THE EXAMINATION OF WEIGHING EQUIPMENT

NATIONAL BUREAU OF STANDARDS
HANDBOOK 94

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

The examination of

WEIGHING EQUIPMENT

Malcolm W. Jensen
and
Ralph W. Smith

NATIONAL BUREAU OF STANDARDS HANDBOOK 94

A Manual for State and Local
Weights and Measures Agencies
Issued March 1, 1965

U.S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

Supersedes NBS Handbook H37

For sale by the Superintendent of Documents
U.S. Government Printing Office, Washington, D.C. 20402
Price $3.00

Commerce itself could hardly subsist unless some security were given (beside the judgment of the purchaser) that the article which he buys is of the quantity which the seller describes; that the weight or measure which is employed is fair.

William J. Lowndes, M. C. (S.C.),
in a report, as a committee chairman, to the
House of Representatives
January 25, 1819

Library of Congress Catalog Card No. 64–60060

Foreword

The present Handbook supersedes and is a revision of National Bureau of Standards Handbook 37, Testing of Weighing Equipment, issued in 1945.

Handbook 37 has been out of print for some years. The demand for technical information and guidance in the area of the examination of weighing devices for suitability and accuracy continues, arising from weights and measures officials, from commercial and industrial users of weighing equipment, and from the manufacturers of such equipment. Such information and guidance are particularly needed in the first instance for the promotion of uniform, effective, official techniques; in the second instance for the development of programs of owner maintenance; and in the third instance for manufacturing guides.

The demand for technical information on the inspection and testing of weighing instruments is stimulated by the rise in the frequency of training schools for weights and measures officials and by the higher technical level of the instruction sought in these schools.

Handbook 94 has been prepared to serve as a manual in its field, to meet the desires and needs mentioned above. It is issued by the Bureau in partial discharge of its statutory function of "cooperation with the States in securing uniformity in weights and measures laws and methods of inspection."

A. V. Astin, *Director*
National Bureau of Standards.

Preface

The present Handbook differs from its predecessor, NBS Handbook 37, in a number of important respects. Comment is here offered on these differences for the benefit of those who are familiar with the earlier publication, and on the pattern of Handbook 94 for the benefit of those using it for initial study and for reference.

A major difference between the two texts is found in the emphasis placed upon practical examination procedures. The present text, by the character and arrangement of its several parts, directs itself first, and with most emphasis, to step-by-step outlines of recommended procedures, supporting these by later discussions of related topics. Thus Part I introduces and then presents a series of examination procedure outlines (EPO's) for basic types of weighing equipment. Part II discusses a series of important topics directly related to the examination process, including brief comment on the new concept of basing official examinations upon a system of selective sampling. Part III is a simplified exploration of certain basic ideas—weighing principles, physical elements and types of scales, and elements of scale performance.

Useful information is presented in the three appendixes. Appendix I reproduces the recommendation of the National Conference on Weights and Measures (in which the NBS Office of Weights and Measures concurs) relative to the selection, installation, and maintenance of vehicle scales. This will be found of direct benefit by potential and actual owners of vehicle scales and of other scales of large capacity, and should be helpful to weights and measures officers when advising with scale owners and users in their jurisdictions. Appendix II is devoted to tables of weights and measures in the customary and metric systems (including notes on the British system), to tables of interrelation of units, customary and metric, and to tables of equivalents of units in terms of other units. Appendix III presents an abbreviated list of publications, for the guidance of those in a position to pursue further studies in the field of weighing instruments, and for purposes of reference.

Finally, there is included an index, to facilitate the location of desired material in this handbook.

The manuscript for this publication was developed according to a plan and outline based primarily upon the examination procedures evolved and the teaching methods successfully followed in the numerous training courses conducted by the staff of the Office of Weights and Measures. Free use was made of material published elsewhere by the National Bureau of Standards (and without citing the sources) whenever it was felt that such material would add to the general usefulness of the handbook without unduly lengthening the text.

Appreciation is expressed for certain technical information, and particularly for drawings and photographs, supplied by manufacturers of weighing equipment. Special thanks are extended to Mr. K. C. Allen, Chairman of the Technical Committee of the Scale Manufacturers Association, who read the entire text of the manuscript and offered numerous constructive technical suggestions. Also, the assistance rendered by members of the staff of the NBS Office of Weights and Measures in reviewing the manuscript is gratefully acknowledged.

Contents

Page

Part II.—ELEMENTS OF OFFICIAL EXAMINATIONS AND RELATED CONSIDERATIONS

APPENDIXES

Page

ABSTRACT

This Handbook is primarily directed to the presentation of a coordinated series of step-by-step Examination Procedure Outlines (EPO's) for weighing equipment, recommended for adoption and use, as minimal requirements, by weights and measures agencies, commercial service agencies, weighing equipment owners and operators, and manufacturers of weighing devices. Supporting information embraces discussions on related topics such as reference and field standards, report forms, tolerances, weighing principles, and elements of scale construction and performance. Extensive weights and measures tables—basic, interrelation of units, and equivalents—and a list of references for further study are appended. An alphabetical index is supplied.

The Examination of WEIGHING EQUIPMENT

Part I.—EXAMINATION PROCEDURES

A condensed treatment of examination procedures and examination procedure outlines for weighing equipment, including a series of twelve recommended outlines.

Chapter 1.—A General Discussion of Examination Procedures for Weighing Devices

Background Information. A knowledge of the fundamentals of the design and operation of a weighing device is a prerequisite to a fully informative and thoroughly satisfactory examination of the device. Technical information along these lines will be found in later chapters of this publication. This can be effectively supplemented by careful study of the catalogs and other descriptive literature of manufacturers of weighing devices, combined with thoughtful study of the devices themselves. This background knowledge should be as broad as practicable and should be kept up to date, advantage being taken of every opportunity of gathering information on design modifications and new patterns.

Elements of an Examination. A proper examination of a weighing device necessarily includes exploration in three principal areas, and these three divisions of the examination are conveniently denominated (1) Inspection, (2) Pre-Test Determinations, and (3) Test.

Inspection. This phase of an examination is concerned with the physical characteristics and condition of a device and how it is being used or abused. Criteria for the inspection are found in the "specifications" and the "regulations" of NBS Handbook 44. [See the discussions of Handbook 44 in chapters 2 and 4.] These deal (1) with elements of design and construction as established originally by the device manufacturer and as subsequently maintained by the owner or operator, and (2) with the conditions of use of the device, the environment in which the device is used, and the probable effect of these factors on weighing results.

Attention to details of design and construction—for determining compliance with specification requirements—is particularly important when a device of a new pattern is first encountered and when a particular device—even though of a familiar pattern—is examined for the first time. In these circumstances the inspection should be more extended and thorough than for routine reexaminations, in respect to design and construction features.

On the other hand, when the device under examination has been in service for some time, attention to possible misuse or abuse, to the possibility of improper modifications or additions to the device by the owner or operator, and to environmental conditions, becomes progressively more important.

Pre-Test Determinations. Before test results can be evaluated or a determination can be made as to the suitability for service of a particular device, the applicable performance criteria must be determined from the rules laid down in the codes. Is the device "new" and thus subject to "acceptance" requirements, has it been so recently reconditioned that it should be treated as a new device, or do "maintenance" requirements apply? What are the numerical values of permissible variations? Are there special sets of values for certain elements—weighbeam, reading face, printer? What value represents the minimum tolerance, below which accuracy demands will not be made? When these questions have been resolved, by reference to appropriate technical requirements, testing can be undertaken.

Test. This concluding phase of the examination develops information on the weighing performance of the scale or the actual value of an equal-arm or counterpoise weight. Involved in the testing of weighing scales are such factors as zero-load balance, "error weights" (under certain circumstances) to facilitate the accurate determination of performance errors, SR (for nonautomatic-indicating scales)—the sensitiveness response of the device—, shifting of the test load on the load-receiving elements of certain scales, the number of, sizes of, and positions for the test loads, and any equal-arm or counterpoise weights used with the scale.

Testing Apparatus—Adequacy and Accuracy. It is axiomatic that tests can be made properly only if, among other things, *adequate* testing apparatus is available. Testing apparatus may be considered adequate only when it is properly designed for its intended use, when it is so constructed that it will retain its characterstics for a reasonable period under conditions of normal use, when it is available in sufficient amount and in denominations appropriate for a proper determination of the value or performance of the equipment under test, and when it is accurately calibrated.

A general principal that has long been recognized by the National Bureau of Standards is that the error on a standard used for testing weighing and measuring equipment should either be known and corrected for when the standard is used or, if the standard is to be used "without correction," its errors should be not greater than 25 percent of the smallest tolerance to be applied when the standard is used. (*As used here and throughout this publication, a "tolerance" is a value fixing the limit of allowable error or departure from true performance or value.*) The reason for observing this principle is to keep at a minimum the proportion of the tolerance on the item being tested that will be "used up" by the error of the standard. Expressed differently, the reason is to give the item being tested as nearly as practicable the full benefit of its own tolerance.

