made enough tests at intermediate points to establish with reasonable certainty the performance characteristics of the particular scale under examination. On most small scales, tests should be made at least at one-quarter, one-half, and full capacity; on larger types, tests should be made at not less than three or four points in the weighing range; large-capacity scales should be tested at intervals of a few thousand pounds; smooth weigh-beam bars should be tested at one-half and full capacity; notched bars should be tested as specified for smooth bars, and in addition at any notches which appear to be worn or in bad condition, and at several notches in the range of most frequent use; automatic-indicating scales with dials or with cylindrical drums should be tested at least at the four points representing each quarter of the direct-reading capacity of the automatic-indicating element, and preferably at eight points representing approximately each eighth of such capacity, and also at intermediate points in the range of greatest use, probably the first quarter. The accuracy of each unit weight and of each possible combination of unit weights on an automatic-indicating scale should, if practicable, be individually determined.

When testing the ratio of a scale on which manually removable weights are utilized, the test should be made with test loads consisting of standard test weights[32] on the load-receiving element, counterpoised with standard weights on the counterpoise hanger of the scale. The object of this test is to determine whether or not the actual scale ratio is near enough to the ratio that is standard for the scale in question, to meet tolerance requirements; obviously, if the test loads were to be counterpoised by means of counterpoise weights belonging to the scale, and these weights were themselves in error by some unknown amount, the results of the ratio test would be of little value.

In the case of a steelyard with a removable poise there exists a situation analagous to the ordinary beam scale which utilizes counterpoise weights, in that the steelyard, as a weighbeam, is supposed to have a definite ratio adapting it for use with a poise—or sometimes with two poises—standardized to a definite value just as a counterpoise weight is standardized. The nominal weights of these steelyard poises are usually even pounds; poises

[32] See discussion of "build-up" or "step" tests, beginning on p. 117.

having nominal weights of 1, 2, 4, 8, or 16 pounds or more may be encountered, the 16-pound poise being largely used on "cotton beams." Obviously these steelyard poises should be separately tested just as counterpoise weights are separately tested, and this should be done before the steelyard beam is tested.

When the steelyard has a tip pivot and is furnished with one or more "bottle" weights (as in the case of some "tierce" beams designed for the weighing of barrels), the beam should be tested for ratio against standard weights, and the bottle weights should be treated in the same way as counterpoise weights are treated.

In the case of a beam scale equipped with a full-capacity weighbeam—that is, one on which no counterpoise weights are intended to be used—there will usually be neither counterpoise hanger nor pivot at the tip of the weighbeam. Moreover, in such cases it is unnecessary to determine the ratio at the weighbeam tip, since the weighbeam poises alone provide the counterforce for the loads; therefore the ratio test as such disappears and becomes merged with the test of the weighbeam.

When testing a notched weighbeam bar, care must be exercised to seat the pawl of the poise firmly into each notch being tested. In the case of a smooth bar the position of the poise with respect to every graduation except zero must be established by the inspector, and great care must be exercised to make accurate and uniform settings lest an error be ascribed to bar or poise which in reality is the result of an improper setting of the poise by the inspector; it may well be repeated that when the poise is pushed back against the zero stop on the bar, the index of the poise should be properly positioned with respect to the zero graduation on the bar.

On a weighbeam having more than one graduated bar, tests should be made of each bar separately, and, theoretically at least, a test should also be made of the combined indications of all bars of the weighbeam in order to demonstrate whether or not the summation of the errors of all bars (each of which may have an individual error which is within tolerance) exceeds the tolerance for the combined load. As a practical matter, however, the combination test need be made only in those cases where two or more bars of a full-capacity beam have capacities nearly the same and there is no other bar the capacity of which is several times the capacity of the bars in question; in such cases the combination test should always be made, applying the appropriate tolerance for the total load involved. An example of such a full-capacity beam would be one having two bars with capacities of 250 and 150 pounds, respectively, or one with two or more bars of the same capacity.

In the test of a large-capacity scale where the amount of test weights available is less than the capacity of the scale, it is necessary for the inspector to resort to a substitution method of test (which may be referred to as a "build-up" or "step" test), or to the use of from one to several "strain" loads in addition to the available load of test weights. The former method is generally the better when carefully carried out but will usually consume a considerably greater amount of time than the strain-load method.

The principle of the substitution method of test is the successive substitution for the test-weight loads of loads of any available material, whereby a total known load of any number of times the value of the available test weights is gradually built up, the scale under examination being utilized for the determination of each substituted load. For example, assume a 5,000-pound platform scale which must be tested with only 2,000 pounds of test weights. The test would be made in the ordinary way up to the point where the distributed load on the platform is 2,000 pounds—all of the available test weights. By means of small weights and/or the movement of a poise, if necessary, the scale would then be brought to a readily reproducible condition of balance, such as exact coincidence between indicator and some graduation, or a weighbeam which just fails to "bump" when released. Now, the 2,000 pounds of test weights would be removed, great care being exercised not to disturb the scale mechanism in any way which would affect the balance condition, and any available material would be carefully added to the platform until the former condition of balance is reproduced; assuming that the scale under test will repeat its indications, it is apparent that there have now been added to the platform just 2,000 pounds of material within that degree of accuracy determined by the ability to duplicate the original balance condition. In other words, there is now available a 4,000-pound test load consisting of 2,000 pounds of test weights and 2,000 pounds of other material. If now any poise which has been moved is restored to its original position and any small weights which may have been utilized in establishing the reproducible balance condition are removed, the scale is in just the same condition as though the test had been started with 4,000 pounds of test weights and had proceeded to the point where 2,000 pounds of that amount had been used. The test would then proceed as before until the platform load reaches 4,000 pounds, when another substitution would be made in the same manner as has been outlined above; or, in the particular case under consideration, the second substitution could be for 1,000 instead of 2,000 pounds, since that would be enough more material to permit reaching the scale capacity with the available test weights.

It may well be repeated that in making these substitutions the greatest care must be exercised each time weights are removed and material is added, to avoid disturbing the scale mechanism in any way which would affect the balance condition; similar care must likewise be used in establishing and duplicating the balance condition on which the substitution depends for its accuracy. Some error is inevitable at each substitution, and unless this error is held down to a minimum, the accumulated error after the several substitutions may reach serious proportions.

Another caution which must be observed is never to change the adjustment of the regular balancing means of the scale during the progress of a substitution test. When a temporary balancing operation is made necessary in order to establish a reproducible balance condition prior to removal of the test-weight load, the inspector must always restore the original conditions which prevailed when the scale was originally balanced at zero after the substitution is completed and before proceeding with the test; this can not be done with precision if the adjustment of the regular balancing means has been changed, hence the instruction that these temporary balancing operations be performed by means of poise movement and/or weights added to platform or counterpoise hanger. When a full-capacity beam scale has a plus error and is equipped with a notched fractional bar, it may be necessary to accomplish this temporary balancing by setting the fractional poise out one or more notches until the beam is balanced low, and then adding enough small weights to produce the desired balance; when an automatic-indicating scale has a plus error, enough small weights may be added to the platform to bring the indicator into coincidence with the next forward graduation.

The principle involved in the use of strain loads, when the supply of test weights is inadequate, is that the known test load is first applied when the scale is carrying no other load (this is frequently referred to as the "light test"), and is subsequently applied one or more times when the scale is under some additional but unknown load which stresses the parts as they are normally stressed under ordinary operating conditions. Under this method, the actual values of the strain loads—which may consist of miscellaneous material, loaded vehicles, grain in a hopper, and the like—are immaterial and are not determined, the strain loads being simply "balanced out" by any convenient means.[33] Thus, after carrying the light test of a motor-truck scale, for instance, as far as may be done with the test weights available, and assuming that it is next desired to make a test in the region up to one-half the nominal scale capacity, the test weights would be removed and a vehicle would be driven onto the platform and the scale brought to a balance; this vehicle would have been so selected that the sum of its gross weight and the total value of the test weights would approximate one-half the nominal capacity of the scale. The test weights would then be added, in one or in several increments, and it would be observed whether or not the scale properly indicates the value of each increment of test weights added. Following this, another strain load would be added, of such a value that the combined weight of strain load and test weights will approximate the value in the region of which it is desired to make the next test; this strain load would then be balanced out and the test weights subsequently added as

[33] The regular balancing means of the scale may be adjusted when arriving at the final balance for a strain load, but this has the disadvantage that the scale cannot then be checked at the conclusion of the test for a possible shift of its zero-load balance.

in the earlier part of the test. This operation may be repeated any desired number of times as long as the gross load does not exceed the weighing capacity of the scale; however, assuming that a reasonably satisfactory amount of test weights is available, not more than two strain loads will ordinarily be utilized, the scale being tested light and when loaded to approximately one-half and full capacities.

There is an important difference between the substitution method and the strain-load method in the manner of applying the tolerances. In the substitution method, all of the load on the load-receiving element of the scale at the time of making any test observation is regarded as *known* load, and any observed error is an error on the *total* load on the scale. In the strain-load method, observed errors are errors on the *test-weight load only,* since before each application of the test-weight load the strain load of unknown value has been balanced out; accordingly, the tolerances to be applied are to be selected according to the value of the *test-weight load* in each instance of an accuracy observation under the strain-load method.

When testing wagon and motor-truck scales the inspector must, of course, have recourse to some mechanical means of transporting his test load, and a motor truck is commonly employed for this purpose; the truck may be one of those equipments specially designed for this work, carrying a large load of special test weights, or it may be an ordinary truck on which 50-pound weights are loaded. In both of these cases inspectors have been known ill advisedly to use the loaded truck as a testing "standard"; that is, a value is assumed as representing the gross weight of the loaded vehicle, and the truck is then used as a mobile test weight. In general this practice is to be strongly condemned. It should be obvious that the gross weight of an automobile truck does not remain constant while the truck is in operation, and that at any given time it is impossible that such weight can be known with the precision demanded for a test weight; even when an effort is made to apply corrections to compensate for water loss and gasoline consumption, the accuracy of the assumed weight may be said to be in very grave doubt. The part of wisdom is to use as test weights only standards constructed with that use in view and suitably maintained so that their values may be unquestioned.

The empty carrying truck may properly be utilized as a strain load in the course of a test of a wagon or motor-truck scale, although sometimes in the case of motor-truck scales, the tare weight of the truck is so small with respect to the tare weights of vehicles ordinarily weighed on the scale that its use as a strain load serves but little purpose.

A loaded truck may properly be used for a rapid, rough, *comparative* test of a group of large-capacity scales; but it is unwise to base official action upon the results of such a comparative test unless a particular scale is found to disagree so seriously with at least several others as to remove all doubt as to its inaccuracy. Another proper use of a loaded truck is for the purpose of making a rough, preliminary check on the performance of a given scale by comparing its indications when the truck is on the platform, first with its rear wheels close to one end of the platform, and second with its rear wheels close to the other end of the platform; such a check gives information as to the relative performance of the two ends of the scale, and when it discloses a considerable difference—considerably more than twice the tolerance on the load in question—rejection may reasonably be based upon such results.

However, the inspector must not lose sight of the important fact that regular *testing* must be conducted with *standard test weights;* an automotive highway vehicle cannot be included in that classification.

When testing any scale, regardless of method, it is very advisable that all poises which are susceptible of being locked in position, be so locked, and that the positions of all poises, particularly those without locking means on smooth weighbeams, be checked before each observation. In the case of beam scales provided with trig loops, the trig should be turned down whenever the load on the platform is being changed by any considerable amount, so as to avoid unnecessary derangement or disturbance of the weighbeam. These instructions are applicable not alone to the center-load accuracy test, but equally to all tests. Whenever a scale gives weight indications on two sides—that is, on the operator's side and the opposite or "customers' " side—a sufficient number of check observations must be made to insure that the indications of the two sides are in agreement.

When an automatic-indicating scale has "unit" weights —that is, weights which are enclosed within the housing and which are applied and removed mechanically from outside the housing—these should be tested in each possible combination. That is to say, the indication of the first unit weight, and the combined indications of the first and second, of the first, second, and third, and so on, should if practicable, each be checked against test weights on the platform, and in such cases the appropriate tolerance for the total indicated weight value is to be applied. These unit-weight combinations are so tested because the weights can only be so used; the third weight, for example, cannot be applied without first applying the first and second weights. Thus, having first tested the reading face up to its capacity, the first unit weight should be applied; the dial indicator should then register zero and if it does not, the amount by which it fails to register zero is the effective error of the first unit weight. The next unit weight is then applied, the platform load being increased to equal the value of both unit weights which are in place, when the reading face should again register zero; the amount, if any, by which the indicator fails to register zero is the effective error of the first and second unit weights in combination. This process should be repeated, adding one unit weight at a time, until all unit weights are in place and tested, when one more addition should be made to the platform load, equivalent to the reading face capacity; under this last condition, with a platform load equivalent to the combined capacity of reading face and all unit weights, the indicator should register this value within the tolerance for the total load in question. After each addition of a unit weight, the inspector will, of course, see to it that the scale properly registers the total value of the unit weights which are then in place; also, when the unit weights are removed, that the registration corresponds at all times with the value of the weights still in place. Loads should be evenly distributed over the load-receiving element throughout these tests.

The test of an automatic-indicating scale with decreasing loads need ordinarily be applied only when examining new scales, particularly when examining for type approval; however, if a particular automatic-indicating scale is being used under conditions where readings are taken following reductions in the amount of the load, a decreasing-load test is appropriate each time such scale is examined.

It is important to remember that tolerances are applied in a special way on a decreasing-load test. The specification dealing with this reads as follows:

> When tests are being made with both increasing and decreasing loads on an automatic-indicating scale, the indications on all increasing loads shall be within the regular tolerances specified, and also at any given load the range between corresponding observations for increasing and decreasing loads shall not be greater than the sum of the tolerances in excess and in deficiency for the load in question.

In testing under this specification, the inspector makes the increasing-load test in the normal manner, requiring the errors to be within the appropriate tolerances, and *recording the values of the errors;* in the decreasing-load test, errors are determined at points at which increasing-load errors have already been determined, *and the two series of errors are compared,* the *difference* between the increasing-load error and the decreasing-load error at each such point being required to be not more than "the sum of the tolerances in excess and in deficiency for the load in question," or, what amounts to the same thing, not more than twice the numerical value of the tolerance for that load. For example: Assume a computing scale of 30 pounds capacity, on which the tolerance at 20 pounds is $\pm 1/2$ ounce. If the scale showed an error of $+1/2$ ounce at 20 pounds with increasing loads, the scale would be considered accurate at 20 pounds with decreasing loads if the observed error did not exceed $+1\frac{1}{2}$ ounces—the difference between these two errors being 1 ounce, or the sum of the tolerances in excess and deficiency for this load; on the same scale, if the increasing-load error at 20 pounds had been $-1/2$ ounce, the observed decreasing-load error could not exceed $+1/2$ ounce for the scale to be approved.

A great many commercial automatic-indicating scales will register "faster" on decreasing-load tests than they will on increasing-load tests. If a provision such as the one under discussion were not in force, and if such scales were to be required to give indications within the ordinary tolerances on tests with both increasing and decreasing loads, it would probably be necessary frequently for the manufacturers deliberately to seal their scales to indicate "slow" on increasing loads in order that they might be within tolerance on decreasing loads. Under the present specification, scales may be brought as nearly as practicable to zero error on increasing loads, the special tolerance provision being ample to care for any reasonable differences between increasing-load and decreasing-load indications, such as may be anticipated on scales properly designed and well constructed.

It is not contemplated that in these tests the loads will be so gently applied and removed as to prevent any oscillation of the mechanism; such a test may sometimes be applied in the laboratory for special purposes, but should not be used in ordinary testing. In making the test with increasing and decreasing loads, the test weights should be applied and removed in normal manner, with no special effort to prevent or to increase ordinary oscillation of the mechanism.

Shift Test.—The shift test is supplementary to the center-load accuracy test, and is made to develop the performance characteristics of a scale when loads are not centered on the load-receiving element—as so frequently happens in ordinary usage—and to determine whether or not the several parts comprising or associated with the lever system are in proper position and relative adjustment. On small-capacity scales—trip, unequal-arm, and counter-platform—the shift test is regularly made with a load corresponding to one-half the nominal capacity of the scale. On small-capacity scales having stabilized load-receiving elements—that is, with but two main load bearings for each pan or platter—the essential shift-test positions for the test load are right, left, front, and rear with respect to the center of the pan or platter and the normal position of the operator, the load being centered as nearly as may be over points half-way between the center and the edge of the pan or platter; observations at two of these positions serve to check the accuracy of the positions of the main load pivots in the lever system, and observations at the other two positions serve to check the correctness of adjustment of the stabilizing elements. When these small-capacity scales are of the "platform" type—that is, with four main load bearings, one near each corner of the platform—the regular shift test positions are right front, left front, right rear, and left rear with respect to the normal position of the operator, the test load being placed as nearly as may be over the center of each quarter of the platform, as indicated by the circles in figure 16.

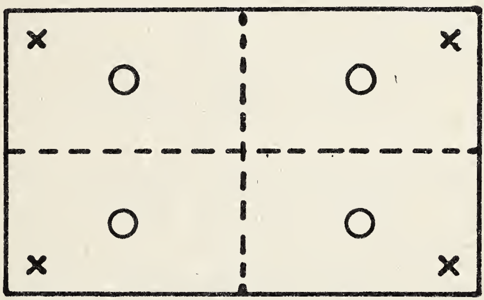

FIGURE 16.—*Shift-test positions for small-capacity platform scales.* The four shift-test positions are indicated by the circles, each at the center of one "quarter" of the platform. The crosses indicate the approximate positions of the main load bearings.

There is another difference between the shift test on a scale with a stabilized load-receiving element and the shift test on a "platform" type of scale; in the former case there is an added tolerance for the shift-test error—that is, error resulting solely from the change in position of the test load—while in the case of the "platform" scale there is, in general, no such added tolerance, all errors being required to be within the regular tolerance regardless of the position of the test load. The only exception to this general rule is the special tolerance provision which applies when corner tests are made on vehicle scales, under which "the tolerance to be applied to the results on the corner shall be twice the tolerance which would otherwise be applied, but the algebraic mean of the errors on the two corners at each end of the scale shall not exceed such regular tolerance." [National Conference scale specification B-2w.]

In testing a "stabilized" type of scale it is therefore necessary to separate the shift error from any other error which may be present. This may be done in either of two ways: (1) With the shift-test load in the center of the pan or platter, cause the scale to show zero error by temporarily "balancing out" any error which may exist; this may be accomplished by changing the balance-ball adjustment or the position of the poise and/or by adding small weights to the pan or platter. Then, making no further "balancing" changes, proceed with the shift test, in which case the observed errors at the several shift-test positions will be, directly, the errors resulting solely from the change in position of the load. Or (2) observe and record the error with the shift-test load at the center of the pan or platter and at each of the shift-test positions, making no change in the "balance" condition of the scale at any time; then correct the observed errors at the several shift-test positions by subtracting algebraically[34] in each case the observed errors at the center position; the results will be the errors resulting solely from the change in position of the load.

On scales of larger capacities—that is, portable, warehouse, wagon, etc.—shift tests are usually made with a load of less than one-half the nominal capacity of the scale, although a shift-test load of one-half the nominal capacity is entirely proper under the specifications. Where the shift-test load does not exceed one-quarter of the nominal scale capacity, it is to be placed as nearly as may be over each main load bearing in turn—that is, over the points marked by crosses in figure 16; if the shift-test load exceeds one-quarter of the scale capacity, then it should be positioned as in the case of a small-capacity platform scale—that is, as indicated by the circles in figure 16.

In the case of motor-truck scales having main levers which are not individually adjustable by means of nose irons, it is customary to omit corner tests except in those instances where it is desirable to determine, by means of test loads, the particular corner or corners associated with some error which has been disclosed, or in those

[34] To subtract algebraically, change the sign of the subtrahend and add. For example, $+\frac{1}{2}$ minus $+\frac{1}{4}$ equals $+\frac{1}{4}$; $+\frac{1}{4}$ minus $+\frac{1}{4}$ equals 0; $+\frac{1}{4}$ minus $-\frac{1}{4}$ equals $+\frac{1}{2}$; $-\frac{1}{4}$ minus $+\frac{1}{4}$ equals $-\frac{1}{2}$; $-\frac{1}{4}$ minus $-\frac{1}{4}$ equals 0; $-\frac{1}{4}$ minus $-\frac{1}{2}$ equals $+\frac{1}{4}$.

instances where the amount of test weights available falls below the recommended minimum, and it is necessary to take every advantage of such weights as are available. However, for the corner test there is substituted an end test, which is particularly necessary in the case of motor-truck scales by reason of the concentration on the rear axle of a motor truck of a very large percentage of the total vehicle weight and the possible high end-loading of a motor-truck scale which may result. It will be apparent that the conditions of use of a motor-truck scale, which is in most cases fairly equally loaded on the two corners at one end of the scale, make the end test an adequate one when this is conducted with an adequate amount of test weights; this consideration also indicates the advisability of including an end test in the case of any vehicle scale, whether or not a corner test is made.

In making an end test, the test-weight load should be equally divided between the two corners at the end under test, and the load should be concentrated as close to the end in question as is practicable. Obviously, this test should be applied to each end of the scale.

In the matter of the size of the test-weight load used for end testing, it should be remembered that a wagon scale is designed for the weighing of wagon loads, in which each axle carries approximately one-half the total load; end loading on a wagon scale should, therefore, never exceed one-half the nominal capacity of the scale. On the contrary, the motor-truck scale is designed for end loading up to the nominal scale capacity, and may properly be tested at the ends up to this amount.

In the case of any scale in which the load-receiving element consists of a hook or ring or in which the load-receiving element is supported from a single point—as the pan or scoop on a hanging scale—it is obvious that no shift test need be made, since no matter how the load is placed on the load-receiving element, it will always react in the same way on the weighing mechanism.

Test for Sensitiveness (*SR test*).—The test for sensitiveness is made on all scales not of the automatic-indicating type, to determine whether or not the mechanism will respond to sufficiently small increments of weight so that determinations of weight may be made with reasonable precision. The measure of the sensitiveness of a scale is its "sensibility reciprocal," or, as it is commonly read and written, its SR. The National Conference specifications define SR as follows:

A-2b(1). GENERAL DEFINITION OF SR.—The amount of weight required to move the position of equilibrium of the weighbeam, pointer, or other indicating device of a scale a definite amount, at the capacity or at any lesser load. SR does not apply to scales having reading faces which indicate directly in terms of weight, but no such reading face which is purely auxiliary to the scale mechanism—such as one, for instance, which may or may not be employed, as desired, in the determination of weight—shall exempt a scale from the SR requirement when this reading face is disconnected or detached.

A-2b(2). SR OF SCALES HAVING WEIGHBEAM AND TRIG LOOP.—The change in load required to move the weighbeam from a position of equilibrium at the center of the trig loop to a position of equilibrium at the top or at the bottom of the trig loop. (See also paragraph A-2b(4).

A-2b(3). SR OF EQUAL-ARM SCALES, AND OF UNEQUAL-ARM SCALES WITHOUT TRIG LOOP.—The change in load required to move the lever system from its position of equilibrium when the scale is in proper balance to a position of equilibrium at either limit of its motion: Provided, however, That when the scale is properly equipped with a well-designed special balance-indicating device comprising two indicators which move in opposite directions, the SR is the change in load required to cause a relative change in the position of rest of the indicators equal to 0.04 inch. (See also Paragraph A-2b(4).

A-2b(4). SR OF SCALES EQUIPPED WITH OVER-AND-UNDER INDICATORS.—In the case of a scale equipped with a device comprising an indicator cooperating with a single balance-indicating or "zero" graduation, the SR is the change in load required to move the indicator from its position of equilibrium when the scale is in proper balance to a position of equilibrium such that there is a clear interval between adjacent edges of the indicator and of the graduation, equal to the appropriate value in the following table:

Class of scale	Clear interval (in.)
Small-capacity scales	0.04
Large-capacity scales other than vehicle scales, livestock scales, and coal mine and tipple scales	0.12
Vehicle scales, livestock scales, and coal mine and tipple scales	0.25

In the case of a scale equipped as above with a device provided with a series of graduations which do not directly indicate weight values, the SR shall be as defined above, or the specified movement shall be increased to a value equal to one division on the graduated scale if this value is greater than that first specified.

A-2b(5). CLASSES OF SR.—Two classes of SR are established: (a) Acceptance or adjustment SR: This is the manufacturers'

SR, or the SR applicable to "new" scales as defined in paragraph A-2q.

(b) Maintenance SR: This is the users' SR, or the SR applicable to scales in use.

There are some instances in which the SR of a scale will be less—that is, the scale will be more sensitive—at large loads than at small loads. Ordinarily, however, the SR will increase as the load increases. A determination of SR should be made at zero load and at full-capacity load; if a scale is not loaded to capacity during the test, then in lieu of the SR determination at full capacity load a determination is made at the maximum applied load. The maximum allowable SR for each class and capacity of scale is stated in the specifications.

The procedure for the SR test is indicated by the definition quoted above. With the scale properly balanced (either at zero load or some other load), the inspector proceeds to determine the value of the change in the load necessary to cause the required change in the balance condition of the scale as specified in the definition for the type of scale under examination. The value of this change is the value of the SR. Or he proceeds to determine merely that a change of load equal to the maximum allowable SR for the scale under test is sufficient, or more than sufficient, to produce the required change of balance condition.

It should be noted that the expression "position of equilibrium" used in the definition means a position of *rest;* for example, a weighbeam in a "position of equilibrium at the top of the loop," is a weighbeam which is at *rest* at such a point that it is *just* in contact with the upper bar of the trig loop. In other words, in this example the SR is the weight required, not merely to cause the weighbeam to swing up to the top of the trig loop, but to *hold* the weighbeam in that position. The "position of equilibrium in the center of the trig loop" is equivalent to "proper zero balance condition"; if a scale is properly "balanced," it is not necessary actually to bring it to rest before the SR test is begun.

When determining the amount of weight required to produce the specified change, it is always advisable to check the correctness of the determination by changing the load by a slight amount and noting that the new load just *fails* to produce the specified change. For example, in a weighbeam and trig loop combination, after the load has been increased sufficiently to hold the weighbeam at the top of the loop, remove a small weight—representing, perhaps, not more than 10 percent of what appears to be the SR. If the first determination has been accurately made, the removal of this small weight should cause the weighbeam to assume a position slightly below the top of the loop; if it does not do so, it indicates that the original added load was too great. It is obvious that, once the weighbeam rests against the top of the loop, weights may be added indefinitely to the load-receiving element without visibly changing the balance indication; the procedure here suggested guards against arriving at too great a value for SR.

As pointed out in the definition of SR, this may be determined in several ways, as by adding weight to the platform, by removing weight from the platform, and by adding weights to the counterpoise hanger and computing the load which they represent on the load-receiving element of the scale.

The simplest and most direct method is to add weights to the load-receiving element, and this method is recommended; whatever method is decided upon, however, should be regularly followed.

If it is desired to make a particularly precise determination of SR, or in the case of a scale in which there is a noticeable difference between the positions of rest when the weighbeam is released first at one limit of its travel and then at the other (or when, on an equal-arm scale, first one pan and then the other is released at the lower limit of its movement), the following method of SR determination may be used: Balance the scale (under whatever load is being used for the test) so that the weighbeam (or one of the pans of an equal-arm scale) is *at rest* at either the upper or lower limit of its travel, *checking* this condition as explained above. Then add or remove weights, as may be required, to bring the weighbeam or pan to rest at the *other* limit of its travel, again checking this condition as before. The amount of weight so added or removed represents *twice* the value of the SR, and one-half of this amount represents the value of the SR.

Commercial scales should always be required to meet the appropriate SR requirements, because accurate weighing results are not to be anticipated on scales which are seriously insensitive.

Test of Manually Removable Weights.—The test of the removable weights used with a scale is separately made on a balance to determine that their actual values correspond within tolerance to the theoretically correct values, so that when used with any accurate scale of appropriate multiple the resulting indications will be accurate. The procedure for testing removable weights is discussed in the following chapter.[35]

Scales intended to be back-balanced are occasionally provided with a "balance" check weight in the form of a bottle weight intended to be suspended from a point at the butt end of the weighbeam, in which position this balance weight is designed to have an effect corresponding to that of a platform load equivalent to the amount by which the scale is to be back-balanced; this arrangement enables the operator to balance the scale or check its balance condition readily and without resort to the larger weights which would be required if balancing weights were to be utilized on the platform. In such a case the inspector must verify the accuracy of the balance weight with the same care as is observed when testing counterpoise weights; this may be done, however, on the scale itself, by comparing the balance indication when the balance weight is in place, with the indication when the correct amount of test weights is on the platform. Other scales of this type are sometimes provided with balancing weights to be used on the platform when establishing the balance; in this case also the inspector must verify the accuracy of these balancing weights, by comparison with test weights on the scale under test, or by a regular test on a testing balance as in the case of ordinary removable weights.

Application of Tolerances.—Depending upon the character of results desired, testing may be either "tolerance testing" or "error testing." In tolerance testing it is desired to know only whether or not the errors on the device under examination are within tolerance; this is the sort of testing which the weights and measures official is most frequently called upon to perform. If,

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[35] See chapter 9, p. 152.

however, in a particular case, it is desired to know the value of the error at each point observed, and not merely that the error does not exceed the tolerance, then error testing is resorted to.

When tolerance testing, a known load is applied on the load-receiving element of the scale and this is opposed by a weighbeam poise set to a corresponding value, by the standard amount of standard weights on the counterpoise hanger, by standard weights on the opposing pan, by the automatically-applied counterforce of the automatic-indicating scale, and so on; if the scale is now found to be in error, the full value of the tolerance is at once applied—as for example, by adding weight on the load-receiving element if the scale is slow, or by removing weight from the load-receiving element or adding weight on the counterpoise hanger if the scale is fast. Having applied the value of the tolerance, if this change is more than sufficient to overcome the error, the scale error is less than the tolerance; if this change is just sufficient to overcome the error, the error is just within tolerance; if this change is not sufficient to overcome the error, the scale is out of tolerance at that point. In either of the first two cases mentioned, the scale is "accurate" because it is within tolerance, and the inspector proceeds at once to his next observation without using time to determine just how large the error may be.