Field testing operations are complicated to some degree when corrections to standards are applied, and except for work of relatively high precision it is recommended that the accuracy of standards used in testing weighing equipment be so established and maintained that the use of corrections is not necessary. Also, whenever it can readily be done, it will be desirable to reduce the error on a standard below the 25-percent point previously mentioned.

The accuracy of testing apparatus should invariably be verified prior to the use of the apparatus. Standards should be reverified as often as circumstances require. Whenever damage to a standard is known or suspected to have occurred, and whenever repairs that might affect the accuracy of a standard have been made, the standard should be recalibrated. Routine recalibration of standards, even when a change of value is not anticipated, should be made with sufficient frequency to establish the fact of their continued accuracy, so that the inspector may always be in an unassailable position with respect to the accuracy of his testing apparatus.

It may be appropriate to mention here the lack of attention to the accuracy of their standards shown by some repairmen and servicemen and by some weights and measures officials, and the inadequate amount of testing apparatus with which servicemen and officials are sometimes provided. Accurate and dependable results cannot be obtained with faulty or inadequate standards, and if either serviceman or official is poorly equipped it cannot be expected that their results will check consistently. Disagreements between servicemen and officials can often be avoided, and the servicing of equipment can usually be expedited and improved, if servicemen and officials will give equal attention to the adequacy, accuracy and maintenance of their testing apparatus.

Examination Procedure Outlines. An Examination Procedure Outline, or "EPO," is a step-by-step checklist and instructional guide for the examination of a device to determine its degree of correctness. The EPO not only lists the several steps in the examination, but lists them in the order in which they should be followed for maximum conservation of the time and effort expended on an examination. With certain qualifications that are discussed in chapter 2, the EPO, if carefully followed, enables the inspector to learn all that he needs to know about a device to enable him to decide upon its acceptability under the applicable rules.

EPO's were developed specifically for use by weights and measures officers in their routine field examinations of commercial devices. The primary objectives were to provide a convenient means by the use of which the inspector could be assured of making an adequate examination, of not omitting some important steps, and of doing this with the least expenditure of time and effort. An important secondary objective was the promotion of uniform procedures among weights and measures jurisdictions.

These EPO's have been taught in many training schools throughout the country. As they became known outside of official circles, interest in them developed on the part of equipment manufacturers, users, and service agencies. It appears, therefore, that their further promotion should be of material assistance to all individuals involved in the installation, maintenance, and servicing of weighing devices, whether or not these are subject to official weights and measures supervision.

Examination Procedure Outlines are further discussed, and the entire series of EPO's for weighing equipment is presented in chapter 2.

Chapter 2.—Examination Procedure Outlines for Weighing Devices

Introduction. The Examination Procedure Outlines comprising the series here presented were developed by the Office of Weights and Measures of the National Bureau of Standards. The series includes an outline for each of the more frequently encountered types of weighing scales, and an outline for equal-arm and counterpoise weights used with weighing scales. If and when the Office of Weights and Measures finds that a need exists for expanding the series by the addition of outlines for other types of scales, such additions will be made; in this case, copies of the new EPO's will be available from the Office of Weights and Measures.

Handbook 44. In National Bureau of Standards Handbook 44, Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices, there are published the design and performance requirements adopted by the National Conference on Weights and Measures and recommended by the Conference and the Bureau for official promulgation. These requirements have been promulgated by a large majority of the States, and they are generally accepted in official and unofficial circles in the United States as the standard guide for the production and regulatory control of weighing and measuring devices.

The Handbook cited is popularly referred to as "Handbook 44" or, more simply, "H44." It comprises a General Code, applicable to all classes of devices, and a series of separate codes, each applicable to a particular class of device; of the latter there are two related to weighing equipment, the code for "Scales" and the code for "Weights." It is apparent, then, that to locate all Handbook 44 material dealing with weighing equipment three codes must be consulted—(1) the General Code; (2) the Scales code; and (3) the Weights code.

H44 Code References. As presented in this chapter, the Examination Procedure Outlines presuppose a sufficient knowledge of the code requirements of H44 to enable the user to locate the details related to any entry in an outline. To illustrate: In the EPO for Computing Scales, entry 1.5. reads simply "Damping means (dash-pot operation)." The informed user will, for details, consult that regulation paragraph of the General Code that deals with "Maintenance of Equipment" and that specification paragraph of the Scales code that deals with "Damping Means." Similarly, in the same EPO, entry 3.1. reads "Shift test—use half-capacity test load." The informed user will turn to those paragraphs of the Notes section of the Scales code that deal with "Shift Test" for information on the prescribed positions of the load during a shift test.

Citations to specific sections or paragraphs of H44 codes that are relevant to the entries of an outline are not incorporated in the EPO's that follow. The omission is deliberate, to avoid misinformation that would otherwise result when references change in H44 as a result of National Conference action.

Loose-leaf and Revised EPO's. The Office of Weights and Measures maintains a supply of complete sets of loose-leaf EPO's in which code citations *are* incorporated, and revisions are prepared whenever necessary to update the references to bring them into conformance with National Conference changes. These EPO's are printed on sheets dimensioned and punched for insertion in binders with H44 material. The advantage, for field use, of having H44 and EPO material in the same binder, is obvious. Replacement of an outdated EPO with one carrying the currently correct code references is also distinctly advantageous. Loose-leaf sets and revisions of individual EPO's will be supplied without cost upon application to the Office of Weights and Measures. (See the buff-colored card insert.)

EPO's Represent Minimal Procedures. It is to be emphasized that the EPO's recommended are to be considered as setting up only the *minimum* examination that should precede official or other formal action. Often it will be found desirable to make a more thorough or extended examination than is contemplated by these minimal procedures, as when a scale of new design is first examined or when abnormalities or inconsistencies of performance are encountered. The expansion or extension of the procedure may be in either the first or the last main division of the outline—"Inspection" or "Test"—or in both. However, an EPO as given herein should, when followed in the normal course of routine examinations, provide for the development of adequate information as to acceptability or nonacceptability of a scale, provided that there is kept in mind throughout the examination one basic principle: A prime objective is to develop as accurately as practicable the probable performance characteristics of the scale under examination *when this scale is being used in its normal service and environment.* As to actual testing procedure, this principle is briefly expressed in the warning that the test of a particular device should be so carried out that it will simulate the conditions of use of that device.

Special-Purpose Scales. There will be encountered from time to time scales that are "ordinary" in that they are conventional in their basic designs as weighing devices, but are "special" in that they incorporate modifications to adapt them to certain particular and special uses. Considered briefly here are the following special-purpose types: Counting scales, "predetermined-weight" scales, "predetermined-volume" scales, tank and hopper scales, and railway track scales. Also, comment is offered on wheel-load weighers, which fall somewhat outside of the foregoing definition of a special-purpose scale.

The weighing characteristics of a special-purpose scale should be determined according to the EPO for the ordinary scale of the same basic design as the special-purpose scale under examination, except insofar as the special modifications make this impracticable or unnecessary. The special features of the special-purpose scale should then receive whatever attention and examination are appropriate.

Counting Scales. These may be designed to give regular weighing service as well as to perform the special service of counting small items; if so, the scale should first be examined as a straight weighing device.

The counting portions of a counting scale will 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.

Predetermined-Weight Scales. A scale designed to indicate only a certain series of weights (as, for example, 10 pounds, 25 pounds, 50 pounds, etc.) need be tested only at those points. If there are a counterpoise hanger and counterpoise weights, the scale 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.

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 give a conventional "in balance" indication.

Predetermined-Volume Scales. Probably the most common example of this class of scale is the "bucket grain tester," designed primarily for the determination of weights-per-bushel of grain. The "buckets" of these testers are capacity measures—one or two dry quarts. The bucket is filled level full of grain and is then hooked to the load loop of a small steelyard. The bar of the steelyard is graduated in terms of weights-per-bushel. The examination of one of these scales is incomplete until the capacity of the bucket has been verified.

Tank and Hopper Scales. The principles of testing are the same as for scales of similar types 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 regularly weighed by the scale.

Railway Track Scales. Special equipment consisting of a short-wheelbase "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 make a meaningful test on a railway track scale. The National Bureau of Standards does operate two 80,000-pound units specially designed for track-scale testing. Also three States—Minnesota, Oregon, and Washington—have equipment and programs in this field.

Wheel-Load Weighers. Wheel-load weighers are ordinarily used in pairs. If two weighers are identified as comprising a pair to be used together, they may be tested as a pair, in which case a special tolerance provision applies. A pair of weighers may be tested with standard weights if an appropriate shallow pit can be constructed, or other safe and convenient facilities can be arranged, so that the two weighers can be "bridged" with an I-beam on which to stack 500-, 1000-, 2500-, or 5000-pound field standards.

When such special arrangements as are described above cannot be made, another, less satisfactory, procedure is to utilize, as a standard for comparison, a motor-truck scale that is known to be accurate and in good condition. An outline follows, for a test of a pair of weighers by this method; the procedure for the test of a single weigher will be obvious.

1. Place the wheel-load weighers in such positions on the platform of the motor-truck scale that each of the wheels of a single axle of a two-axle 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 position, balance the motor-truck scale.
3. Drive a loaded two-axle truck onto the motor-truck scale so that the wheels of one axle rest on the platforms of the two weighers. *The other two truck 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 that the wheel-load weighers may be called upon to handle in regular service.

Scales of Unusual Design. From time to time variations from conventional design will be encountered among the scales being examined. In such situations it may become desirable to introduce some additional steps or even to omit a recommended step in order to adapt a procedure most effectively to the scale at hand. When confronted with a scale of unusual design the inspector must first acquire an understanding of the use to which the scale is put in the course of its regular operation. The second move, obviously, is to select the EPO for the basic type to which the scale belongs, to be used as a guide insofar as it is appropriate to do so. The inspector is then prepared to devise a test procedure for this particular scale that will develop its performance characteristics when in service and that will conform to sound testing techniques. It is in these situations that the user of an outline needs to call upon his testing experience, and upon his knowledge of the fundamentals of design and operation of weighing equipment, observing the principles underlying the recommended EPO's even though minor changes must be introduced in a particular basic outline.

Suitability for Use. A further exception may be noted to full recognition of the appropriate EPO as setting up a complete basis for acceptability or nonacceptability of a scale. The Handbook 44 General Code contains the following provision:

> **Suitability of Equipment.**—Commercial equipment shall be suitable for the service in which it is used with respect to all elements of its design, including but not limited to its weighing capacity (for weighing devices), * * * the character, number, size, and location of its indicating or recording elements, and the value of its minimum graduated interval.

Overall suitability of the particular device under examination *in the service and in the environment in which the device is or will be used* should therefore receive careful consideration, wholly apart from the technical character and performance of the device as disclosed by an examination based on an EPO.

The Testing of Weights. In the EPO for Weights—Equal-Arm and Counterpoise, alternative test procedures are presented. This departure from the normal pattern for an EPO is dictated by the circumstance that in the majority of weights and measures organizations the field inspectors are not now provided with balances suitable for the proper testing of equal-arm and counterpoise weights and the application to them of the small tolerances prescribed in the H44 Weights code. Where this situation exists, the approved method of testing loose weights—equal-arm and counterpoise—on a balance cannot be followed. The recognition granted by the EPO to the less satisfactory alternative of testing loose weights on the scale on which they are expected to be used in service is thus a concession to an existing fact that can be deplored but cannot, it appears, be readily changed.

How to Use EPO's. It is strongly recommended that the inspector have before him throughout his examination of a piece of weighing equipment the appropriate EPO as well as Handbook 44 in its latest form. If the inspector is continuously examining equipment of a single design he may, after a time, commit to memory the several steps of the applicable EPO in their proper order, and the applicable H44 requirements. If, however, his attention is directed first to one and then to another of a variety of equipment designs, the probability of omitting one or more steps as he passes from one design to another is increased. A regular habit of using the EPO's as checklists, and proceeding systematically according to outline, is recommended as being conducive to completeness and uniformity of examination.

Order of Presentation. The EPO's are presented in the following order:

- Computing Scales
- Hanging Scales
- Equal-Arm Nonautomatic-Indicating Scales
- Equal-Arm Automatic-Indicating Scales
- Unequal-Arm Scales—Beam and Automatic-Indicating
- Prescription, Jewelers, Cream-Test, and Moisture-Test Scales
- Platform Beam Scales
- Platform Automatic-Indicating Scales
- Monorail Scales and "Meat Beams"—Beam and Automatic-Indicating
- Livestock and Animal Scales—Beam and Automatic-Indicating
- Vehicle Scales—Beam and Automatic-Indicating
- Automatic Grain Hopper Scales
- Weights—Equal-Arm and Counterpoise

Examination Procedure Outline for COMPUTING SCALES

This outline may be followed for automatic-indicating computing scales of cylinder and fan types and for prepackaging scales.

1. INSPECTION:

   1.1. Level condition—have adjusted if necessary.
   1.2. Zero-load balance—have adjusted if necessary.
   1.3. Support for scale.
   1.4. Parallax condition.
   1.5. Damping means (dash-pot operation).
   1.6. Value of minimum graduated interval.
   1.7. Drainage (if wet commodities are weighed).
   1.8. Customer readability.
   1.9. Reading agreement among all indicating and recording elements.
   1.10. Environmental factors (cleanliness, obstructions, etc.).
   1.11. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   Recheck zero-load balance each time test load is removed.
   If scale is equipped with ticket printer, print ticket at each test load and check weight and money values.
   3.1. Shift test—use half-capacity load.
   3.2. Increasing-load test—at 1, 3, 7, 15 ounces, then at each pound to capacity.
   3.3. Decreasing-load test—use half-capacity load.
   3.4. Money-value test.
   3.5. Recheck zero-load balance.

Examination Procedure Outline for HANGING SCALES

This outline may be followed for dial and straight-face scales.

1. INSPECTION:

   1.1. Suspension of scale.
   1.2. Zero-load balance—have adjusted if necessary.
   1.3. Value of minimum graduated interval.
   1.4. Drainage (if wet commodities are weighed).
   1.5. Customer readability.
   1.6. Reading agreement—front and back.
   1.7. Environmental factors (cleanliness, etc.).
   1.8. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   3.1. Increasing-load test—at least at each quarter of reading face and at each quarter of scale capacity.
   3.2. Decreasing-load test—use half-capacity load.
   3.3. Recheck zero-load balance.

Examination Procedure Outline for EQUAL-ARM NONAUTOMATIC-INDICATING SCALES

This outline may be followed for equal-arm nonautomatic-indicating scales *except prescription, jewelers, cream-test, and moisture-test scales.*

1. INSPECTION:

   1.1. Zero-load balance—have adjusted if necessary.
   1.2. Support for scale—including level.
   1.3. Damping means (if scale is so equipped).
   1.4. Drainage (if wet commodities are weighed).
   1.5. Customer readability
   1.6. Environmental factors (cleanliness, etc.).
   1.7. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   Recheck zero-load balance each time test load is removed.
   3.1. SR at zero load.
   3.2. Shift test—use half-capacity load and shift on each pan with load centered on other pan.
   3.3. Ratio test (equality of arms) at half and full capacity.
   3.4. SR at capacity.
   3.5. Increasing-load test—test weighbeam at two points of each side of zero, or at half and full weighbeam capacity.
   3.6. Recheck zero-load balance.
   3.7. Test weights supplied with scale—see EPO for Weights.

Examination Procedure Outline for EQUAL-ARM AUTOMATIC-INDICATING SCALES

This outline may be followed for equal-arm automatic-indicating scales whether or not equipped with weighbeams.

1. INSPECTION:

   1.1. Zero-load balance—have adjusted if necessary.
   1.2. Support for scale—including level.
   1.3. Damping means (if scale is so equipped).
   1.4. Value of minimum graduated interval.
   1.5. Drainage (if wet commodities are weighed).
   1.6. Customer readability.
   1.7. Reading agreement—front and back.
   1.8. Environmental factors (cleanliness, etc.).
   1.9. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   Recheck zero-load balance each time test load is removed.

   3.1. Shift test—use half-capacity load and shift on each pan with load centered on other pan.
   3.2. Ratio test (equality of arms) at half and full capacity.
   3.3. Increasing-load test: (a) If equipped with weighbeam, test at two points on each side of zero on each bar, preferably at half and full capacity. (b) Test over-and-under indicator, at two points, including capacity, on each side of zero.
   3.4. Decreasing-load test: Use half indicator capacity load.
   3.5. Recheck zero-load balance.
   3.6. Test weights supplied with scale—see EPO for weights.

Examination Procedure Outline for UNEQUAL-ARM SCALES—BEAM AND AUTOMATIC-INDICATING

1. INSPECTION:

   1.1. Zero-load balance—have adjusted if necessary.
   1.2. Support for scale—including level.
   1.3. Damping means (if scale is so equipped).
   1.4. Drainage (if wet commodities are weighed).
   1.5. Value of minimum graduated interval.
   1.6. Customer readability.
   1.7. Reading agreement—front and back.
   1.8. Environmental factors (cleanliness, etc.).
   1.9. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   Recheck zero-load balance each time test load is removed.

   3.1. SR at zero load—if beam scale.
   3.2. Shift test—use half-capacity load.
   3.3. Increasing-load test: (a) If equipped with weighbeam, test at two points on each side of zero on each bar, preferably at half and full capacity. (b) Test over-and-under indicator at two points, including capacity, on each side of zero.
   3.4. Decreasing-load test—use half indicator capacity load.
   3.5. Recheck zero-load balance.
   3.6. Test weights supplied with scale—see EPO for weights.