In tolerance testing, if an automatic-indicating scale has a plus error and it is inconvenient to make the tolerance change by removing weight from the platform, weight equivalent to the difference between the value of one subdivision on the chart and the value of the tolerance may be added to the platform, and the chart indication read with respect to the first chart graduation in advance of the one originally under consideration. For example, assume a 10-pound chart with 1-ounce graduations on which the tolerance at a 5-pound load is $\pm\frac{1}{4}$ ounce. Assume that when a 5-pound weight is applied to the platter, the indicator stands slightly in advance of the 5-pound graduation. Instead of reducing the load on the platter to 4 pounds $15\frac{3}{4}$ ounces, it is permissible to increase the load by $\frac{3}{4}$ ounce—which is 1 ounce (the value of one subdivision on the chart) minus $\frac{1}{4}$ ounce (the value of the tolerance), and then consider the scale indication with respect to the 5-pounds-and-1-ounce graduation, instead of the 5-pound graduation as would have been done had the tolerance change originally been made by removal of weight from the platter.[36] In this example, if the scale indication is equal to or less than 5 pounds 1 ounce, the scale is within tolerance at this point. This method may also be used with respect to weighbeam graduations.

When making the tolerance change by adding weight to a counterpoise hanger, it must be remembered to add, not the weight equal to the actual tolerance value, but instead a weight which, when applied on the hanger, and considering the multiple of the scale, will be *equivalent* to the actual tolerance on the load-receiving element; in other words, the weight added to the counterpoise hanger will be equal to the tolerance value divided by the scale multiple. For example, assume a portable scale which at some given load has a plus error, the tolerance for that load being ½ pound. Adding weight to the counterpoise is equivalent to removing weight from the platform; we can therefore apply the tolerance in the assumed case by adding weight on the counterpoise; the multiple of the scale being approximately 100, the weight to be added to the counterpoise to correspond to the tolerance of ½ pound on the platform is therefore one one-hundredth of one-half pound, or 0.005 pound (35 grains);[37] the addition to the counterpoise, then, of actual weights equaling 0.005 pound, or 35 grains, is the equivalent, for tolerance purposes in this example, to the removal of ½ pound from the platform.

When error testing, the inspector will change the value of the platform load or of the weights on the counterpoise, or in some other manner will bring about a condition of "balance," such that the scale will indicate a definite weight value; then the amount by which the platform load differs from the scale indication is the actual error of the scale at that point. Error testing requires more time than tolerance testing and, for econ-

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[36] If the value of the tolerance exceeds the value of one of the graduations, the difference between the amount by which the tolerance exceeds the closest integral multiple of the graduation value, and the value of one graduation, may be applied to the load-receiving element and the scale indication then considered with respect to the next succeeding graduation.

[37] The error in the multiple of the scale may be neglected in this computation, the designed multiple being used, as in the example.

omy of time and effort, should be resorted to only when it is desirable to determine the actual values of errors.

It must be borne in mind that it is only when the scale is caused to duplicate its zero-load balance or when poise or indicator is in coincidence with a graduation mark, that precise results can be obtained. Estimation of the value of an error from a too-high or too-low weighbeam, from a poise position intermediate between two weighbeam graduations, or from an indicator position intermediate between two reading-face graduations, will give results of only approximate accuracy; skill in estimation of readings between graduation marks may be developed with practice, but estimation should not be resorted to when precision of results is demanded and other means are available.

With respect to the application of tolerances and the precise determination of errors, testing procedure may be materially simplified and expedited by what, for want of a better term, may be called the "error-weight method." This method is designed to make it possible directly to determine plus errors and to apply tolerances on scales having plus errors, by changing the amount of certain auxiliary weights on the load-receiving element of the scale, leaving the normal test load unchanged. The method offers no advantages in the case of equal-arm scales[38] or of minus errors on scales of any type. However, since it is not ordinarily known in advance whether a scale is going to run fast or slow on test, and since the error-weight procedure cannot conveniently be introduced after a series of observations has been started, the use of the method as standard practice is to be recommended in all tests of large-capacity scales, and also in other tests (except those on equal-arm scales) whenever the units of the test load are of such size that they cannot quickly and conveniently be broken down for the removal of the relatively small amounts of load corresponding to the errors or tolerances.

The procedure under this method is as follows: For error testing, the scale under examination is first "balanced" with a small initial load of "error weights," the

[38] In the case of an equal-arm scale, it is not necessary to reduce the test load to determine the magnitude of any error; the necessary weights to establish equilibrium may always be added to the "high" pan, and these will represent the amount of the error.

amount of the error weights being such that this will probably exceed any error developed in the course of the test; for example, 5 pounds should ordinarily be sufficient in the case of a portable scale and 10 pounds in the case of a warehouse scale, while for a vehicle scale, 50 pounds is a convenient amount. For a counter scale, which it might be inconvenient to rebalance at zero indication with even a small amount of balancing weights on the load-receiving element, the advantages sought may be obtained by using fractional weights in the first increment of test load applied, and continuing these as a part of the test load throughout the test, provided that additional small weights are available for use if and when minus errors occur. For tolerance testing, the total of the error weights need not exceed the tolerance on the largest test load to be used in the course of the test.

The error weights may be balanced out on the scale by any convenient means. If the ordinary balancing means of the scale has sufficient range to permit this, its use is to be preferred; in this case the inspector must remember to rebalance the scale properly at the conclusion of the test, so that it may be left in proper operating condition. If the scale is equipped with a counterpoise hanger, the scale may be approximately balanced with the auxiliary weights in position by the addition of material (not necessarily weights) on the hanger, final balance being obtained by means of the ordinary balancing mechanism; when this method is used, inadvertent removal from the hanger, during the test, of any of the added material, must be carefully guarded against. If the scale is equipped with a weighbeam poise provided with a locking screw, this poise may be positioned to counterbalance the auxiliary weights and then be locked in position; in this case, the test of the weighbeam bar so utilized will be separately made after the remainder of the test is completed, a new zero-load balance being established, of course, with the poise at the zero position and without any error weights in place.

In the case of an automatic-indicating scale, if the scale cannot conveniently be balanced by the regular means with the indicator at zero when the desired error weights are in place, it may be balanced with the indicator at any weight graduation slightly in advance of zero, but preferably at one representing less than the amount of error weights used. In this event, due account must be taken of the zero-test-load indication of the scale, in all test observations. For example, if a scale with a 500-pound reading face is caused to indicate 2 pounds when 5 pounds of error weights are in place, and the test load is added in 100-pound increments, indications of 102 pounds, 202 pounds, etc. would represent errorless performance; in this example, the final reading-face interval—402 to 500 pounds—would be tested by adding 100 pounds of test weights and removing 2 pounds of error weights, thus in effect adding only 98 pounds of test weights.

Under the error-weight method of error testing, the amount of auxiliary weights is so adjusted at each observation as to cause the scale to indicate correctly the amount of the test load, the zero-load balance condition being carefully duplicated in each instance; the difference, then, between the original amount of error weights and the amount found necessary for any test observation, is the amount of the error at that point. If the amount of error weights for a particular observation has been increased as compared with the original amount, the scale is slow and the sign of the error is minus, whereas if less than the original amount of error weights has been used, the scale is fast and the sign of the error is plus. If abnormally large plus errors, in excess of the amount of the error weights, develop in the course of a test, precise determination of such errors is ordinarily not essential, and these may be read directly by means of weighbeam or reading face; similarly, error weights need not ordinarily be added to determine precisely any abnormally large minus errors which may develop.

For tolerance testing, it is only necessary at each observation to modify the amount of error weights by the amount of the tolerance for the test load in question; if this change is insufficient to cause a correct indication, the scale is out of tolerance at that point.

In applying tolerances, care must be exercised to select the proper tolerance values. There are tables of tolerances for different classes of scales, but the tabular values must at times be modified in accordance with general limitations set up. For example, it may be specified that the tolerance shall in no case be less than the value of one of the minimum graduations on the weighbeam; in this case tabular values would be followed down to a point where the tolerance stated in the table equals the value of one of the smallest weighbeam graduations on the particular scale under examination, and then this same tolerance would be used at all points below this. Acceptance and adjustment tolerances (applicable to new or newly reconditioned scales)[39] are ordinarily one-half the values of corresponding maintenance tolerances, and should be applied whenever it is appropriate to do so.

In the tolerances of the National Conference on Weights and Measures, currently published in NBS Handbook H29, the tolerance values shown in the tables are maintenance tolerances, that is, they are for application to scales *in use* as distinguished from *new* or *newly reconditioned* scales, and any general limitations, such as are referred to above, are stated immediately preceding the table to which they apply.

Outlines of Test Procedure.—The material contained in this chapter up to this point has been more or less general in character and is largely applicable to any scale which the inspector is called upon to test. The principles discussed should be thoroughly grasped, so that they may be applied when testing any particular scale. In what follows there will be given certain specific instructions relative to different types of scales, the classification being that already followed in chapters 4 and 5. This material has been arranged largely in outline form, so as to emphasize the various steps in the recommended test routine. Detailed procedure is not ordinarily given, since such details have, to a considerable extent, already been discussed; certain brief instructions are necessarily repeated. Where deemed advisable, the outline of test has been supplemented by brief descriptive or explanatory matter relating to the particular type of scale in question, such material having been placed in "Notes" or

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[39] The National Conference specifications for scales define "new" scales as follows [Paragraph A-2q]:

"Scales which are about to be put into use for the first time or which have recently been put into use and are being tested for the first time by the weights and measures official. Scales which have been reconditioned or overhauled or which have been condemned for repairs by a weights and measures official and subsequently adjusted or repaired shall, upon the first test thereafter, be construed to be 'new' scales for the purpose of the application of tolerances."

as footnotes to the several outlines; this material is frequently of major importance and should be carefully considered in connection with each outline.

Before any regular test is undertaken the scale should be in balance (except cream-test scales and scales designed to be back-balanced) and, in the case of counter and portable types, it should also be in level and substantially supported. The exception to this is when, for a particular purpose, it is desired to learn what is the weighing performance of the scale in the condition in which the inspector finds it. Also "inspection" of each scale examined, as discussed in chapter 7, is an essential part of the test. These general instructions are not repeated in the following outlines. It should be clearly understood that the outlines specify *minimum* test requirements; whenever practicable the test should be amplified by including observations at points in addition to those specified.

OUTLINES OF TEST PROCEDURE BASED ON MINIMUM TEST REQUIREMENTS

EQUAL-ARM TYPE:

1. Test for SR under zero load.[40]
2. Test for ratio (equality of arms), using half-capacity and full-capacity loads centered on each pan.
3. Test for SR under full-capacity load.[41]
4. Test for shift error, using a half-capacity load, in right, left, front, and rear positions.[42] Keep load on one pan centered while shifting the position of the load on the other pan. To develop the maximum shift error, weights may be shifted to off-center positions on both pans. (NOTE.—There is a special tolerance for shift-test errors.)
5. Test weighbeam, if any, at not less than two points, including capacity of the bar.
6. Test reading-face indications, if any, at least at approximately one-quarter, one-half, and full-capacity of reading face of conventional "fan" type, and at two points on each side of the "zero" of an "over-and-under" type.
7. Test removable weights.

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[40] Not applicable on a scale having an automatic weight-indicating element.

[41] See footnote 40.

[42] Omit on a scale with a hanging pan.

UNEQUAL-ARM TYPE — INCLUDING AUTOMATIC-INDICATING COUNTER SCALES WITH STABILIZED PAN OR PLATTER:

1. Test for SR under zero load.[43]
2. Test for ratio, using half- and full-capacity loads centered on the pan.[44]
3. Test for SR under capacity load.[45]
4. Test for shift error, using a half-capacity load, in right, left, front, and rear positions. (NOTE.—There is a special tolerance for shift-test errors.)
5. Test weighbeam, if any, at not less than two points on each bar, including capacity of each bar.
6. Test reading-face indications, if any, with increasing loads as follows:
   a. Fan charts: At least at approximately one-quarter, one-half, and full capacity of chart.
   b. Circular or cylindrical charts: At least at each quarter-capacity point of chart. Inclusion of several additional test points in first quarter of reading-face capacity is advisable.
7. Test reading-face indications with decreasing loads at same points as in increasing-load test.[46]
8. Test counterpoise weights, if any.

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[43] Not applicable on a scale having an automatic weight-indicating element.

[44] Not applicable on a scale not designed to utilize counterpoise weights.

[45] See footnote 43.

[46] This applies to scales having automatic weight-indicating elements, (1) whenever examining a new type, or other circumstances demand a particularly rigid test, and (2) whenever the regular use of the scale involves weight observations following a reduction of the initial load.

COUNTER PLATFORM TYPE:

1. Test for SR under zero load.[47]
2. Test for ratio, using loads, centered on platform, as follows:[48]
   a. Weighing capacity, 100 pounds or less: Half- and full-capacity load.
   b. Weighing capacity over 100 pounds: Half- and full-capacity load if practicable; in all cases at least 50- and 100-pound loads.
3. Test for SR under maximum test-load used.[49]
4. Test for shift error as follows:
   a. Weighing capacity, 200 pounds or less: Use half capacity load, centered over each quarter of platform in turn.
   b. Weighing capacity over 200 pounds: Use half-capacity load if practicable, centered over each quarter of platform in turn; in no case use less than 100-pound load.
5. Test weighbeam, if any, at not less than two points on each bar, including capacity of each bar.
6. Test reading-face indications, if any, with increasing loads as follows:
   a. Fan charts: At least at approximately one-quarter, one-half, and full capacity of chart.
   b. Circular or cylindrical charts: At least at each quarter-capacity point of chart. Inclusion of several additional test points in first quarter of reading-face capacity is advisable.
7. Test reading-face indications with decreasing loads at same points as in increasing-load test.[50]
8. Test counterpoise weights, if any.

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[47] Not applicable on a scale having an automatic weight-indicating element.

[48] Not applicable on a scale not designed to utilize counterpoise weights.

[49] See footnote 47.

[50] This applies to scales having automatic weight-indicating elements (1) whenever examining a new type or other circumstances demand a particularly rigid test, and (2) whenever the regular use of the scale involves weight observations following a reduction of the initial load.

SUSPENDED TYPE:

1. Test for SR under zero load.[51]
2. Test for ratio using half- and full-capacity loads.[52]
3. Test for SR under full-capacity load.[53]
4. Test weighbeam, if any, at not less than two points on each bar, including capacity of each bar.[54]
5. Test reading-face indications, if any, with increasing loads as follows:
    a. Fan charts: At least at approximately one-quarter, one-half, and full capacity of chart.
    b. Circular or cylindrical charts: At least at each quarter-capacity point of chart. Inclusion of several additional test points in first quarter of reading-face capacity is advisable.
6. Test reading-face indications with decreasing loads at same points as in increasing-load test.[55]
7. Test counterpoise weights, if any.

(NOTE.—Accurately ascertain the weight of, and make proper allowance for any hooks, chains, etc., utilized in applying the test-weight load.)

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[51] Not applicable on a scale having an automatic weight-indicating element.