Examination Procedure Outline for PRESCRIPTION, JEWELERS, CREAM-TEST, AND MOISTURE-TEST SCALES

1. INSPECTION:

   1.1. Zero-load balance.
   1.2. Support for scale—including level.
   1.3. Weighbeam.
   1.4. Poise.
   1.5. Balance indicator.
   1.6. Arresting or damping means.
   1.7. Marking and use (if Class B prescription scale).
   1.8. Environmental factors (cleanliness, etc.).
   1.9. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.

3. TEST:

   Recheck zero-load balance each time test load is removed.
   On a cream-test scale, balance on each pan 2 ounces for each bottle the pan is designed to accommodate before start of test.
   3.1. SR at zero load.
   3.2. Shift test—shift on each pan, using a half-capacity load for a prescription or jewelers scale, an 18-gram load for a cream-test scale or a moisture-test scale.
   3.3. Ratio test (equality of arms) at half and full capacity.
   3.4. SR at maximum load.
   3.5. Increasing-load test—test weighbeams at half and full capacity on each bar.
   3.6. Recheck zero-load balance.
   3.7. Test weights supplied with scale—see EPO for Weights.

Examination Procedure Outline for
PLATFORM BEAM SCALES

This outline may be followed for counter, portable, floor, and built-in platform beam scales *except livestock and vehicle scales.*

1. INSPECTION:
   - 1.1. Zero-load balance, as found.
   - 1.2. Weighbeams.
   - 1.3. Poises.
   - 1.4. Value of minimum graduated interval.
   - 1.5. Attachments or modifications.
   - 1.6. Environmental factors (cleanliness, obstructions to platform, etc.).
   - 1.7. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:
   - 2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   - 2.2. Minimum tolerance value applicable.

3. TEST:

   Error weights—balance small weights on platform, the smallest weight being equal to the minimum tolerance value and the total value of the weights being equal to the tolerance value at maximum test load.

   Recheck zero-load balance each time test load is removed.

   - 3.1. SR at zero load.
   - 3.2. Shift test—use quarter-capacity load centered successively over each main load support, or half-capacity load centered successively in each quarter of platform.
   - 3.3. Ratio test (multiple or lever system) at one-half and maximum test loads, using standard weights on counterpoise hanger if scale is so equipped.
   - 3.4. SR at maximum test load.
   - 3.5. Increasing-load test—test weighbeams at half and full capacity of each bar.

3.6. Remove error weights and establish correct zero-load balance.

3.7. Test counterpoise weights, if any—see EPO for Weights.

Examination Procedure Outline for
PLATFORM AUTOMATIC-INDICATING SCALES

This outline may be followed for counter, portable, floor, and built-in platform automatic-indicating scales *except livestock and vehicle scales.*

1. INSPECTION:

   1.1. Level condition (if appropriate)—have adjusted if necessary.
   1.2. Zero-load balance—have adjusted if necessary.
   1.3. Damping means (dash-pot operation).
   1.4. Value of minimum graduated interval.
   1.5. Environmental factors (cleanliness, obstructions to platform, etc.).
   1.6. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

   Recheck zero-load balance each time test load is removed.

   If the scale is equipped with a ticket printer, print ticket at each test load.

   3.1. Shift test—use quarter-capacity load centered successively over each main load support, or half-capacity load centered successively in each quarter of platform.
   3.2. Increasing-load test—at least at each quarter of reading-face capacity.
   3.3. Decreasing-load test—use half-capacity load.
   3.4. Weighbeam test (if scale is so equipped) at half and full capacity of each bar.
   3.5. Unit-weight test (if scale is so equipped)—test each weight separately.
   3.6. Recheck zero-load balance.

Examination Procedure Outline for MONORAIL SCALES AND "MEAT BEAMS"— BEAM AND AUTOMATIC-INDICATING

1. INSPECTION:

   1.1. Zero-load balance, as found.
   1.2. Condition of levers, fixtures, connections, rails (as appropriate).
   1.3. Freedom of live parts.
   1.4. Weighbeams and poises (if scale is so equipped).
   1.5. Value of minimum graduated interval.
   1.6. Attachments or modifications.
   1.7. Environmental factors (cleanliness, etc.).
   1.8. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.

3. TEST:

Error weights—place small weights on or suspend them from the live rail or other load-receiving element, the smallest weight being equal to the minimum tolerance value and the total value of the weights being equal to the tolerance value at maximum test load.

Auxiliary gear (chains, hooks, or the like to support test loads)—suspend from live rail as required.

Balance in the error weights and auxiliary gear.

Recheck zero-load balance each time test load is removed.

BEAM SCALES

3.1. SR at zero load.
3.2. Shift test for monorail scale—use load of not less than 100 pounds or more than one-half capacity successively at each end of live rail.
3.3. Ratio test (multiple of lever system) at one-half and maximum test loads, using standard

weights on counterpoise hanger if scale is so equipped.

3.4. SR at maximum test load.

3.5. Increasing-load test—test weighbeams at half and full capacity of each bar.

3.6. Remove error weights and auxiliary gear (if any) and establish correct zero-load balance.

3.7. Test counterpoise weights, if any—see EPO for Weights.

AUTOMATIC-INDICATING SCALES

3.8 Shift test for monorail scale—use load of not less than 100 pounds or more than one-half capacity successively at each end of live rail.

3.9. Increasing-load test—at least at each quarter of reading-face capacity.

3.10. Decreasing-load test—use load equal to one-half of reading-face capacity.

3.11. Weighbeam test (if scale is so equipped) at half and full capacity of each bar.

3.12. Unit-weight test (if scale is so equipped)—test each weight separately.

3.13. Remove error weights and auxiliary gear and establish correct zero-load balance.

Examination Procedure Outline for LIVESTOCK AND ANIMAL SCALES—BEAM AND AUTOMATIC—INDICATING[1]

1. INSPECTION:

   1.1. Zero-load balance—if automatic-indicating scale, have adjusted if necessary.
   1.2. Installation.
   1.3. Stock rack.
   1.4. Weighbeams and poises, if beam scale.
   1.5. Value of minimum graduated interval.
   1.6. Attachments or modifications.
   1.7. Environmental factors (cleanliness, obstructions to platform, etc.).
   1.8. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:

   2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   2.2. Minimum tolerance value applicable.
   2.3. "Used" capacity—multiply square feet of platform area by 110 lb for cattle, by 70 lb for calves and hogs, or by 50 lb for sheep.

3. TEST:

   Error weights—if beam scale, balance small weights on platform, the smallest weight being a one-pound weight and the total value of the weights being equal to the tolerance value at maximum test load.
   Recheck zero-load balance each time test load is removed.
   If the scale is equipped with a ticket printer, print ticket at each test load to check weight values.
   3.1. SR at zero load—if beam scale.
   3.2. Shift test—use a quarter-capacity load successively at each corner of platform or, if the lever system has more than two sections, centered successively over each section.

---

[1] If livestock or animal scales are being tested in a cooperative program with the U.S. Department of Agriculture, note the directives of "Scales and Weighing Memorandum No. 1, Instructions for Testing Livestock Scales," copies of which are available from the U.S. Department of Agriculture, Packers and Stockyards Division, Agricultural Marketing Service, Washington, D.C. 20250.

3.3. Ratio test for beam scales utilizing counterpoise weights—test at one-half and maximum test loads, using standard weights on counterpoise hanger.

3.4. Increasing-load test: (a) Carry the distributed-load test up at least to the "used" capacity of the scale. (b) If beam scale, test at 50-lb increments on fractional bar, 100-lb increments for first 1000 lb, and at least at three other points on main weighbeam bar including "used" capacity.[1] (c) If automatic-indicating scale, test at 100-lb increments for first 1000 lb, and if possible at each quarter of dial capacity. Test all unit or drop weights normally used.

3.5. SR at maximum test load—if beam scale.

3.6. Decreasing-load test, if automatic-indicating scale—use one-half of "used" capacity.

3.7. Counterpoise-weight and unit-weight test (if scale is so equipped)—test each weight separately. For counterpoise weights, see EPO for Weights.

3.8. If beam scale, remove error weights and establish correct zero-load balance; if automatic-indicating scale, simply correct zero-load balance.

[1] In acknowledgement of differences among jurisdictions in denominations of test weights, this constitutes a minimum increasing-load test of a livestock beam scale as recommended by the Packers and Stockyards Division of the U.S. Department of Agriculture.

Examination Procedure Outline for VEHICLE SCALES—BEAM AND AUTOMATIC-INDICATING

1. INSPECTION:
   - 1.1. Zero-load balance—if automatic-indicating scale, have adjusted if necessary.
   - 1.2. Installation.
   - 1.3. Weighbeams and poises.
   - 1.4. Value of minimum graduated interval.
   - 1.5. Pit.
   - 1.6. Attachments and modifications.
   - 1.7. Environmental factors (cleanliness, obstructions to platform, etc.).
   - 1.8. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:
   - 2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   - 2.2. Minimum tolerance value applicable.

3. TEST:

   Error weights—if beam scale, balance small weights on platform, the smallest weight being equal to the minimum tolerance value and the total value of the weights being equal to the tolerance value at maximum test load.