[52] Not applicable on a scale not designed to utilize counterpoise weights.

[53] See footnote 51.

[54] In the case of a steelyard having removable poises, use standard hanger weights instead of poises furnished, testing these poises separately, or first establish the correctness of the weights of the removable poises.

[55] This applies to scales having automatic weight-indicating elements, (1) whenever examining a new type or other circumstances demand a particularly rigid test, and (2) whenever the regular use of the scale involves weight observations following a reduction of the initial load.

PORTABLE PLATFORM AND WAREHOUSE TYPES:

1. Test for SR under zero load.[56]
2. Test for shift error, using a quarter-capacity load centered successively over each main load bearing, or a half-capacity load centered successively over each quarter of the platform.
3. Test for ratio, using a half-capacity load and a full-capacity load, centered on or evenly distributed over the platform.[57]
4. Test for SR under full-capacity load.[58]
5. Test weighbeam, if any, at not less than two points on each bar, including capacity of each bar.
6. Test reading-face indications, if any, with increasing loads at least at each quarter-capacity point of reading face.
7. Test reading-face indications with decreasing loads at same points as in increasing-load test.[59]
8. Test each combination of unit weights and reading face against test weights on the scale platform.[60]
9. Test counterpoise weights, if any.

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[56] Not applicable on a scale having an automatic weight-indicating element.

[57] Not applicable on a scale not designed to utilize counterpoise weights.

[58] See footnote 56.

[59] This applies to scales having automatic weight-indicating elements, (1) whenever examining a new type or other circumstances demand a particularly rigid test, and (2) whenever the regular use of the scale involves weight observations following a reduction of the initial load.

[60] This applies to scales having enclosed "unit" weights, mechanically applied and removed from outside the housing.

OVERHEAD-LEVER TYPE:

1. Test for SR under zero load.[61]
2. Test for shift error as follows:[62]
   a. Monorail scale: Use a half-capacity load suspended successively from points very close to each end of the weighing rail.
   b. Platform scale: Use a quarter-capacity load concentrated successively close to each corner of the platform.
3. Test for ratio, using a half-capacity load and a full-capacity load centered on or evenly distributed over the weighing rail or platform.[63]
4. Test for SR under full-capacity load.[64]
5. Test weighbeam, if any, at not less than two points on each bar, including capacity of each bar.
6. Test reading-face indications, if any, with increasing loads as follows:
   a. Fan charts: At least at approximately one-quarter, one-half, and full-capacity of chart.
   b. Circular or cylindrical charts: At least at each quarter-capacity point of chart. Inclusion of several additional test points in first quarter of reading-face capacity is advisable.
7. Test reading-face indications with decreasing loads at same points as in increasing-load test.[65]
8. Test each combination of unit weights and reading face against test weights on the scale platform.[66]

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[61] Not applicable on a scale having an automatic weight-indicating element.

[62] Not applicable on a scale having a load-receiving element freely suspended from a single point of the weighing mechanism, as, for example, a hook, a hanging can, etc.

[63] Not applicable on a scale not designed to utilize counterpoise weights.

[64] See footnote 61.

[65] This applies to scales having automatic weight-indicating elements, (1) whenever examining a new type or other circumstances demand a particularly rigid test, and (2) whenever the regular use of the scale involves weight observations following a reduction of the initial load.

[66] This applies to scales having enclosed "unit" weights, mechanically applied and removed from outside the housing.

VEHICLE TYPES (WAGON AND MOTOR-TRUCK SALES):

1. Test for SR under zero load.[67]
2. Test for shift error as follows:[68]
   a. A-lever pattern: Use a load of several thousand pounds, but not exceeding one-quarter scale capacity, successively concentrated as nearly as practicable over each main load bearing.
   b. Wagon scale, any pattern:[69] In addition to (a), if applicable, use all available test weights up to but not exceeding one-half scale capacity, successively concentrated at each end of platform, equally distributed with respect to the corners.
   c. Motor-truck scale, any pattern:[70] In addition to (a), if applicable, use all available test weights up to full scale capacity, applying these in two or three increments successively concentrated first at one end of the platform and then at the other end, the weights in all cases being equally distributed with respect to the corners. (If only a relatively small amount of test weights is available, compare the performance at the two ends of the scale by weighing a loaded vehicle and then weighing it in reversed position, so that the rear wheels will be positioned successively at each end of the platform.)
3. Make a distributed-load test, using all available test weights up to full scale capacity, the test

[67] Not applicable on a scale having an automatic weight-indicating element.

[68] If the scale employs manually removable counterpoise weights, use standard weights on the counterpoise hanger. If the scale is equipped with a full-capacity weighbeam, use the weighbeam elements. If the scale is equipped with a reading face, use the reading-face indications.

[69] A detailed discussion of the testing methods employed by the National Bureau of Standards with its Vehicle Scale Testing Unit, which carries fifteen 1,000-pound test weights, will be found beginning on page 75 of the report of the Twenty-eighth National Conference on Weights and Measures, National Bureau of Standards Miscellaneous Publication M161.

[70] See footnote 69.

load being equally distributed over the scale platform.[71,72] Economy of movement of test weights may be realized by conducting the distributed-load test intermediate between the two end tests.

4. If the available test weights do not equal full scale capacity, employ at least one strain load in combination with the test weights, to bring the gross load as nearly as practicable up to full scale capacity or at least up to the value of the maximum loads ordinarily weighed on the scale.
5. Test for SR under maximum loading of scale.[73]
6. Test each tare and fractional weighbeam bar at two points approximating one-half and full capacity of the bar. Also, if practicable, check any notched bar at all notches which appear to be worn or otherwise of questionable accuracy.
7. Test counterpoise weights, if any.

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[71] See footnote 68.

[72] If the scale is equipped with a reading face, this should be checked at least at each quarter-capacity point, and preferably at each 1,000-pound point, throughout its range. Utilize each test-weight load used, for testing reading-face indications, and also for testing the indications of any weighbeam bars (or combinations of such bars) with which the scale may be equipped. If the scale is equipped with unit weights, the unit weights should be checked, if practicable, in each possible combination.

[73] See footnote 67.

RAILWAY TRACK TYPE:

Note.—Special equipment consisting of a short-wheel base "test weight car" having a known value of not less than 30,000 pounds, (and preferably two such cars, one having a weight twice that of the other) is essential for a rapid, convenient, and proper test of a railway track scale; tests of such scales with test-weight loads of a few thousand pounds are practically useless and in some cases definitely misleading.

The test of a railway track scale corresponds essentially to the test of other large-capacity scales; the test-weight car or cars are "spotted" successively in certain specified positions with respect to the main levers of the scale. A detailed outline of test procedure is omitted here because the weights and measures officer—largely by reason of lack of proper equipment—is rarely in a position to test a railway track scale.

COMPUTING TYPE.

Note.—The weighing portion of a computing scale is to be tested in the same way as has been outlined for a noncomputing scale of similar type of construction.

The money-value graduations on a computing-scale chart are fixed in relation to the weight graduations when the chart is made. As part of the routine test of a scale it is practicable to check only a few out of the hundreds or thousands of value graduations on the chart. It *is* advisable, however, at least to check the zero-load indications for both weight and money values and to check the money values at some one load (representing half-capacity or more) clear across the chart, to make certain that the computed money values agree with the prices-per-pound which are shown, and that the chart is mounted in proper alinement.

COUNTING TYPE.

Note.—The straight weighing portion—if any—of a counting scale is to be tested in the same way as an ordinary scale of similar type of construction.

The counting portions of a counting scale are to be tested by testing the ratio between each load-receiving element (platform, large scoop, etc.) and the corresponding element or elements (small pans, scoops, etc.) designed to receive the small, hand-counted number of articles; the latter elements correspond, in principle, to the counterpoise hanger on an ordinary weighing scale.

When the relation between the load-receiving element and the small scoop or pan may be varied, the ratio is to be tested at several points.

In all cases, regular test procedure as outlined for the basic type of the scale under examination, including such factors as test for SR, shift test, etc., is to be followed except insofar as it may be necessary or advisable to modify or amplify this as a result of the special design of the scale under examination.

PREDETERMINED-WEIGHT TYPE.

Note.—When a scale is "back balanced" a certain amount, this condition is checked by the application to the load-receiving element of test weights equal to the nominal amount by which the scale is back balanced; the scale should then be "in balance."

A scale designed to indicate only a certain series of weights (as, for example, 12¼, 24½, 49 pounds, etc.) will be tested only at those points. If all of the indications are weighbeam or reading-face indications, the test is to be made as for an ordinary full-capacity beam or automatic-indicating scale. If there are a counterpoise hanger and counterpoise weights, the ratio and the weights are to be tested separately as in the case of an ordinary weighing scale. If "bottle weights" or "hook weights" are supplied, and these are intended to be applied at the tip of the weighbeam, a ratio test and separate tests of the weights are to be made as before; if such weights are intended to be applied elsewhere than at the tip of the beam, the scale indications should be tested with these weights actually in place in all intended combinations.

In all cases, regular test procedure as outlined for the basic type of the scale under examination, including such factors as test for SR, shift test, and the like, is to be followed except insofar as it may be necessary or advisable to modify or amplify this as a result of the special design of the scale under examination.

PREDETERMINED-VOLUME TYPE.

Note.—In all cases, regular test procedure as outlined for the basic type of the scale under examination, including such factors as test for SR, shift test, and the like, is to be followed except insofar as it may be necessary or advisable to modify or amplify this as a result of the special design of the scale under examination.

The complete test of this type of scale involves a volume determination on the load-receiving element, which may be made by means of a volumetric comparison with standard capacity measures.

PREDETERMINED-CHARACTER-OF-LOAD TYPE:

CREAM-TEST SCALES.

1. Without reference to the initial balance condition of the scale, center or distribute equally on the pan (of a single-pan scale) or on each pan (of a double-pan scale) a load equal to 2 ounces[74] multiplied by the figure representing the number of test bottles the pan is designed to receive, and then balance the scale with this load in place. (For example, on a 4-bottle equal-arm scale, each pan is designed to receive two bottles; the load to be placed on each pan before balancing is therefore 2×2 ounces, or 4 ounces.)
2. Test for SR.
3. Test for arm length with an additional load (or loads) of 18 grams or its approximate equivalent, 5/8 ounce, centered on the pan (or pans).
4. Test for shift error, using the load of 18 grams or 5/8 ounce and shifting this to the various positions on the pan which may be occupied by a cream-test bottle and to positions on the pan in which the weight may reasonably be placed when cream samples are being weighed. (NOTE.—There is a special tolerance for shift-test errors.)

WHEEL-LOAD WEIGHERS.

Note.—Wheel-load weighers are ordinarily used in pairs and, if so, they may be so tested; see specifications for special requirements and tolerances in such cases.

Without specialized equipment it is impracticable to test these devices by direct application of test weights. The recommended procedure is to utilize as a standard for comparison, a motor-truck scale which is known to be accurate and in good condition. The following outline is based on the use of such a scale and contemplates the test of a pair of wheel-load weighers; the procedure for the test of a single weigher will be obvious.

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[74] 2 ounces approximates the gross weight of a test bottle containing an 18-gram "charge" of cream.

1. Place the wheel-load weighers in such positions on the platform of a motor-truck scale that each of the wheels of a single axle of a truck may be driven onto the platforms of the weighers, *with the other two wheels of the truck off the platform of the motor-truck scale.*
2. With the weighers in place, balance the motor-truck scale.
3. Drive a loaded truck onto the motor-truck scale so that the wheels of one axle rest on the platforms of the two weighers. *The other two wheels must be off the scale entirely.*
4. With the truck in place, compare the weight indications of the motor-truck scale and the combined indications of the two weighers; assuming zero error in the motor-truck scale, any difference between the indications of the scale and the wheel-load weighers is the error of the pair of weighers at the load in question.
5. Repeat (3) and (4) a number of times, using both front-axle and rear-axle loads, and using loads of different gross weights, so that tests may be made at numerous points throughout the range of the weighers. A particular effort should be made to test at the lightest and at the heaviest axle loads which the wheel load weighers may be called upon to handle in regular service.

TANK AND HOPPER SCALES.

Note.—The principles of testing are the same as for scales of similar type of construction having the conventional platform. The application of the test-weight load will frequently present a problem, but the effort should be to follow, insofar as practicable, the procedure outlined for platform scales of equivalent capacity. Special cradles to receive the test-weight load may frequently be used to advantage; these are sometimes permanently attached to the frame, while at other times the cradle is designed to be hung from the frame only at the time of testing. In the latter case provision is sometimes made for suspending the cradle in such a way that the load may be concentrated directly over or very close to each of the main load bearings of the lever system.

Whenever it is removable, the cradle and accompanying tackle may with advantage be standardized at a definite weight and used as a part of the known test load; when this is done, however, cradle and tackle must be standardized with the same care and accuracy as a test weight of equivalent value, and must be treated with the same care as a test weight so as to minimize changes in their masses. When not standardized, cradle and tackle must, of course, be "balanced out" before the test load is applied.

It will ordinarily be very convenient to apply a variety of strain loads, or to use the substitution method of building up a test load, by running into the tank or hopper the desired weights of the commodity which the scale is regularly used to weigh.

Specialized Types.

Note.—In regard to the many specialized types of scales which may be encountered from time to time, it can only be said that the inspector must first acquire an understanding of the use to which the scale is put in the course of its regular operation, and must then devise a test, based on the principles and procedure already given, which will best develop the performance characteristics of that particular scale. Whenever such a scale is used for weighing commodity, the test should be such as to develop the performance characteristics of the scale in its "commodity range," that is, in that portion of its weighing range in which the actual commodity weighing takes place.

Approval, Rejection and Condemnation.—The results of the inspection and test of a scale will determine the official action to be taken by the weights and measures officer with respect to that scale. If the results are satisfactory, the scale will be approved for commercial use; if the results are unsatisfactory in one or more respects, the scale will be rejected, or "condemned for repairs," if the inspector feels that suitable repairs can be made, otherwise it will be "condemned" outright.

The sealing, rejection, and condemnation of commercial devices is discussed at some length in chapters 17 and 18 of National Bureau of Standards Handbook H26, Weights and Measures Administration,[75] to which reference should be made. It need only be repeated here that whenever a commercial device is approved it should be marked with the appropriate official "seal" to indicate this approval; that when a device is rejected it should be suitably marked to indicate this fact, and should be reexamined as soon as practicable after repairs have been completed; and that a device should be condemned outright only when it is not susceptible of repair, and that in such a case suitable steps should be taken to insure against its further commercial use.

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[75] p. 123-133.

Chapter 9.—WEIGHTS USED WITH COMMERCIAL SCALES: INSPECTION; TESTING EQUIPMENT; TESTING; OUTLINES OF TEST PROCEDURE; SEALING, CONDEMNING, ADJUSTING

Inspection.—The inspection of weights intended for use with commercial scales is a very simple matter. They should be examined to see that the provisions of the specifications applicable to them are compiled with. The weights should be made of suitable material and should be properly finished; they should be clean and should not be coated with a soft material of any kind; all adjusting material should be securely driven into the adjusting holes or otherwise secured in the adjusting cavity; no adjusting material should project beyond the surface of the weight adjacent to the adjusting hole; and each weight (except as specifically exempted by the specifications from this requirement) should be plainly marked with its nominal value, and, in the case of a weight intended for use on a multiplying-lever scale, also with its designed counterpoise value, that is, its counterpoise value when used on a scale of that multiple for which the weight is designed. A weight marked to show intended use on a scale having a given multiple should never be permitted in use on a scale of some other multiple; if the weight cannot be restored to a scale of the proper multiple it should be confiscated as an improper weight, notwithstanding the fact that its actual value, as marked, may be accurate.