   Recheck zero-load balance each time test load is removed.

   If the scale is equipped with a ticket printer, print ticket at each test load.

   - 3.1. SR at zero load—if beam scale.
   - 3.2. Increasing-load test: (a) Use not less than two loads successively over each section of lever system and also, on a two-section scale, centered on the platform. (b) If beam scale, test at not less than three points on each weighbeam bar. (c) If automatic-indicating scale, test at not less than three points on reading face, including each quarter of reading-face capacity.

3.3. Strain-load test—use tolerances for test-weight loads only.
3.4. SR at maximum scale loading—if beam scale.
3.5. Decreasing-load test, if automatic-indicating scale—use test load equal to one-half of reading-face capacity.
3.6. Counterpoise-weight and unit-weight test (if scale is so equipped)—test each weight separately. For counterpoise weights, see EPO for Weights.
3.7. If beam scale, remove error weights and establish correct zero-load balance; if automatic-indicating scale, supply correct zero-load balance.

Examination Procedure Outline for AUTOMATIC GRAIN HOPPER SCALES

1. INSPECTION:
   - 1.1. Zero-load balance.
   - 1.2. Installation.
   - 1.3. Weighbeam bars.
   - 1.4. Poises.
   - 1.5. Value of minimum graduated interval.
   - 1.6. Condition of working parts (levers, rods, pivots, bearings, gates, linkage, etc.).
   - 1.7. Environmental factors (cleanliness, obstructions, etc.).
   - 1.8. Other General and Scales code requirements.

2. PRE-TEST DETERMINATIONS:
   - 2.1. Tolerance requirements applicable—acceptance or maintenance, values, application.
   - 2.2. Minimum tolerance value applicable.

3. TEST:
   - 3.1. SR at zero load.
   - 3.2. Ratio test (multiple of lever system) at one-half and maximum test loads, using standard weights in the weight box against standard weights in or upon the weigh hopper.
   - 3.3. SR at maximum test load.
   - 3.4. Scale-weight test—test each scale weight separately by placing it in the weight box and checking for accurate scale balance against test weights in or upon the weigh hopper.
   - 3.5. Residue-weighbeam test (if scale is so equipped) —lock main weighbeam, then determine SR and test accuracy of residue beam at one-half and full capacity of this beam.
   - 3.6. Recheck zero-load balance.
   - 3.7. Test drafts: As a final check, test the operation of the entire scale installation by checkweighing several drafts of grain that have been weighed by the scale. Repeat the test draft procedure if the scale is used for more than one type of grain by first checkweighing with a heavy grain such as wheat and then checkweighing with a light grain such as oats.

Examination Procedure Outline for WEIGHTS—EQUAL-ARM AND COUNTERPOISE

1. INSPECTION:
   - 1.1. Material.
   - 1.2. Design—smooth surface, no sharp edges or corners.
   - 1.3. Finish.
   - 1.4. Marking of nominal and counterpoise values.
   - 1.5. Cleanliness.
   - 1.6. Loose adjusting material.

2. PRE-TEST DETERMINATIONS:
   - 2.1. Type and multiple of scale with which weights are used.
   - 2.2. Tolerance requirements applicable—acceptance or maintenance, values.

3. TEST:

Recommended Procedure

Use an equal-arm balance with SR, accuracy, and repeatability at least as good as one-tenth the acceptance tolerance on the smallest weight of the group of weights under test.

3.1. Place on the left pan of the balance the weight to be tested, and on the other pan place a standard weight (or an accumulation of standard weights) of the same nominal value.

3.2. If the pans do not balance exactly (or the indicator does not oscillate equally on both sides of the center of the graduated scale), place on the high pan a standard weight equal to the tolerance on the weight under test. If this brings the high pan to balance position or lower, the weight under test may be considered acceptable; if not, the weight is unacceptable.

Alternative Procedure

If the scale with which the weight under test is used conforms to official requirements, it may be used (although certainly not with the confidence with which the precise balance is used) to test its equal-arm or counterpoise weights.

For Equal-Arm Weights.

3.3 Balance the equal-arm scale with a standard weight equal in nominal value to the weight under test on the left pan and with any appropriate balancing material on the right pan.

3.4. Replace the standard weight on the left pan with the weight under test.

3.5. If the pans do not now exactly balance, place on the high pan a standard weight equal to the tolerance on the weight under test. If this brings the high pan to balance position or lower, the weight under test may be considered acceptable; if not, the weight is unacceptable.

For Counterpoise Weights.

3.6. Place a standard weight equal in nominal value to the weight under test *plus* a standard weight equal to the tolerance on that weight on the counterpoise hanger of the compound-lever scale.

3.7. Place any appropriate balancing material on the load-receiving element of the scale, and, utilizing the balance ball, bring the weighbeam into a position of equilibrium at the very top, but not actually touching the top, of the trig loop or other limiting stop.

3.8 Replace the standard weight with the weight under test (do not remove the "tolerance" weight).

3.9. Should the weighbeam now be lower than it was when balanced in step 3.7., remove the tolerance weight from the counterpoise hanger. Then, if the weighbeam is restored to its high balance position or actually touches the trig loop or other limiting stop, the weight under test may be considered acceptable; if not, it is unacceptably *heavy*.

3.10. If, following 3.8, the weighbeam is actually touching the trig loop or other limiting stop, add to the counterpoise a second "tolerance" weight. If this additional load lowers the weighbeam so that it no longer touches the top of the trig loop or other limiting stop, the weight under test may be considered acceptable; if not, it is unacceptably *light*.

(For ordering EPO sheets, see postcard in back of this handbook.)

Part II.—ELEMENTS OF OFFICIAL EXAMINATIONS AND RELATED CONSIDERATIONS

An exploration of facts and factors underlying or closely related to the examination of weighing equipment by weights and measures agencies.

Chapter 3.—Some General Observations on Weights and Measures Supervision

What is Weights and Measures Enforcement? The responsibilities of the weights and measures agencies of the States and their local subdivisions extend, in general, to all matters concerned with the commercial determination of quantity. Regulatory controls are exercised (1) over the mechanical devices used for commercial weighing and measuring, (2) over the manner of their use, and (3) over the end results of their use, that is, the accuracy of commercial weighing and measuring. Regulatory control extends also to representations of quantity involved in buying and selling operations, to frauds connected therewith, and to the numerous related provisions of the weights and measures statutes. Involved are activities in the office, the laboratory, and the field—in the office for administrative purposes, in the laboratory for standards maintenance and control and for making studies and investigations of many kinds, and in the field for examination of commercial equipment and supervision over commercial practices and personnel.

The discharge of these responsibilities divides conveniently into two principal categories—mechanical activities and supervisory activities. The first category embraces the activities directly concerned with the suitability of the weighing and measuring devices themselves, as mechanical instruments. The second category embraces all those activities of a nonmechanical character that comprise the general enforcement or "supervisory" group. The combination of these two groups of activities makes it possible for the weights and measures officer to fulfill his primary function of seeing to it that equity prevails in all commercial determinations of quantity.

Scope of this Publication. In this Handbook attention is confined to one main division of the mechanical-activities group of weights and measures responsibilities, that dealing with weighing equipment and comprising weighing scales and the equal-arm and counterpoise weights used with them. (The other main division of mechanical activities deals with measuring equipment.) Supervisory activities are treated in NBS Handbook 82, Weights and Measures Administration.

Industrial and Wholesale Weighing Equipment. In some weights and measures jurisdictions there has developed the unfortunate practice of confining weights and measures supervision largely to retail establishments, so that industrial, manufacturing, and many wholesale establishments are ignored almost entirely. Where a weights and measures department is seriously undermanned there is justification for adopting this practice as a temporary expedient in order to give attention first to those matters that most directly affect that group in the community least able to protect its own interests—the retail purchasing public. But continuance of this practice over long periods is not recommended.

In the first place, the duties of the weights and measures officer, as set forth in the law, extend to all weighing and measuring devices used commercially in his jurisdiction. Moreover, as a public officer, he should serve his community as a whole and should not confine his efforts to the interests of any single group. Finally, it should be obvious that any activity in the community affects the community as a whole and thus affects each individual in that community, and that, in consequence, the best service that the weights and measures official can render to the individual will be well-balanced, impartial service to every element in the community.

However, it is not on these general grounds alone that a comprehensive weights and measures program is justified. There are innumerable instances in which the interests of the individual are affected with surprising directness by the weighing and measuring operations in industrial, manufacturing, and wholesale establishments.

Again, the tremendous volume of business transacted by industrial and manufacturing plants results in immense sums of money changing hands on the basis of weighing operations of various kinds. The aggregate error in the course of a year's business as a result of even a small inaccuracy in the weighing equipment utilized may be tremendous. Such discrepancies may represent the margin of profit that determines the business life of a firm or of an individual; moreover it should be remembered that these errors may be in either direction, and whether plus or minus are sure eventually to have an adverse effect.

As embraced in that class of equipment referred to as meriting the regular attention of the weights and measures officer, the following typical groups may be mentioned: Equipment used in actual buying or selling, equipment used in checking the quantity of purchases, equipment used in tare determinations, and equipment used in computing or checking any charge or payment for services rendered.

Noncommercial Weighing Equipment. Aside from the equipment just referred to, which is "commercial" in the weights and measures sense, there is another class of equipment that is frequently met by the official in manufacturing and industrial plants. This is equipment originally designed by the manufacturer, in most instances, for commercial use, but that is not being used commercially; that is, it is being used for such purposes as compounding, gathering data for production or cost records, keeping track of stock used in manufacturing processes, and the like, operations that are not "commercial" in that the quantity determinations made do not directly enter into a buying or selling transaction.

The weights and measures official is very apt to feel that he should not test noncommercial equipment used in industry and trade for several reasons: First, he is not required under the law to do this; second, if the owner does not want the test made, the official is not in a position to demand that this be done; and third, if such equipment is tested and proves to be unsatisfactory the official has no authority to reject or condemn it. As a result, much of this equipment is never inspected or tested, and in consequence it is frequently in poor condition.

These cases present a very real danger because of the possibility that the equipment currently found to be noncommercial may later on find its way into commercial use. To guard against this, the official should treat as commercial any weighing devices that are ever used commercially; and whenever it seems probable that other apparatus is likely to be used commercially, either by accident or intention, every effort should be made to hold such apparatus to the same standards as are enforced in the case of regular commercial equipment. Then, in the case of all strictly noncommercial apparatus that is not tested, it is advisable that the official conspicuously mark each piece of equipment to show that it has not been tested and that it must not be used for commercial purposes until it has been tested and approved for such use. This marking can best be accomplished by means of a distinctive tag containing the necessary statement and warning, attached by a lead-and-wire seal, as, for example, "Not Tested—Do Not Use for Commercial Purposes." The official should also keep a record of the noncommercial equipment in use at each establishment in his territory, and should check up on this at each regular inspection trip to make sure that it is still properly marked, and that it is still properly to be classified as noncommercial.

However, there will be many times when the official, as the weights and measures expert, will be asked by the owners to test noncommercial equipment. The conscientious officer, as a public service, will want to accede to such requests. Whether or not such examinations will be undertaken will depend upon such considerations as the importance of the equipment in question, the time that may reasonably be spared for such work, and the availability of other testing services. If a noncommercial device is found upon examination to meet all of the applicable "commercial" requirements, the device may properly be sealed; any devices so sealed would, of course, be exceptions to the general recommendation of the preceding paragraph for the marking of noncommercial devices with a warning against commercial use.

Quite aside from the satisfaction of rendering his best service to his entire community, there is a further reward for the weights and measures officer who carries on his work in the broad manner recommended herein. Industrial and business interests will appreciate the value of the service rendered to them by the efficient weights and measures officer, and this appreciation will find its expression in a hearty support of the department. In its turn, this support will assist in bringing about that official recognition of the great economic importance of weights and measures supervision that may confidently be expected to result in expansion and increased opportunities for service.

Postage Scales. Scales used by business and industrial concerns for the determination of postal charges offer a special problem to the weights and measures official. These scales are in one sense used in a commercial operation—the determination of charges for the service of transporting and delivering mail matter, for the purpose of the prepayment of such charges by the mailer. But the case becomes special by reason of the fact that the Federal Government has final authority for the determination of postal charges, using for this purpose Federally owned scales for which the Post Office Department may prescribe special performance requirements. When an industrial owner of a postal scale requests the weights and measures officer to test such scale, it is suggested that if the test is undertaken the examination be based upon the appropriate commercial requirements for a scale of the general design of the one under test.

Post Office Scales. At times an official may be asked by a local postmaster to test one or more scales in use in the post office. Under the terms of the Postal Manual, a postmaster who suspects that a particular scale or scales under his control are defective may authorize a State or local weights and measures official to examine these, applying his regular commercial performance requirements. It is suggested that, for purposes of record, the official may properly ask that the postmaster's request for his services be in writing. If the performance of a scale so tested fails to meet commercial requirements, the postmaster should be informed of this fact; it is then the postmaster's responsibility to have the defective scale replaced.

The postmaster's request that the official test certain scales does not confer on the official any authority over the scales in question, which are the property of and are used by the Federal Government. The testing service is rendered by the official merely as a courtesy to the Federal authorities.

Rejection and Condemnation of Commercial Equipment. The weights and measures statute normally contains a provision to the general effect that when the official finds, upon his examination of a commercial device, that it is incorrect, he shall take one of two actions. If in the exercise of his best judgment he decides that the device is susceptible of satisfactory repair, he is directed to reject the device, mark it to show that it is not acceptable for commercial use, and require that suitable repairs be made within such reasonable period as he may specify. If, on the other hand, his judgment is that the device is not susceptible of satisfactory repair, or that it is so designed or installed that it cannot be brought into compliance with the applicable technical requirements, he is directed to condemn the device and is authorized to seize and destroy it. Provision is ordinarily made for confiscation of rejected devices that are not repaired as required, and the law usually provides that, pending repairs, rejected equipment shall neither be used nor disposed of in any way but shall be held at the disposal of the official.

These broad powers should be used by the official with discretion. He should keep always in mind the property rights of an equipment owner, and cooperate in working out arrangements whereby an owner can realize at least something from equipment that has been condemned. In cases of doubt, the official should initially reject rather than condemn outright. Destruction of equipment is a harsh procedure, as is also confiscation; power to seize and destroy is necessary for adequate control of extreme situations, but seizure and destruction should be resorted to only when clearly justified.

On the other hand, rejection is clearly inappropriate for some items of equipment. If a device is incorrect and it is either impracticable or impossible to adjust or repair it, or if its design or installation is improper or faulty and suitable modification seems to be out of the question, the official has no alternative to condemnation, and immediate destruction or confiscation may be the best procedures. However, most worn-out weighing equipment has some value, as scrap if nothing else, and salvage can properly be permitted so long as the official is assured that the incorrect device will not get into commercial use.

Tagging of Equipment. It will ordinarily be practicable to mark or tag as "rejected" each item of equipment found to be incorrect and considered susceptible of proper reconditioning, and this should always be done unless the repairs are to be begun immediately. However, the tagging of equipment as "condemned" to indicate that it is permanently out of service, is not to be recommended if there is any other way in which the equipment can definitely be put out of service. When it is decided that equipment cannot successfully be repaired, dismantling, removal from the premises, or confiscation by the official are preferable to mere marking.

It is occasionally found that an establishment has in use commercial equipment, but that there is also at hand some equipment that is not in service, that may never be put in service, that is of a type that is suitable for commercial service, and that might be used commercially at some future time. The official may choose from three possible courses of action. (1) The out-of-service equipment may be examined and otherwise treated just as is equipment in commercial service. (2) If the equipment in question is readily portable, it may be required that it be removed from the premises to eliminate possibility of its inadvertent use for commercial purposes. (3) The out-of-use equipment may be marked "NONSEALED" with a tag stating that the device has not been officially examined and that it must not be used commercially until it has been so examined and has been approved for commercial service.

Finally, there are instances of noncommercial equipment and commercial equipment installed or used in close proximity. In such a case, if there is a reasonable probability that the noncommercial equipment might be used for commercial purposes, (1) this should be treated by the official as commercial equipment, (2) a physical separation of the two groups of equipment should be effected so that misuse of the noncommercial equipment will be effectively prevented, or (3) the noncommercial equipment should be tagged to show that it is in noncommercial service, has not been officially examined, and is not to be used commercially.

Sealing of Equipment. There are two classes of weights and measures "seals," (1) approval seals and (2) security seals. The approval seal is placed upon a device that has been found, upon examination, to be correct, and indicates that the device has been approved for commercial use. A security seal is one sometimes used upon an adjustable element of a device to discourage or disclose any unauthorized use of such element to alter the performance of the device after it has been found to be, or has been placed, in accurate condition. Security seals are but little used on weighing devices and will not, therefore, be further considered here, and the "seals" and "sealing" in the three paragraphs that follow will be understood to mean seals and sealing to indicate official weights and measures approval.

All equipment that is officially approved for commercial use (with certain exceptions to be pointed out later) should be suitably marked, or "sealed." Because it is desirable that the public be advised that the equipment that is used to serve them has been officially examined and approved, the seal should, within reasonable limits, be as conspicuous as circumstances permit and should be of such a character and so applied that it will be reasonably permanent. The seal should be so positioned on a piece of equipment that it will be conspicuous, particularly to the public. Uniformity of position of the seal on similar types of equipment is also desirable as an aid to the public in determining quickly that a piece of equipment has been examined and found correct.

It will be necessary for the official to have more than one form of seal to meet the requirements of different kinds of equipment. For most scales, good quality, weather resistant (plastic-coated), water-adhesive or pressure-sensitive paper seals, or decalcomania seals are recommended; these may be somewhat more expensive than other types, but their qualities of permanence and good appearance recommend them highly. In general, the lead-and-wire seal is not recommended as an approval seal.