A weight which has been broken and repaired should not be permitted in use unless the repairing has restored the weight practically to the condition of a new weight. Homemade and makeshift weights, even though they may possibly be within tolerance at the moment, will almost certainly fail of compliance with one or more of the provisions of the specifications, and their use may be forbidden on those grounds.

Testing Equipment.—Testing balances and standard weights constitute the equipment necessary for the testing of weights used with commercial scales. Standard weights must be available in such amount and denominations that loads may be built up corresponding to the nominal value of each of the weights to be tested. In addition there must be available a set of small weights, from which may be selected weights representing the value of the tolerance on each commercial weight tested.

Two portable testing balances should be provided; they should be designed to be quickly and easily disassembled and packed to prevent damage while being transported, and should be of the equal-arm type,[76] equipped with pointer and graduated scale to indicate the condition of balance. One balance having a capacity of 10 pounds on each pan and an SR[77] not exceeding 1 grain at any load, will be suitable for testing weights above 1 ounce; the other balance should have a capacity of 1 ounce on each pan and an SR not exceeding 0.015 grain (approximately 1 milligram) at any load, and will be used for testing weights of 1 ounce and less.

The arm lengths of the testing balance should be so nearly equal that the arm-length error may be neglected in ordinary weighing. The arm-length error on the 10-pound balance should not exceed 2 grains on 10 pounds; the 1-ounce balance should have an arm-length error not greater than 0.05 grain (approximately 3 milligrams) on 1 ounce.

It is advisable for the inspector to check the arm length and SR of each of his testing balances at frequent intervals, particularly after they have been subjected to any rough handling during transportation or when for any other cause there is reason to anticipate possible damage. Arm length may be checked by balancing with zero load, then applying equal test-weight loads on either pan and noting that the zero-load balance condition is repeated. The loads may then be reversed on the pans, when the zero balance condition should again be repeated. Agreement between the conditions of balance under both

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[76] For special purposes, balances having arms in the ratio of 5:1, or some other convenient ratio, may sometimes be advisable, but these are not to be recommended for general testing.

[77] The SR of a balance equipped with an indicator cooperating with a graduated scale, is the change in load required to cause a change in the position of equilibrium of the indicator equal to one division of the graduated scale; in other words, it is the change in load required to move the indicator from a position of rest in coincidence with one graduation to a position of rest in coincidence with the next graduation.

conditions of loading shows the two loads to be the same in weight and serves as a rough check against any change in the values of the test weights.

If the two arms of the balance are found to be unequal, the balance should not be used for direct weighing[78] until the arm-length error has been reduced to meet the prescribed requirement for the balance in question; such an adjustment on a testing balance should not be attempted in the field, and in any event should only be undertaken by one experienced in making such adjustments. Notwithstanding an arm-length error, if the balance is otherwise in good condition, it may be used for making substitution weighings, as explained below.

Testing.—Commercial weights should always be tested on the inspector's testing balance[79] directly against standard test weights; a test of weights made on the commercial scale with which they are being used is not a proper test, even though the platform load or the load on the opposing pan of the commercial scale may consist of standard test weights.

Testing may be done by "direct weighing" or by "substitution weighing."[80] Direct weighing is the simpler of the two methods, and consists of placing the weight under test on one pan of the balance and standard weights on the other pan, and making a direct comparison. In using this method some error is always introduced, resulting from the inevitable arm-length error of the balance, and the method is recommended only for testing in which the existing arm-length error of the balance is negligible in comparison with the desired precision of the results. It is considered impracticable to raise the recommended

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[78] It is sometimes practicable to use for direct weighing a balance having a considerable error in arm length, by applying corrections for the errors which have been found to exist; the errors should have been carefully determined at different loads, because the error may not be directly proportional to the load; the correction to be applied when a given weight is being tested will be determined by the value of the weight and the load-error characteristics of the balance. This method is not to be generally recommended, especially when the errors are relatively large; in any case of a balance having a considerable arm-length error, the substitution method of weighing (see p. 155) is simpler and safer to use, and is to be preferred.

[79] Where the value of the commercial weight exceeds the capacity of the testing balance, as may happen on rare occasions, it will be necessary to use a commercial scale; only the best and most sensitive commercial scale available should be utilized; if the scale is of the beam type, the comparison should be made at the tip of the weighbeam by comparing the weights under test with standard weights on the counterpoise hanger of the scale.

[80] A third recognized method of weighing known as the "transposition method," is not considered advisable for the class of testing under consideration, and therefore is not discussed.

arm-length requirements for inspectors' 10-pound testing balances so high as to produce a balance which may safely be used for testing by direct weighing all commercial weights within its range. However, a testing balance conforming to the requirements for equality of arms as given hertofore may safely be used, without any correction for arm-length error, for testing by direct weighing the large majority of commercial weights which will be encountered. The substitution method should be used when results of greater precision are desired.

In testing a weight by the substitution method of weighing, a standard weight (or weights) equal to the nominal value of the weight to be tested is balanced on one pan of the balance against material of any kind on the other pan, and the rest point of the balance is noted. The weight to be tested is then substituted for the standard weight (or weights), and the new rest point of the balance is compared with the first. Thus it will be seen that only one arm of the balance is directly used in the weight comparison, and any inequality in arm length has no effect. Substitution weighing requires somewhat more time than direct weighing but is susceptible of producing results of greater accuracy.

The SR of the testing balance should be considerably smaller than the smallest tolerance which will be applied to weights tested on the balance. Here again, however, practical considerations dictate recommended requirements for the testing balances, and the specified maximum SR is somewhat higher than is desirable for certain tests. In testing some small weights, therefore, especially under manufacturers' tolerances, it will probably be found that the value of the tolerance approaches the value of the SR of the testing balance. In these cases special care must be exercised in manipulating the balance and in determining the rest points of the balance, since otherwise it cannot be determined with precision whether or not the weight under test is within tolerance, and an inaccurate weight might be approved or an accurate one condemned.

Outlines of Test Procedure.—Simple testing procedures under each of the two testing methods discussed—direct weighing and substitution weighing—are outlined below:

TESTING BY DIRECT WEIGHING:—

1. Balance the testing balance so that the pointer and the zero on the graduated scale will coincide when the beam is at rest. This condition is the same as when, with the beam oscillating, the pointer swings through approximately equal, but successively diminishing, arcs on either side of the zero graduation.
2. On one pan of the balance place standard weights in an amount equal to the nominal value of the first weight to be tested.
3. Place on the other pan of the balance the weight to be tested.
4. With the fingers, steady the balance pans in such a position that the pointer and the zero on the scale are displaced by one or two divisions, so that the beam will oscillate slightly when the pans are released; then release the pans. If the zero balance condition is duplicated the loads on the two pans are equal and the weight under test is correct without any observable error.
5. Usually, however, one of the pans will drop below the other, indicating that the load on that pan is heavier than the load on the other pan. If it is the pan holding the standard weight which falls, the weight under test is lighter than standard. To learn whether or not its error exceeds the tolerance, apply weights equaling the tolerance on the weight under test[81] to the pan containing the weight under test. (The tolerance for any particular weight will be selected from the table of tolerances for weights according to the nominal value and character of the weight.) Steady and release the pans as before. If the load on the pan containing the weight under test is now the heavier, it indicates that the error on the weight is less than the tolerance; if the zero-load balance condition is duplicated, the error just equals the tolerance; in either case the weight is to be approved as accurate within

tolerance. If when the tolerance weight is applied as above the load on the pan containing the weight under test is still the lighter, the error on the weight exceeds the tolerance, and the weight should be condemned for repairs or confiscated as circumstances dictate.

6. If the weight under test is heavier than standard, the balance action and the procedure outlined in 5 above will be reversed as to pans, but otherwise will be the same; that is, the pan containing the standard weights will rise in the first instance, the tolerance weights will be applied to the pan containing the standard weights, etc.

TESTING BY SUBSTITUTION.

1. By this method, but one arm of the balance is directly used in the weight comparison, and the condition of zero-load balance is immaterial.
2. On one pan of the balance place standard weights in an amount equal to the nominal value of the weight to be tested.

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[81] In those cases in which the value of the tolerance on the weight to be tested is smaller than the value of the smallest standard weight carried, the tolerance must be translated into deflections of the indicator of the balance, as follows: Determine the SR of the balance when each pan is under a load corresponding to the value of the weight being tested, by adding to one pan a small weight sufficient to cause a change in the rest point equal to two or three divisions on the graduated scale; divide the value of the added weight by the number of divisions of change in rest point and the result will be the SR, or the weight required, under the load in question, to cause a change of rest point equal to one division. Knowing the weight represented by one division, the tolerance in terms of scale divisions is found by dividing the tolerance by the weight representing one scale division. For example, assume the weight under test to be a 2-grain weight, on which the tolerance is 0.04 grain, and assume the smallest standard weight carried to be a 0.05-grain weight. The rest point of the balance having been determined with 2 grains in each pan, add the 0.05-grain weight to one pan. Suppose that the resulting change in rest point is equivalent to 4 divisions on the graduated scale. Dividing 0.05 grain by 4 we arrive at 0.012 grain as the SR of the balance. Dividing 0.04 grain by 0.012 grain we arrive at 3.3 scale divisions as the change in rest point equivalent to the desired tolerance. To apply this tolerance observe whether or not the rest point, when the weight is being tested, differs from the original rest point by more than 3.3 scale divisions; if it does, the weight under test is not within the tolerance.

This method need be resorted to only in the case of certain very small prescription weights. Within the range of loads for which it will be used the SR of the balance will vary but little; it will, therefore, be necessary to re-determine this value only occasionally, as a check on the sensitiveness of the balance or when it is desired to make a very close determination.

In making observations such as are discussed above, it is very desirable that the inspector train himself to estimate positions of the balance pointer to tenth-divisions of the graduated scale.

3. On the other pan of the balance place any material in sufficient amount so that the pointer and the zero on the graduated scale will coincide when the beam is at rest. This condition is the same as when, with the beam oscillating, the pointer and the zero graduation are separated by approximately equal, but successively diminishing, distances on successive swings of the beam.[82]
4. Remove the standard weights from the first pan and substitute the weight to be tested.
5. Steady and release the pans. If the balance condition established in 3 above is duplicated the weight under test agrees with the standard weight, and is accurate.
6. Usually, however, the weight under test will be either lighter or heavier than the standard weight. If it is lighter, its pan will rise. In this case, apply to this pan weights equaling the appropriate tolerance,[83] then steady and release the pans. If the pan containing the weight under test now tends to fall below the position corresponding to the balance point established in 3 above, the error on the weight is less than the tolerance; if the balance condition referred to is duplicated, the error just equals the tolerance; in either case the weight is to be approved as accurate within tolerance. If after the application of the tolerance weight the pan containing the weight under test still tends to rise, the error on the weight exceeds the tolerance, and the weight should be condemned for repairs or confiscated as circumstances dictate.

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[82] It is not strictly necessary that this initial rest point be at the zero on the graduated scale of the balance; in fact, tests may be made with equal accuracy and somewhat more quickly by utilizing any rest point which can be conveniently established within several divisions of the zero. It must be remembered, however, that the rest point so established then beocmes the reference point for subsequent observations when the weight under test is substituted for the standard.

In the interests of simplicity, it is believed that the procedure outlined in the text, in which all observations are referred to the zero on the graduated scale, is to be preferred unless the inspector does enough substitution weighing to become skilled in the use of this method.

[83] See footnote 81, p. 157.

7. If the weight under test is heavier than standard, the balance action and the procedure outlined in 6 above will be reversed as to pans but otherwise will be the same; that is, the pan when containing the weight under test will fall in the first instance, the tolerance weights will be applied to the opposite pan, etc.[84]

Sealing, Condemning, Adjusting, etc.—On first test, approved weights should be neatly stamped on the top surface with a steel die leaving an impress of the letters constituting the official seal. In addition they may be stamped with the last two figures of the year. On subsequent tests, only the figures indicating the year need be added. A large and a small set of dies should be provided, so that the size of the stamped seal may be appropriate to the size of the weight. The foregoing applies to all weights except those which are so small that it is impracticable to mark them at all,—as, for instance, small knob weights and small prescription weights used by pharmacists. It is also advisable to use the sealing stamp on any lead adjusting plugs which may be present in a weight.

In the case of inaccurate weights which are susceptible of repair, and which the inspector desires to condemn for repairs, steps must be taken to safeguard against their getting back into use before repairs have been made. It is not practicable to fasten a condemned-for-repairs tag to a weight; however, tough envelopes, marked in a manner similar to the tags, and designed to be closed by a gummed flap or by fastening with a lead-and-wire seal, may be used to segregate inaccurate weights pending their repair. In the absence of some such arrangement or the very definite assurance that the inaccurate weights will be repaired at once, it is preferable that they be destroyed or confiscated.

Destruction or confiscation should always be resorted to in the case of improper or inaccurate weights not susceptible of proper repair.

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[84] Ordinarily the arm-length error of the balance may be entirely neglected when the tolerance weight is used on the pan opposite to that containing the weight under test; however, for very precise work, if the arm-length error is large, due allowance must be made for its effect in increasing or decreasing the effective value of the tolerance weight.

Weights with removable screw knobs are readily adjusted by adding or removing adjusting material to or from the adjusting cavity beneath the knob. Counterpoise weights which are too heavy may be corrected by drilling on the under side; a large drill is best for this purpose, so that the hole may be shallow with sloping sides. Several such holes are preferable to one deep hole in which foreign material may inadvertently be collected and retained. Counterpoise weights which are too light may, if the error is not too great, be corrected by drilling one or more straight-walled holes and filling them with lead tightly driven in. The gain in weight results from the difference between the densities of the material removed and of the lead which replaces it. Care should be taken that such holes do not extend through the top surface of the weight, and the holes should be so positioned as not to weaken the weight unduly. Adjusting material should not project beyond the edge of the hole.

Weights which are being adjusted should be brought as close as practicable to their correct value, and not merely within tolerance.

Appendix I.—SCHEDULE OF WEIGHTS AND EQUIPMENT FOR FIELD USE

NOTE.—Except as otherwise specified, all weights should conform to the requirements of National Bureau of Standards class C.

VEHICLE-SCALE TESTING EQIUPMENT

For the adequate testing of vehicle scales, a specially-designed equipment is a practical necessity. For this purpose the following is recommended:

1. A short wheelbase motor truck equipped with mechanical means, preferably power-operated, for loading and unloading the test weights listed in (2) below. If practicable, the gross weight of the unloaded vehicle should not exceed the value of the test-weight load, in order that when the unloaded vehicle is used as a strain load, there may not remain any portion of the weighing range of the scale up to the weight of the loaded vehicle, which will be untested with test weights.

2. A test-weight load of 10,000 to 20,000 pounds, in 500-pound or 1,000-pound units, but including at least two 500-pound weights. (It may be advisable to include from 1,000 to 2,000 pounds of 50-pound weights in addition to the weights of large denomination, for use in the testing of certain of the smaller types of large-capacity scales, and for use in situations where it is impracticable to utilize the large-denomination test weights.)

3. A two-wheeled, hand-operated "cart" for moving test weights after these have been unloaded from the carrying vehicle.

4. Set of "error weights" consisting of: Grip-handled weights, 20, 20, 20, 10, 10, 5, 5 pounds; cylindrical grooved weights, 2, 2, 2, 2, 1, 1 pounds.

5. Set of counterpoise weights consisting of: Slotted weights, 5, 2, 2, 1, 0.5, 0.2, 0.2, 0.1 pounds; cylindrical weights, 0.05, 0.02, 0.02, 0.01 pound; cupped aluminum-alloy weights, 0.005, 0.002, 0.002, 0.001, 0.0005, 0.0002, 0.0002, 0.0001 pound.

6. Duplicates of the 10-pound equal-arm balance and set of grain weights, as listed below for "General Testing."

Miscellaneous equipment, including a small hydraulic jack, level, pry and crow bars, flash lamp, small tools, and sealing and record equipment.

NOTES.—The foregoing list includes certain items which are duplicated in the list which follows, recommended for the general testing of scales other than vehicle scales. This duplication is necessary when general testing and the testing of vehicle scales are to be carried on simultaneously, and in any event, it is advisable that the vehicle-scale testing equipment be complete in itself.

For information relative to the vehicle-scale testing equipments of the National Bureau of Standards and of a number of the State and local weights and measures jurisdictions, consult the references given on pages 102-103 of this Handbook.

WEIGHTS AND EQUIPMENT FOR GENERAL TESTING

Avoirdupois Weights.—Forty (or more) 50-pound cast-iron test weights.

Set of grip-handled weights, 20, 20, 10, 5 pounds or 25, 10, 10, 5 pounds.

Set of weights, 2, 2, 1 pounds, 8, 4, 2, 1, ½, ¼, ⅛, $\frac{1}{16}$, $\frac{1}{16}$ ounces.

One 1-pound flat cylindrical slotted weight, diameter about 4 inches.

Set of weights, 20, 10, 5, 2, 2, 1, ½ grains.

Troy Weights.—Set of weights, 10, 5, 2, 2, 1 ounces, 10, 5, 2, 2, 1 pennyweights. National Bureau of Standards class B, or class C adjusted to class B tolerances.

Apothecaries Weights.—Set of weights, 1, 1 ounce, 4, 2, 2, 1, ½ drams, 2, 1 scruples, 10, 5, 2, 2, 1, 0.5, 0.2, 0.2, 0.1, 0.05 grains.[1] National Bureau of Standards class B, or class C adjusted to class B tolerances.

Metric Weights.—If a large number of weighing scales of relatively large capacity graduated in the metric system are to be tested, it may be found advisable to procure a supply of 20-kilogram cast-iron test weights, the necessary number of such weights depending upon the capacities of the scales in question. In this event a set of weights, 10, 5, 2, 2, 1 kilograms, and another set, 500, 200, 200, 100, 50, 20, 20, 10, 5, 2, 2, 1 grams, 500, 200, 200, 100, 50, 20, 20, 10 milligrams may also be supplied. However, ordinarily such large metric scales as may be encountered can be tested by utilizing weights in the customary system, making the necessary conversions to determine the proper metric indications.

If only the metric weights in pharmacies are to be tested, two sets of weights will be required, the first to consist of 1 kilogram, 500, 200, 200, 100, 50, 20, 20, 10, 5, 2, 2, 1 grams, for use in testing counter-scale weights (these may occasionally be encountered), and the second to consist of 20, 10, 5, 2, 2, 1 grams, 500, 200, 200, 100, 50, 20, 20, 10, 5, 2, 2, 1 milligrams, National Bureau of Standards class B, or class C adjusted to class B tolerances, for use in testing prescription scales and weights.

Balances.—One portable 10-pound equal-arm balance with suspended pans, having an SR of 1 grain.

One portable 1-ounce equal-arm balance with suspended pans, having an SR of 1 milligram.

(The purchase of the 1-ounce balance may be postponed until testing in pharmacies or jewelry stores is to be undertaken.)

Miscellaneous.—Seals, seal press, record forms, flash lamp, level, and tools such as screw drivers, pliers, wrenches, hammer, etc., are required.

Substantial carrying cases are necessary for the transportation of standards and equipment.

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[1] The two 1-ounce weights are duplicated to facilitate the test of equal-arm prescription scales having the usual capacity of 1 ounce, or 30 grams.

Appendix II.—GENERAL TABLES OF WEIGHTS AND MEASURES[2]

Part 1. TABLES OF UNITED STATES CUSTOMARY WEIGHTS AND MEASURES

LINEAR MEASURE

12 inches (in.)	=1 foot (ft)
3 feet	=1 yard (yd)=36 inches
5½ yards	=1 rod (rd), pole, or perch=16½ feet
40 rods	=1 furlong (fur.)=220 yards=660 feet
8 furlongs	=1 statute mile (mi)=1 760 yards=5 280 feet
3 miles	=1 league=5 280 yards=15 840 feet

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6 080.20 feet	=1 nautical, geographical, or sea mile

AREA MEASURE[3]

144 square inches (sq in.)	=1 square foot (sq ft)
9 square feet	=1 square yard (sq yd)=1 296 square inches
30¼ square yards	=1 square rod (sq rd)=272¼ square feet
160 square rods	=1 acre=4 840 square yards=43 560 square feet
640 acres	=1 square mile (sq mi)
1 mile square	=1 section [of land]
6 miles square	=1 township=36 sections=36 square miles

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2 Other and more detailed information on standards and units of weights and measures will be found in the following publications of the National Bureau of Standards:

Miscellaneous Publication M64, "History of the Standard Weights and Measures of the United States." (Available through purchase from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 15 cents a copy.)

Miscellaneous Publication M121, "Units of Weight and Measure—Definitions and Tables of Equivalents." (Available through purchase from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 15 cents a copy.)

Miscellaneous Publication M122, "Weights and Measures in Congress." Not available by purchase, but may be consulted in libraries maintaining sets of Bureau publications.

Letter Circular LC449, "Standards of Length, Mass, and Time." (Available from the National Bureau of Standards, Washington 25, D. C., free upon request.)

Letter Circular LC517, "Motorists' Manual of Weights and Measures." (Available from the National Bureau of Standards, Washington 25, D. C., upon request.)

Letter Circular LC681, "Units and Systems of Weights and Measures." (Available from the National Bureau of Standards, Washington 25, D. C., upon request.)

3 Squares and cubes of units are sometimes abbreviated by using "superior" figures. For example, ft^2 means square foot, and ft^3 means cubic foot.

CUBIC MEASURE[4]

1 728 cubic inches (cu in.)	=1 cubic foot (cu ft)
27 cubic feet	=1 cubic yard (cu yd)

GUNTER'S OR SURVEYORS CHAIN MEASURE

7.92 inches (in.)	=1 link (li)
100 links	=1 chain (ch)=4 rods=66 feet
80 chains	=1 statute mile (mi)=320 rods=5 280 feet

LIQUID MEASURE[5]

4 gills (gi)	=1 pint (pt) [=28.875 cubic inches]
2 pints	=1 quart (qt) [=57.75 cubic inches]
4 quarts	=1 gallon (gal) [=231 cubic inches] =8 pints=32 gills

APOTHECARIES FLUID MEASURE

60 minims (min or ♏)	=1 fluid dram (fl dr or f ʒ) [=0.225 6 cubic inch]
8 fluid drams	=1 fluid ounce (fl oz or f ℥) [=1.804 7 cubic inches]
16 fluid ounces	=1 pint (pt or O) [=28.875 cubic inches] =128 fluid drams
2 pints	=1 quart (qt) [=57.75 cubic inches]=32 fluid ounces=256 fluid drams
4 quarts	=1 gallon (gal) [=231 cubic inches]=128 fluid ounces=1 024 fluid drams

DRY MEASURE[6]

2 pints (pt)	=1 quart (qt) [=67.200 6 cubic inches]
8 quarts	=1 peck (pk) [=537.605 cubic inches]=16 pints
4 pecks	=1 bushel (bu) [=2 150.42 cubic inches]=32 quarts

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[4] See footnote 3.

[5] When necessary to distinguish the *liquid* pint or quart from the *dry* pint or quart, the word "liquid" or the abbreviation "liq" should be used in combination with the name or abbreviation of the *liquid* unit.

[6] When necessary to distinguish the *dry* pint or quart from the *liquid* pint or quart, the word "dry" should be used in combination with the name or abbreviation of the *dry* unit.

AVOIRDUPOIS WEIGHT[7]

[The "grain" is the same in avoirdupois, troy, and apothecaries weight.]

$27\frac{11}{32}$ grains	=1 dram (dr)
16 drams	=1 ounce (oz)=437½ grains
16 ounces	=1 pound (lb)=256 drams=7 000 grains
100 pounds	=1 hundredweight (cwt)[8]
20 hundredweights	=1 ton (tn)=2 000 pounds[9]

In "gross" or "long" measure, the following values are recognized:

112 pounds	=1 gross or long hundredweight[10]
20 gross or long hundredweights	=1 gross or long ton=2 240 pounds[11]

TROY WEIGHT

[The "grain" is the same in avoirdupois, troy, and apothecaries weight.]

24 grains	=1 pennyweight (dwt)
20 pennyweights	=1 ounce troy (oz t)=480 grains
12 ounces, troy	=1 pound troy (lb t)=240 pennyweights=5 760 grains

APOTHECARIES WEIGHT

[The "grain" is the same in avoirdupois, troy, and apothecaries weight.]

20 grains	=1 scruple (s ap or ℈)
3 scruples	=1 dram apothecaries (dr ap or ʒ)=60 grains
8 drams, apothecaries	=1 ounce apothecaries (oz ap or ℥)=24 scruples=480 grains
12 ounces, apothecaries	=1 pound apothecaries (lb ap or ℔)=96 drams apothecaries=288 scruples=5 760 grains

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[7] When necessary to distinguish the *avoirdupois* dram from the *apothecaries* dram, or to distinguish the *avoirdupois* dram or ounce from the *fluid* dram or ounce, or to distinguish the *avoirdupois* ounce or pound from the *troy* or *apothecaries* ounce or pound, the word "avoirdupois" or the abbreviation "avdp" should be used in combination with the name or abbreviation of the *avoirdupois* unit.

[8] When the terms "hundredweight" and "ton" are used unmodified, they are commonly understood to mean the 100-pound hundredweight and the 2 000-pound ton, respectively; these units may be designated "net" or "short" when necessary to distinguish them from the corresponding units in *gross* or *long* measure.

[9] See footnote 8.

[10] See footnote 8.

[11] See footnote 8.

NOTES ON BRITISH WEIGHTS AND MEASURES TABLES

In Great Britain, the yard, the avoirdupois pound, the troy pound, and the apothecaries pound, are, for all commercial purposes, identical with the units of the same names used in the United States. The tables of British linear measure, troy weight, and apothecaries weight are the same as the corresponding United States tables, except for the British spelling "drachm" in the table of apothecaries weight. The table of British avoirdupois weight is the same as the United States table up to 1 pound; above that point the table reads:

14 pounds	=	1 stone
2 stones	=	1 quarter = 28 pounds
4 quarters	=	1 hundredweight = 112 pounds
20 hundredweight	=	1 ton = 2 240 pounds

The present British gallon and bushel, known as the "Imperial gallon" and "Imperial bushel" are, respectively, about 20 percent and 3 percent larger than the United States gallon and bushel. The Imperial gallon is defined as the volume of 10 avoirdupois pounds of water under specified conditions, and the Imperial bushel is defined as 8 Imperial gallons. Also, the subdivision of the Imperial gallon as presented in the table of British apothecaries measure differs in two important respects from the corresponding United States subdivision, in that the Imperial gallon is divided into 160 fluid ounces (whereas the United States gallon is divided into 128 fluid ounces), and a "fluid scruple" is included. The full table of British measures of capacity (which are used alike for liquid and for dry commodities) is as follows:

4 gills	=	1 pint
2 pints	=	1 quart
4 quarts	=	1 gallon
2 gallons	=	1 peck
8 gallons [4 pecks]	=	1 bushel
8 bushels	=	1 quarter

The full table of British apothecaries measure is as follows:

20 minims	=	1 fluid scruple
3 fluid scruples	=	1 fluid drachm = 60 minims
8 fluid drachms	=	1 fluid ounce
20 fluid ounces	=	1 pint
8 pints	=	1 gallon = 160 fluid ounces.

Part 2. TABLES OF METRIC WEIGHTS AND MEASURES

LINEAR MEASURE

10 millimeters (mm)	=1 centimeter (cm)
10 centimeters	=1 decimeter (dm)=100 millimeters
10 decimeters	=1 meter (m)=1 000 millimeters
10 meters	=1 dekameter (dkm)
10 dekameters	=1 hectometer (hm)=100 meters
10 hectometers	=1 kilometer (km)=1 000 meters

AREA MEASURE

100 square millimeters (mm^2)	=1 square centimeter (cm^2)
10 000 square centimeters	=1 square meter (m^2)=1 000 000 square millimeters
100 square meters	=1 are (a)
100 ares	=1 hectare (ha)=10 000 square meters
100 hectares	=1 square kilometer (km^2)= 1 000 000 square meters

VOLUME MEASURE

10 milliliters (ml)	=1 centiliter (cl)
10 centiliters	=1 deciliter (dl)=100 milliliters
10 deciliters	=1 liter[12] (l)=1 000 milliliters
10 liters	=1 dekaliter (dkl)
10 dekaliters	=1 hectoliter (hl)=100 liters
10 hectoliters	=1 kiloliter (kl)=1 000 liters

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[12] The liter is defined as the volume occupied, under standard conditions, by a quantity of pure water having a mass of 1 kilogram. This volume is very nearly equal to 1 000 cubic centimeters or 1 cubic decimeter; the actual metric equivalent is, 1 liter = 1 000.028 cubic centimeters. (The change in this equivalent from the previously published value of 1 000.027 is based on a recomputation of earlier data, carried out at the International Bureau of Weights and Measures.) Thus the milliliter and the liter are larger than the cubic centimeter and the cubic decimeter, respectively, by 28 parts in 1 000 000; except for determinations of high precision, this difference is so small as to be of no consequence.

CUBIC MEASURE

1 000 cubic millimeters (mm^3)	=1 cubic centimeter (cm^3)
1 000 cubic centimeters	=1 cubic decimeter (dm^3)= 1 000 000 cubic millimeters
1 000 cubic decimeters	=1 cubic meter (m^3)=1 stere= 1 000 000 cubic centimeters =1 000 000 000 cubic millimeters

WEIGHT

10 milligrams (mg)	=1 centigram (cg)
10 centigrams	=1 decigram (dg)=100 milligrams
10 decigrams	=1 gram (g)=1 000 milligrams
10 grams	=1 dekagram (dkg)
10 dekagrams	=1 hectogram (hg)=100 grams
10 hectograms	=1 kilogram (kg)=1 000 grams
1 000 kilograms	=1 metric ton (t)

NOTE.—In the metric system of weights and measures, designations of multiples and subdivisions of any unit may be arrived at by combining with the name of the unit the prefixes *deka, hecto,* and *kilo,* meaning, respectively, 10, 100, and 1 000, and *deci, centi,* and *milli,* meaning, respectively, one-tenth, one-hundredth, and one-thousandth. In some of the foregoing metric tables, some such multiples and subdivisions have not been included for the reason that these have little, if any, currency in actual usage.