In the case of certain very small weights, the size of which precludes satisfactory stamping with a steel die, an exception is made to the general rule that all equipment approved for commercial use be individually sealed.

Periodic Examinations. Traditionally in the United States (as elsewhere) it has been the normal weights and measures requirement that all commercial weighing and measuring devices be offically examined at regular intervals, the prescribed period between successive examinations usually being one year.

Examination by Sample. With the development of the glass "milk bottle" and its common use, as a commercial measure-container, it became impracticable for the limited personnel of weights and measures agencies to examine individually every such bottle in use, or purchased to be placed in use. Recourse was had to the expedient of examination by sample, a procedure under which a representative sample of a relatively large "lot" of bottles is selected at random; each of the sample bottles is thoroughly examined; and the entire lot of bottles is approved or rejected upon the basis of the results obtained on the examination of the sample bottles.

With the advent of single-service paperboard measure-containers, examination by sample of these items became a practical necessity, for because of sanitary considerations it is out of the question to water-test them.

Elimination of Retesting. There is also a second example of a departure from the traditional pattern of device examination. The physical characteristics of certain measures are such that, once having been examined and found accurate, there is little or no probability that they can become inaccurate in service. The milk bottle and the glass graduate are good examples of the measures in this group. While periodic inspection may be and probably is advisable in some cases, periodic retesting is essentially useless.

Delayed Retesting. A third example of deviation from the traditional pattern is found in the case of measures of such construction that in the absence of major damage or repairs, accuracy characteristics are not apt to change and continued accuracy can be verified without a complete retest. Here the agency may set up special guidelines for the retesting of the devices, suspending the normal requirement for annual retests. Vehicle tanks used as measures are an example of devices in this group.

Examination by Selective Sampling. It will be observed that of the devices in the first three groups discussed above, all are measures of simple type, and that the fourth group is likewise made up of measures, although slightly more complex. It is only very recently that any departure from traditional procedures has been advocated with respect to weighing devices, and the proposed innovation is as yet in the experimental stage. The proposal involves sampling, but it is by no means a system of examination by sample such as is in effect for the measure groups previously considered, where the acceptability of a lot is determined by the results of an examination of a sample of the lot. It is, rather, a system of regulatory control based upon examination of only a limited number of devices of all classes, *including weighing devices*, chosen for examination by selective sampling of the devices that are in commercial service.

The principle underlying the proposal for examination by selective sampling is the proposition that it should be the responsibility of the commercial user of a weighing or measuring device of whatsoever kind to procure initially a device that meets the requirements of the official codes of specifications and tolerances, to maintain that device at all times in such condition that it will continue to conform to code requirements, and to use that device as prescribed in the official regulations; and that the responsibility of the weights and measures agency in the mechanical phase of its activities should be limited to policing action to verify that the user of a commercial device lives up to his responsibilities and to initiate punitive measures if these become necessary to require him to do so. Under this proposal all routine periodic examinations of equipment are done away with.

A causative factor behind the proposal for examination by selective sampling is the recognition of the very great difficulty (that exists almost universally) of obtaining a field staff adequate in number to do the mechanical work in the traditional manner and in addition to give adequate attention to the needed supervisory work, particularly package control. Two results are sought: (1) Placement of responsibility for the correctness of a commercial weighing or measuring device upon the user, where it is felt it rightfully belongs. (2) Realization of a well-balanced pattern of regulatory weights and measures control in all of its phases by relieving the official agency of much of the routine mechanical service now furnished —gratuitously—to equipment users.

Statutory Requirements. The frequent impossibility of adhering strictly to a statutory time schedule for field examinations of commercial equipment has recently been recognized by a number of State legislatures. Authority has been granted to the administrative heads of their weights and measures agencies to substitute for a rigid examination schedule a program calling for less frequent examinations for particular classes of devices when such a modification is deemed expedient and justified. Advantage is being taken of this authority to put into operation, gradually and somewhat tentatively, but with full legal sanction, what may be termed programs of "selective examination." In only one State, however, has there been a changeover to a full program of "examination by selective sampling." This State is Wisconsin where, in 1961, the law was amended to prescribe examination by selective sampling, and where the operation of this new system seems to be progressing with success.

Further reference to examination by selective sampling will not be made in this Handbook, and the remaining text has been written from the traditional viewpoint of periodic examinations of all commercial equipment. In any jurisdiction making a transition to the selective-sampling system for the mechanical phase of its activities, it will be a simple matter to adapt to its uses the appropriate information and recommendations presented in this publication.

Chapter 4.—The Legal Authority

The Independence of the States. The legal basis for a regulatory system of weights and measures supervision derives from the weights and measures statute of the State or the ordinance of the county or city. This is because the Congress has seen fit to leave this field almost exclusively to the States and their political subdivisions, limiting its own directives to devices and practices directly related to the exchange of only a few specific commodities or groups of commodities, and even here taking action usually only when the commodities are moving in interstate commerce. (The Federal participation in the examination of commercial weighing equipment can be dismissed with the statement that, in general, it is confined to certain livestock and poultry scales.)

Efforts toward uniformity. In 1905 a group of State weights and measures officials was called together in Washington by the National Bureau of Standards to consider matters of mutual interest, especially the diversity which then existed among the States in their weights and measures statutes. This group organized itself (under NBS sponsorship, which has continued without interruption) into the body that soon came to be known as the National Conference on Weights and Measures. One of the first objectives of this new body was the development of a Model State Law on Weights and Measures, to be recommended for enactment in the interest of promoting uniformity among the States. From time to time since then the Model Law has been broadened and strengthened, and the efforts to realize a greater degree of uniformity through promotion of its enactment have been intensified. Progress has been gratifying, particularly in recent years; now it is not uncommon for a State to enact the Model Law practically without change, either as its first effort in setting up a comprehensive weights and measures program or as a replacement for outmoded laws and a modernization of the statutory basis for weights and measures control.

Elements of the Model Law. Considered as a whole, the Model Law represents a coordinated group of provisions adequate to form a sound statutory basis for a broad and effective system of regulatory control, for enactment under the general police power of the State. Specifically, it deals with the following matters, among others:

1. Establishment of the State standards of length, mass, and capacity, and the verification and periodic reverification of such standards. (This action by a State is required, because the Congress has never established such standards for the entire country by Federal law.)

2. Prescription of an effective plan of organization for the State weights and measures agency.

3. Specification in general but unmistakable terms of the powers and duties of all of the officials contemplated by the law.

4. Explicit definition of the authority of the several groups of officials contemplated by the law.

5. Specification of methods of sale for particular commodities or classes of commodities, of requirements for package marking, and of the principle of sale by net rather than by gross weight.

6. Prohibition of delivery of less than the represented quantity and of false or misleading representations of price or quantity in connection with the buying, selling, offering for purchase or sale, or advertising of commodities and services.

7. Promulgation, under adequate safeguards, of rules and regulations covering technical and procedural matters not suitable for statutory treatment.

8. Definition of special and technical terms.

9. Penalties.

The Specifications, Tolerances, and Regulations. The most important of the "rules and regulations" (mentioned in item 7 immediately above) to be promulgated, under statutory authority, by the principal weights and measures officer of the State, are the codes of "specifications, tolerances, and regulations for commercial weighing and measuring devices." The development of recommended material of this kind, and its maintenance in up-to-date form have been an important function of the National Conference on Weights and Measures since its organization. This function of the Conference parallels its function relating to the Model Law. Both functions are of equal importance, although changes are required more frequently in the specifications and tolerances than in the Model Law.

In their activities in relation to specifications, tolerances, and regulations, the Conference and its committees receive technical assistance from the National Bureau of Standards, and particularly from its Office of Weights and Measures. It is part of the mission of this Division of the Bureau to employ its staff of engineers and technicians in making studies and investigations in any area associated with weights and measures standards, testing equipment, examination procedures, and technical requirements. The OWM program in this field is an active one, and results and conclusions are made available not only to the Conference but also to other interested groups.

The H44 Codes. The specifications, tolerances, and regulations adopted by the National Conference are arranged in a series of separate codes, one for each class of equipment—scales, weights, liquid-measuring devices, etc.—plus one "General Code" that applies basically to all classes of equipment. (This arrangement was adopted to avoid repetition of certain fundamental requirements.) These codes are published by the National Bureau of Standards in loose-leaf form in NBS Handbook 44, and are kept up-to-date by means of replacement sheets issued by the Bureau whenever the codes are changed by the National Conference by amendment or by addition of new language. Collectively this material is commonly referred to as the "H44 Codes."