In certain cases, particularly in scientific usage, it becomes convenient to provide for multiples larger than 1 000 and for subdivisions smaller than one-thousandth. Accordingly, the following prefixes have been introduced and these are now generally recognized.

myria, meaning 10 000
mega, meaning 1 000 000
micro, meaning one-millionth.

A special case is found in the term "micron" (abbreviated as μ [the Greek letter mu]), a coined word meaning one-millionth of a meter (equivalent to one-thousandth of a millimeter); a millimicron (abbreviated as $m\mu$) is one-thousandth of a micron (equivalent to one-millionth of a millimeter), and a micromicron (abbreviated as $\mu\mu$) is one-millionth of a micron (equivalent to one-thousandth of a millimicron or to 0.000 000 001 millimeter.)

Part 3. TABLES OF INTERRELATION OF UNITS OF MEASUREMENT

[Exact equivalents are indicated by bold face type]

UNITS OF LENGTH

Units	Inches	Links[a]	Feet	Yards	Rods
1 inch =	**1**	0.126 263	0.083 333 3	0.027 777 8	0.005 050 51
1 link =	**7.92**	**1**	**0.66**	**0.22**	**0.04**
1 foot =	**12**	1.515 152	**1**	0.333 333	0.060 606 1
1 yard =	**36**	4.545 45	**3**	**1**	0.181 818
1 rod =	**198**	**25**	**16.5**	**5.5**	**1**
1 chain =	**792**	**100**	66	**22**	**4**
1 mile =	**63 360**	8000	5280	**1760**	**320**
1 centimeter =	**0.3937**	0.049 709 60	0.032 808 33	0.010 936 111	0.001 988 384
1 meter =	**39.37**	4.970 960	3.280 833	1.093 611 1	0.198 838 4

Units	Chains[a]	Miles	Centimeters	Meters
1 inch =	0.001 262 63	0.000 015 782 8	2.540 005	0.025 400 05
1 link =	**0.01**	**0.000 125**	20.116 84	0.201 168 4
1 foot =	0.015 151 5	0.000 189 393 9	30.480 06	0.304 800 6
1 yard =	0.045 454 5	0.000 568 182	91.440 18	0.914 401 8
1 rod =	**0.25**	**0.003 125**	502.9210	5.029 210
1 chain =	**1**	**0.0125**	2011.684	20.116 84
1 mile =	**80**	**1**	160 934.72	1609.3472
1 centimeter =	0.000 497 096 0	0.000 006 213 699	**1**	**0.01**
1 meter =	0.049 709 60	0.000 621 369 9	**100**	**1**

[a] Gunter's or Surveyors.

UNITS OF AREA

Units		Square inches	Square links[a]	Square feet
1 square inch	=	1	0.015 942 3	0.006 944 44
1 square link	=	62.7264	1	0.4356
1 square foot	=	144	2.295 684	1
1 square yard	=	1296	20.6612	9
1 square rod	=	39 204	625	272.25
1 square chain	=	627 264	10 000	4356
1 acre	=	6 272 640	100 000	43 560
1 square mile	=	4 014 489 600	64 000 000	27 878 400
1 square centimeter	=	0.154 999 69	0.002 471 04	0.001 076 387
1 square meter	=	1549.9969	24.7104	10.763 87
1 hectare	=	15 499 969	247 104	107 638.7

Units		Square yards	Square rods	Square chains[a]
1 square inch	=	0.000 771 605	0.000 025 507 6	0.000 001 594 23
1 square link	=	0.0484	0.0016	0.0001
1 square foot	=	0.111 111 1	0.003 673 09	0.000 229 568
1 square yard	=	1	0.033 057 85	0.002 066 12
1 square rod	=	30.25	1	0.0625
1 square chain	=	484	16	1
1 acre	=	4840	160	10
1 square mile	=	3 097 600	102 400	6400
1 square centimeter	=	0.000 119 598 5	0.000 003 953 67	0.000 000 247 104
1 square meter	=	1.195 985	0.039 536 7	0.002 471 04
1 hectare	=	11 959.85	395.367	24.7104

Units		Acres	Square miles
1 square inch	=	0.000 000 159 423	0.000 000 000 249 1
1 square link	=	0.000 01	0.000 000 015 625
1 square foot	=	0.000 022 956 8	0.000 000 035 870 1
1 square yard	=	0.000 206 612	0.000 000 322 831
1 square rod	=	0.006 25	0.000 009 765 625
1 square chain	=	0.1	0.000 156 25
1 acre	=	1	0.001 562 5
1 square mile	=	640	1
1 square centimeter	=	0.000 000 024 710 4	0.000 000 000 038 610 06
1 square meter	=	0.000 247 104	0.000 000 386 100 6
1 hectare	=	2.471 04	0.003 861 006

UNITS OF AREA—Con.

Units		Square centimeters	Square meters	Hectares
1 square inch	=	6.451 626	0.000 645 162 6	0.000 000 064 516
1 square link	=	404.6873	0.040 468 73	0.000 004 046 87
1 square foot	=	929.0341	0.092 903 41	0.000 009 290 34
1 square yard	=	8361.307	0.836 130 7	0.000 083 613 1
1 square rod	=	252 929.5	25.292 95	0.002 529 295
1 square chain	=	4 046 873	404.6873	0.040 468 7
1 acre	=	40 468 726	4046.873	0.404 687
1 square mile	=	25 899 984 703	2 589 998	258.9998
1 square centimeter	=	1	0.0001	0.000 000 01
1 square meter	=	10 000	1	0.0001
1 hectare	=	100 000 000	10 000	1

[a] Gunter's or Surveyors.

UNITS OF VOLUME

Units		Cubic inches	Cubic feet	Cubic yards
1 cubic inch	=	1	0.000 578 704	0.000 021 433 47
1 cubic foot	=	1728	1	0.037 037 0
1 cubic yard	=	46 656	27	1
1 cubic centimeter	=	0.061 023 38	0.000 035 314 45	0.000 001 307 94
1 cubic decimeter	=	61.023 38	0.035 314 45	0.001 307 943
1 cubic meter	=	61 023.38	35.314 45	1.307 942 8

Units		Cubic centimeters	Cubic decimeters	Cubic meters
1 cubic inch	=	16.387 162	0.016 387 16	0.000 016 387 16
1 cubic foot	=	28 317.016	28.317 016	0.028 317 016
1 cubic yard	=	764 559.4	764.5594	0.764 559 4
1 cubic centimeter	=	1	0.001	0.000 001
1 cubic decimeter	=	1 000	1	0.001
1 cubic meter	=	1 000 000	1000	1

UNITS OF CAPACITY—LIQUID MEASURE

Units	Minims	Fluid drams	Fluid ounces	Gills
1 minim =	1	0.016 666 7	0.002 083 33	0.000 520 833
1 fluid dram =	60	1	0.125	0.031 25
1 fluid ounce =	480	8	1	0.25
1 gill =	1920	32	4	1
1 liquid pint =	7680	128	16	4
1 liquid quart =	15 360	256	32	8
1 gallon =	61 440	1024	128	32
1 milliliter =	16.2311	0.270 518	0.033 814 8	0.008 453 69
1 liter =	16 231.1	270.518	33.814 8	8.453 69
1 cubic inch =	265.974	4.432 90	0.554 113	0.138 528
1 cubic foot =	459 603	7660.05	957.506	239.377

Units	Liquid pints	Liquid quarts	Gallons	Milliliters
1 minim =	0.000 130 208	0.000 065 104	0.000 016 276	0.061 610 2
1 fluid dram =	0.007 812 5	0.003 906 25	0.000 976 562	3.696 61
1 fluid ounce =	0.0625	0.031 25	0.007 812 5	29.5729
1 gill =	0.25	0.125	0.031 25	118.292
1 liquid pint =	1	0.5	0.125	473.166
1 liquid quart =	2	1	0.25	946.332
1 gallon =	8	4	1	3785.329
1 milliliter =	0.002 113 42	0.001 056 71	0.000 264 178	1
1 liter =	2.113 42	1.056 71	0.264 178	1000
1 cubic inch =	0.034 632 0	0.017 316 0	0.004 329 00	16.3867
1 cubic foot =	59.8442	29.9221	7.480 52	28 316.22

Units	Liters	Cubic inches	Cubic feet
1 minim =	0.000 061 610 2	0.003 759 77	0.000 002 175 79
1 fluid dram =	0.003 696 61	0.225 586	0.000 130 547
1 fluid ounce =	0.029 572 9	1.804 69	0.001 044 38
1 gill =	0.118 292	7.218 75	0.004 177 52
1 liquid pint =	0.473 166	28.875	0.016 710 1
1 liquid quart =	0.946 332	57.75	0.033 420 1
1 gallon =	3.785 329	231	0.133 681
1 milliliter =	0.001	0.061 025 1	0.000 035 315 4
1 liter =	1	61.025 1	0.035 315 4
1 cubic inch =	0.016 386 7	1	0.000 578 704
1 cubic foot =	28.316 22	1728	1

UNITS OF CAPACITY—DRY MEASURE

Units	Dry pints	Dry quarts	Pecks	Bushels
1 dry pint =	1	0.5	0.0625	0.015 625
1 dry quart =	2	1	0.125	0.031 25
1 peck =	16	8	1	0.25
1 bushel =	64	32	4	1
1 liter =	1.816 21	0.908 103	0.113 513	0.028 378
1 dekaliter =	18.1621	9.081 03	1.135 13	0.283 78
1 cubic inch =	0.029 761 6	0.014 880 8	0.001 860 10	0.000 465 025
1 cubic foot =	51.4281	25.7140	3.214 26	0.803 564

Units	Liters	Dekaliters	Cubic inches	Cubic feet
1 dry pint =	0.550 598	0.055 059 8	33.600 312 5	0.019 444 6
1 dry quart =	1.101 197	0.110 119 7	67.200 625	0.038 889 3
1 peck =	8.809 57	0.880 957	537.605	0.311 114
1 bushel =	35.2383	3.523 83	2150.42	1.244 456
1 liter =	1	0.1	61.0251	0.035 315 4
1 dekaliter =	10	1	610.251	0.353 154
1 cubic inch =	0.016 386 7	0.001 638 67	1	0.000 578 704
1 cubic foot =	28.316 2	2.831 62	1728	1

UNITS OF MASS NOT GREATER THAN POUNDS AND KILOGRAMS

Units	Grains	Apothecaries scruples	Pennyweights
1 grain =	1	0.05	0.041 666 67
1 apothecaries scruple =	20	1	0.833 333 3
1 pennyweight =	24	1.2	1
1 avoirdupois dram =	27.343 75	1.367 187 5	1.139 323
1 apothecaries dram =	60	3	2.5
1 avoirdupois ounce =	437.5	21.875	18.229 17
1 apothecaries or troy ounce =	480	24	20
1 apothecaries or troy pound =	5760	288	240
1 avoirdupois pound =	7000	350	291.6667
1 milligram =	0.015 432 356	0.000 771 618	0.000 643 014 8
1 gram =	15.432 356	0.771 618	0.643 014 85
1 kilogram =	15 432.356	771.6178	643.014 85

UNITS OF MASS NOT GREATER THAN POUNDS AND KILOGRAMS—Con.

Units		Avoirdupois drams	Apothecaries drams	Avoirdupois ounces
1 grain	=	0.036 571 43	0.016 666 7	0.002 285 71
1 apothecaries scruple	=	0.731 428 6	0.333 333	0.045 714 3
1 pennyweight	=	0.877 714 3	0.4	0.054 857 1
1 avoirdupois dram	=	1	0.455 729 2	0.0625
1 apothecaries dram	=	2.194 286	1	0.137 142 9
1 avoirdupois ounce	=	16	7.291 67	1
1 apothecaries or troy ounce	=	17.554 28	8	1.097 142 9
1 apothecaries or troy pound	=	210.6514	96	13.165 714
1 avoirdupois pound	=	256	116.6667	16
1 milligram	=	0.000 564 383 3	0.000 257 205 9	0.000 035 273 96
1 gram	=	0.564 383 3	0.257 205 9	0.035 273 96
1 kilogram	=	564.383 32	257.205 94	35.273 96

Units		Apothecaries or troy ounces	Apothecaries or troy pounds	Avoirdupois pounds
1 grain	=	0.002 083 33	0.000 173 611 1	0.000 142 857 1
1 apothecaries scruple	=	0.041 666 7	0.003 472 222	0.002 857 143
1 pennyweight	=	0.05	0.004 166 667	0.003 428 571
1 avoirdupois dram	=	0.056 966 146	0.004 747 178 8	0.003 906 25
1 apothecaries dram	=	0.125	0.010 416 667	0.008 571 429
1 avoirdupois ounce	=	0.911 458 3	0.075 954 861	0.0625
1 apothecaries or troy ounce	=	1	0.083 333 33	0.068 571 43
1 apothecaries or troy pound	=	12	1	0.822 857 1
1 avoirdupois pound	=	14.583 333	1.215 277 8	1
1 milligram	=	0.000 032 150 74	0.000 002 679 23	0.000 002 204 62
1 gram	=	0.032 150 74	0.002 679 23	0.002 204 62
1 kilogram	=	32.150 742	2.679 228 5	2.204 622 341

Units		Milligrams	Grams	Kilograms
1 grain	=	64.798 918	0.064 798 918	0.000 064 798 9
1 apothecaries scruple	=	1295.9784	1.295 978 4	0.001 295 978
1 pennyweight	=	1555.1740	1.555 174 0	0.001 555 174
1 avoirdupois dram	=	1771.8454	1.771 845 4	0.001 771 845
1 apothecaries dram	=	3887.9351	3.887 935 1	0.003 887 935
1 avoirdupois ounce	=	28 349.527	28.349 527	0.028 349 53
1 apothecaries or troy ounce	=	31 103.481	31.103 481	0.031 103 48
1 apothecaries or troy pound	=	373 241.77	373.241 77	0.373 241 77
1 avoirdupois pound	=	453 592.4277	453.592 427 7	0.453 592 427 7
1 milligram	=	1	0.001	0.000 001
1 gram	=	1000	1	0.001
1 kilogram	=	1 000 000	1000	1

UNITS OF MASS NOT LESS THAN AVOIRDUPOIS OUNCES

Units	Avoirdupois ounces	Avoirdupois pounds	Short hundredweights	Short tons
1 avoirdupois ounce =	1	0.0625	0.000 625	0.000 031 25
1 avoirdupois pound =	16	1	0.01	0.0005
1 short hundredweight =	1600	100	1	0.05
1 short ton =	32 000	2000	20	1
1 long ton =	35 840	2240	22.4	1.12
1 kilogram =	35.273 957	2.204 622 34	0.022 046 223	0.001 102 311 2
1 metric ton =	35 273.957	2204.622 34	22.046 223	1.102 311 2

Units	Long tons	Kilograms	Metric tons
1 avoirdupois ounce =	0.000 027 901 79	0.028 349 53	0.000 028 349 53
1 avoirdupois pound =	0.000 446 428 6	0.453 592 427 7	0.000 453 592 43
1 short hundredweight =	0.044 642 86	45.359 243	0.045 359 243
1 short ton =	0.892 857 1	907.184 86	0.907 184 86
1 long ton =	1	1016.047 04	1.016 047 04
1 kilogram =	0.000 984 206 4	1	0.001
1 metric ton =	0.984 206 40	1000	1

Part 4. TABLES OF EQUIVALENTS

NOTES.—When the name of a unit is enclosed in brackets (thus, [1 hand]......), this indicates (1) that the unit is not in general current use in the United States, or (2) that the unit is believed to be based on "custom and usage" rather than on formal authoritative definition.

Equivalents involving decimals are, in most instances, rounded off to the third decimal place except where they are exact, in which cases these exact equivalents are so designated.

LENGTHS

1 angstrom (A) .... 0.1 millimicron (exactly); 0.000 1 micron (exactly); 0.000 000 1 millimeter (exactly); 0.000 000 004 inch

1 cable's length .... 120 fathoms; 720 feet; 219.456 meters

1 centimeter (cm) .... 0.393 7 inch (exactly)

1 chain (ch) (Gunter's or surveyors)	66 feet 20.117 meters
[1 chain (engineers)]	100 feet 30.480 meters
1 decimeter (dm)	3.937 inches (exactly)
1 dekameter (dkm)	32.808 feet
1 fathom	6 feet 1.829 meters
1 foot (ft)	0.305 meter
1 furlong (fur.)	10 chains (surveyors) 660 feet 220 yards ⅛ statute mile 201.168 meters
[1 hand]	4 inches
1 inch (in.)	2.540 centimeters
1 kilometer (km)	0.621 mile
1 league (land)	3 statute miles 4.828 kilometers
1 link (li) (Gunter's or surveyors)	7.92 inches (exactly) 0.201 meter
[1 link (li) (engineers)]	1 foot 0.305 meter
1 meter (m)	39.37 inches (exactly) 1.094 yards
1 micron (μ [the Greek letter mu])	0.001 millimeter (exactly) 0.000 039 37 inch (exactly)
1 mil	0.001 inch (exactly) 0.025 4 millimeter
1 mile (mi) (statute or land)	5 280 feet 1.609 kilometers

1 mile (mi) (nautical, geographical, or sea, U. S.)	1.152 statute miles 6 080.20 feet 1.853 kilometers
[1 mile (mi) (nautical, international)]	1.852 kilometers (exactly) 6 076.10 feet 1.151 statute miles 0.999 U. S. nautical miles
1 millimeter (mm)	0.039 37 inch (exactly)
1 millimicron (mμ [the English letter m in conjuncton with the Greek letter mu])	0.001 micron (exactly) 0.000 000 039 37 inch (exactly)
1 point (typography)	0.013 837 inch (exactly)[13] 0.351 millimeter
1 rod (rd), pole, or perch	16½ feet 5½ yards 5.029 meters
1 yard (yd)	0.914 meter

AREAS OR SURFACES

1 acre	43 560 square feet 4 840 square yards 0.405 hectare
1 are (a)	119.596 square yards 0.025 acre
1 hectare (ha)	2.471 acres
[1 square (building)]	100 square feet
1 square centimeter (cm^2)	0.155 square inch
1 square decimeter (dm^2)	15.500 square inches
1 square foot (sq ft)	929.034 square centimeters
1 square inch (sq in.)	6.452 square centimeters

[13] This value is nearly $^1/_{72}$ inch.

1 square kilometer (km^2)	247.104 acres 0.386 square mile
1 square meter (m^2)	1.196 square yards 10.764 square feet
1 square mile (sq mi)	259.000 hectares
1 square millimeter (mm^2)	0.002 square inch
1 square rod (sq rd), sq pole, or sq perch	25.293 square meters
1 square yard (sq yd)	0.836 square meter

CAPACITIES OR VOLUMES

1 barrel (bbl), liquid	31 to 42 gallons[14]
1 barrel (bbl), standard, for fruits, vegetables, and other dry commodities except cranberries	7 056 cubic inches 105 dry quarts 3.281 bushels, struck measure
1 barrel (bbl), standard, cranberry	5 826 cubic inches 86 45/64 dry quarts 2.709 bushels, struck measure
1 bushel (bu) (U. S.) (struck measure)	2 150.42 cubic inches (exactly) 1.244 cubic feet 0.969 British bushel 35.238 liters
[1 bushel, heaped (U. S.)]	2 747.715 cubic inches 1.278 bushels, struck measure[15]
[1 bushel (bu) (British Imperial) (struck measure)]	1.032 U. S. bushels, struck measure 2 219.360 cubic inches

[14] There are a variety of "barrels," established by law or usage. For example, Federal taxes on fermented liquors are based on a barrel of 31 gallons; many State laws fix the "barrel for liquids" as 31½ gallons; one State fixes a 36-gallon barrel for cistern measurement; Federal law recognizes a 40-gallon barrel for "proof spirits"; by custom, 42 gallons comprise a barrel of crude oil or petroleum products for statistical purposes, and this equivalent is recognized "for liquids" by four States.

[15] Frequently recognized as 1¼ bushels, struck measure.

1 cord (cd) (firewood)	128 cubic feet
1 cubic centimeter (cm^3)	0.061 cubic inch
1 cubic decimeter (dm^3)	61.023 cubic inches
1 cubic foot (cu ft)	7.481 gallons 0.804 bushel 28.317 cubic decimeters
1 cubic inch (cu in.)	0.554 fluid ounce 4.433 fluid drams 16.387 cubic centimeters
1 cubic meter (m^3)	1.308 cubic yards
1 cubic yard (cu yd)	0.765 cubic meter
1 cup, measuring	8 fluid ounces ½ liquid pint
1 dram, fluid (or liquid) (fl dr or f ʒ) (U. S.)	⅛ fluid ounce 0.226 cubic inch 3.697 milliliters
[1 dram, fluid (fl dr) (British)]	0.961 U. S. fluid dram 0.217 cubic inch 3.552 milliliters
1 dekaliter (dkl)	2.642 gallons 1.135 pecks
1 gallon (gal) (U. S.)	231 cubic inches 0.134 cubic foot 3.785 liters 0.833 British gallon 128 U. S. fluid ounces
[1 gallon (gal) (British Imperial)]	277.42 cubic inches 1.201 U. S. gallons 4.546 liters 160 British fluid ounces
1 gill (gi)	7.219 cubic inches 4 fluid ounces 0.118 liter
1 hectoliter (hl)	26.418 gallons 2.838 bushels

1 hogshead (hhd), liquid	63 gallons (two 31½-gallon barrels) 238.476 liters
1 liter	1.057 liquid quarts 0.908 dry quart 61.025 cubic inches
1 milliliter (ml)	0.271 fluid dram 16.231 minims 0.061 cubic inch
1 ounce, fluid (or liquid) (fl oz or f ℥) (U. S.)	1.805 cubic inches 29.573 milliliters 1.041 British fluid ounces
[1 ounce, fluid (fl oz) (British)]	0.961 U. S. fluid ounce 1.734 cubic inches 28.412 milliliters
1 peck (pk)	8.810 liters
1 pint (pt), dry	33.600 cubic inches 0.551 liter
1 pint (pt), liquid	28.875 cubic inches (exactly) 0.473 liter
1 quart (qt), dry (U. S.)	67.201 cubic inches 1.101 liters 0.969 British quart
1 quart (qt), liquid (U. S.)	57.75 cubic inches (exactly) 0.946 liter 0.833 British quart
[1 quart (qt) (British)]	69.354 cubic inches 1.032 U. S. dry quarts 1.201 U. S. liquid quarts
1 tablespoon	3 teaspoons[16] 4 fluid drams ½ fluid ounce
1 teaspoon	⅓ tablespoon[17] 1⅓ fluid drams[18]

[16] The equivalent "1 teaspoon=1⅓ fluid drams" has been found by the Bureau to correspond more closely with the actual capacities of "measuring" and silver teaspoons than the equivalent "1 teaspoon=1 fluid dram" which is given by a number of dictionaries.

[17] See footnote 16.

[18] See footnote 16.

WEIGHTS OR MASSES

1 assay ton[19] (AT)	29.167 grams
1 carat (c)	200 milligrams 3.086 grains
1 dram, apothecaries (dr ap or ʒ)	60 grains 3.888 grams
1 dram, avoirdupois (dr avdp)	$27\frac{11}{32}$ (=27.344) grains 1.772 grams
gamma, *see* microgram	
1 grain	64.799 milligrams
1 gram (g)	15.432 grains 0.035 avoirdupois ounce
1 hundredweight, gross or long[20] (gross cwt)	112 avoirdupois pounds 50.802 kilograms
1 hundredweight, net or short (cwt or net cwt)	100 avoirdupois pounds 45.359 kilograms
1 kilogram (kg)	2.205 avoirdupois pounds
1 microgram (γ [the Greek letter gamma])	0. 000 001 gram (exactly)
1 milligram (mg)	0.015 grain
1 ounce, avoirdupois (oz avdp)	437.5 grains (exactly) 0.911 troy or apothecaries ounce 28.350 grams
1 ounce, troy or apothecaries (oz t, or oz ap, or ℥)	480 grains 1.097 avoirdupois ounces 31.103 grams
1 pennyweight (dwt)	1.555 grams

[19] Used in assaying. The assay ton bears the same relation to the milligram that a ton of 2 000 pounds avoirdupois bears to the ounce troy; hence the weight in milligrams of precious metal obtained from one assay ton of ore gives directly the number of troy ounces to the net ton.

[20] The gross or long ton and hundredweight are used commercially in the United States to only a limited extent, usually in restricted industrial fields. These units are the same as the British "ton" and "hundredweight."

1 pound, avoirdupois (lb avdp)	7 000 grains 1.215 troy or apothecaries pounds 453.592 grams
1 pound, troy or apothecaries (lb t or lb ap)	5 760 grains 0.823 avoirdupois pound 373.242 grams
1 scruple (s ap or ℈)	20 grains 1.296 grams
[1 stone (British)]	14 avoirdupois pounds
1 ton, gross or long[21] (gross tn)	2 240 avoirdupois pounds 1.12 net tons (exactly) 1.016 metric tons
1 ton, metric (t)	2 204.622 avoirdupois pounds 0.984 gross ton 1.102 net tons
1 ton, net or short (tn or net tn)	2 000 avoirdupois pounds 0.893 gross ton 0.907 metric ton

[21] The gross or long ton and hundredweight are used commercially in the United States to only a limited extent, usually in restricted industrial fields. These units are the same as the British "ton" and "hundredweight."

Appendix III.—MATERIAL FOR STUDY AND REFERENCE

There are listed below certain publications which will be found useful for study in the field of scale design and construction and for reference in the field of foreign weights and measures units. Some of these publications may no longer be available for purchase and thus can only be consulted in libraries, whereas others are still obtainable through purchase.

A Treatise on Weighing Machines, by George A. Owen. The second edition of this book was published in 1937 by Charles Griffin & Co., Ltd., 42 Drury Lane, Strand, W. C. 2, London, England; some slight revision has been made as compared with the first edition, published in 1922. The volume comprises slightly over 200 pages and carries 175 text illustrations and plates. References to commercial weighing devices are to devices used in Great Britain; details of the design of these will be found in many instances to differ from corresponding details of devices in current use in the United States, and in numerous cases the British names for scale parts and assemblies differ from the names currently used in the United States to designate corresponding parts and assemblies. Principles of construction, however, are fundamental, and apply equally to scales of British and other manufacture; the more extended treatment of such principles in Owen's book, as compared with the very brief treatment in the earlier pages of this volume, makes the Treatise a valuable study text for the weights and measures officer desirous of expanding his knowledge in this field.

Scales and Weighing—Their Industrial Applications, by Herbert T. Wade. Published in 1924 by The Ronald Press Co., New York, N. Y. The volume comprises approximately 475 pages and 116 illustrations. The text has been written "with special reference to control of plant operation, transportation, and commercial transactions" and aims to "set forth definitely and simply the advantages to be obtained through intelligent selection, use, and maintenance of scales." This book will be of interest particularly to the new weights and measures officer desirous of learning quickly to recognize many of the differing types of commercial scales which are in use in this country; the illustrations include some cut-away and phantom views which are helpful in showing the arrangement of component parts.

The Construction of the Balance, by E. Brauer, translated from the German by Henry Charles Walters. Published in 1909 by the Incorporated Society of Inspectors of Weights and Measures (Great Britain). The volume comprises something over 300 pages and 246 illustrations and figures. A considerable part of this book is devoted to the design and construction of the balance, including detailed mathematical treatment; attention is also given to the adaptation to commercial weighing devices (largely of German design) of the weighing principles discussed. The book will be of interest to those desirous of making more than a casual study of the subject.

Dictionary of Applied Physics, edited by Sir Richard Glazebrook. Under the vocabulary entries "balances" and "weighing machines," will be found helpful discussions, covering in brief form the subjects treated much more extensively by Brauer's "Construction of the Balance" and Owen's "Treatise on Weighing Machines," respectively. It should be kept in mind that the authors of both articles are British, and that their subjects are treated from the British viewpoint.

Webster's New International Dictionary, Second Edition (*Unabridged*). Under the vocabulary entry "weight" there will be found an extensive "Table of Weights," listing names of units, locations in which they are or have been used, native equivalents, and the United States and metric equivalents. (Similarly, under the vocabulary entry "measure" there will be found a "Table of Measures.") This material was reviewed and revised before publication, with reference to the data on file at the National Bureau of Standards.

Conversion Equivalents in International Trade, by Stephen Naft. Published in 1931 by The Commercial Museum, Philadelphia, Pa. The volume comprises something over 350 pages. The scope of the publication is indicated by the subtitle: Weights, measures, gauges, currencies, technical and special units in commerce and industry. Simple and compound conversion factors and tables are presented, together with an alphabetical list of foreign and domestic "weights, measures, currencies and units."

Tate's Modern Cambist, by William F. Spalding. Published by Effingham Wilson, 16, Copthall Ave., E.C. 2, London, England. The latest edition is that of 1929, being the twenty-eighth. The volume comprises approximately 730 pages, and is primarily a manual of the monetary systems and foreign exchanges of the world. For each of the principal countries, however, there is included information on the weights and measures in use. It should be noted that in this publication, when equivalents of volumetric units are given in terms of bushels, gallons, quarts, pints, and so on, these are the Imperial bushel, gallon, etc., and not the United States bushel, gallon, etc.

The Statesman's Year Book. Published annually by Macmillan Co., Ltd., St. Martin's St., London, England. "A statistical and historical annual of the states of the world," the 1942 issue comprising some 1,474 pages. Included for each of the principal countries is information relative to its weights and measures. Volumetric equivalents are in terms of Imperial units, as in the case of the Modern Cambist.

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