The codes ordinarily deal exclusively with the mechanical instrumentalities of weighing and measuring. Specifications are concerned with design, construction, materials, and workmanship; tolerances are the limits of the variations from the true standards of performance or value that will be permitted by the official when he tests commercial weighing and measuring devices; regulations relate primarily to the use or maintenance of commercial devices. Specifications are intended to insure (1) that devices are so made that they may readily be used for the purposes intended without detriment to the accuracy of the results or to the interests of the buyer or seller, (2) that devices are so made that they are reasonably permanent in their indications and adjustments, and (3) that devices are not so made that they are conducive to the perpetration of fraud. Tolerances are required by reason of the fact that mechanical devices are never perfect even when new, and that they deteriorate in use; it therefore becomes necessary to countenance errors. The tolerances are based upon such considerations as the accuracy demands in the probable fields of use of the different classes of devices, manufacturing expediency, costs of refinements necessary to decrease errors, and limitations in reading the indications of the devices. Regulations are primarily directed to the owners and operators of devices, and are intended to assist in bringing about accurate weighing and measuring.

In the early days of organized weights and measures supervision, codes of specifications and tolerances were usually lacking, and in reality it rested largely on the judgment of the individual inspector whether or not a device was approved for use. As may readily be imagined, this plan led to much confusion and an almost entire absence of uniformity, even in restricted jurisdictions. It was recognized that to remedy the situation, specifications and tolerances should be reduced to written form so that all interested persons might know definitely the requirements for any particular device. This matter was taken up for serious study by the National Conference on Weights and Measures in cooperation with the National Bureau of Standards, with the idea of developing comprehensive codes of specifications and tolerances that might be recommended for general adoption, thus providing the opportunity for uniformity among the States in this important regard.

As a result, very great advances have been made in the direction of uniformity through the promulgation by the majority of the States, without serious change, of the recommendations of the Conference and the National Bureau of Standards. Moreover, this movement is still going on, newly established departments usually adopting the recommended codes as representing the most authoritative information on the subject, and older departments keeping their regulations up to date by amending them to conform to recent changes recommended, and incorporating new codes as these are developed.

Notwithstanding amendments, sometimes of a minor character, that are found necessary from time to time, particularly to keep abreast of equipment development, all of the older codes referred to may be said to be in reasonably stable form. This is to be expected, because normal procedure in the development of a new code is as follows: First, the needs of the situation, and any tentative code language that may have been drafted, are very carefully studied by members of the technical staff of the Office of Weights and Measures of the Bureau. Second, with the technical counsel of the OWM staff, formal language is worked out by an experienced committee of the National Conference. Next the proposed code is distributed for free discussion by weights and measures officials from all parts of the country and by representatives of the affected equipment manufacturers. In due time a code may be tentatively adopted by the Conference, in which case this will remain tentative for at least one year. Normally, full adoption by the Conference will ultimately take place.

Uniformity of Technical Requirements. It is fully as desirable—perhaps even more so—that uniformity prevail among the States in their technical requirements for commercial weighing and measuring equipment and in their regulations for its use as it is that there be uniformity in statutory weights and measures provisions. Weights and measures jurisdictions are urged to promulgate and adhere to the National Conference codes, to the end that uniform requirements may be in force throughout the country. This action is recommended even though a particular jurisdiction may not wholly agree with every detail of the National Conference codes. Uniformity of specifications and tolerances is an important factor in the manufacture of commercial equipment. Deviations from standard designs, to meet the special demands of individual weights and measures jurisdictions, are expensive, and any increase in costs of manufacture or servicing is, of course, passed on to the purchaser of equipment.

Another consideration supporting the recommendation for uniformity of requirements among weights and measures jurisdictions is the cumulative and regenerative effect of the widespread enforcement of a single standard of design and performance. The enforcement effort in each jurisdiction can then reinforce and support the enforcement effort in all other jurisdictions. More effective regulatory control can be brought about, and this result can actually be realized with less individual effort, under a system of uniform requirements.

Since the National Conference codes represent the majority opinion of a large and representative group of experienced regulatory officials, and since these codes are recognized by equipment manufacturers as their basic guide in the design and construction of commercial weighing and measuring equipment, the acceptance and promulgation of the codes by each State offer many important advantages.

A convenient and very effective form of promulgation successfully used in a considerable number of States is promulgation by citation of National Bureau of Standards Handbook 44.

The Status of Regulations. When Model Law provisions have been enacted in a State and regulations are promulgated in conformity therewith, the regulations have the force and effect of law and may be enforced with the same vigor and success as though they had been written into the statute by the legislature. Thus, when so promulgated, the specifications, tolerances, and regulations for commercial weighing and measuring devices become enforceable legal requirements, to be treated with due respect by all concerned with their application or affected by their provisions.

Format of the H44 Codes. In the H44 codes, every code paragraph carries an identifying symbol consisting of one or two letters and one or more numbers in decimal arrangement. Symbols may be duplicated in different codes, but positive identification of a particular paragraph is possible if its code and paragraph symbol are cited. Thus, for example, there is only one "Scales code, N.1.3.1." paragraph and only one location in H44 for a paragraph so identified. In the case of paragraphs of the General Code, each paragraph symbol is preceded by "G-", identifying the material at once as part of the General Code.

For the "specific" codes (Scales, Weights, etc.) and for the General Code a standard pattern of division into sections is followed insofar as such sections are appropriate for the particular code in question. (Each specific code opens with a paragraph entitled "General Code References" and without an identifying symbol. Such a paragraph is not strictly a part of the code, and is included merely as a helpful reminder.) The standard pattern is as follows:

A. Application.
(Paragraph symbols, A.1., A.2., etc.)

D. Definitions.
(Paragraph symbols, D.1., D.2., etc.)

S. Specifications.
(Paragraph symbols, S.1., S.1.1., S.2., etc.)

N. Notes.
(Paragraph symbols, N.1., N.1.1., N.1.2., etc.)

P. Performance Requirements Except Tolerances.
(Paragraph symbols, P.1., P.1.1., P.1.1.2., etc.)

T. Tolerances.
(Paragraph symbols, T.1., T.1.1., T.1.1.1., T.1.2., etc.)

R. Regulations
(Paragraph symbols, R.1., R.2., R.3., etc.)

The section on Application and the section on Definitions are for the information of all users of the code, and the purpose of each is adequately indicated by its title.

The section on Specifications is primarily directed to the equipment designer and manufacturer, and deals with mechanical details of commercial devices.

The section on Notes is primarily directed to the examining official, and supplies instructions on testing procedures.

The sections on Performance Requirements Except Tolerances and on Tolerances are self-defining as to their character, and are for the information and guidance of all users of the code.

The section on Regulations deals largely with the use of commercial devices and the responsibilities in relation thereto of equipment users, to whom the requirements are primarily directed.

All parts of a code, of course, are directed, for enforcement purposes, to the weights and measures official.

Chapter 5.—The Role of the National Bureau of Standards and its Office of Weights and Measures

Creation of the National Bureau of Standards. For almost 70 years immediately prior to 1901, Federal activity in the area of weights and measures was centered in the Office of Weights and Measures of the U.S. Treasury Department. The Act of March 3, 1901, created the National Bureau of Standards as the successor to that Office, but with greatly enlarged functions. The original "organic act" of the Bureau was amended in 1913, 1930, 1932, and 1950 as need arose for changing or broadening the operations of the Bureau. Originally assigned to the Treasury Department, the National Bureau of Standards was transferred to the new Department of Commerce and Labor in 1903. Ten years later, "Commerce and Labor" was divided into "Commerce" and "Labor," and the National Bureau of Standards was assigned to the Department of Commerce, where it has since remained.

The principal functions of the National Bureau of Standards with respect to weights and measures administration may be summarized by saying that the Bureau has the custody of the national standards of weight and measure, that it tests the reference standards of the States, and that through its Office of Weights and Measures it cooperates closely with State and local weights and measures officials by supplying technical information, advice on practical problems of administration, and training of personnel. These activities are not of a "regulatory" character, the Bureau having no enforcement power or authority.

Organization of the Bureau. The Bureau consists of four institutes: (1) the Institute for Basic Standards, (2) the Institute for Materials Research, (3) the Central Radio Propagation Laboratory, and (4) the Institute for Applied Technology. In general, the technical activities of the institutes are separated into "divisions," and divisions are broken down into "sections." One of the technical divisions of the Institute for Applied Technology is the Office of Weights and Measures. Other parts of the Bureau having a direct relation to weights and measures matters are the Length Section and the Mass and Volume Section, both in the Metrology Division of the Institute for Basic Standards.

Cooperation with the States. Under its statutory authority to undertake "cooperation with the States in securing uniformity in weights and measures laws and methods of inspection" the Bureau acts, through its Office of Weights and Measures, in an advisory capacity in the promotion of efficiency, adequacy, and uniformity in all technical phases of State and local weights and measures administration. There is available in the Bureau a large amount of technical weights and measures information, and members of the staff are experienced in dealing with practical field problems. This information and the results of this experience are freely offered to weights and measures officials and others interested. Upon occasion, special studies and investigations are made by the Office of Weights and Measures and by technical sections of the Bureau to develop information and procedures relative to new devices and new fields of enforcement activity.

National Conference on Weights and Measures. The National Conference on Weights and Measures is a voluntary organization, active in all matters related to regulatory weights and measures control. Its primary, voting membership is from the ranks of State and local weights and measures officers. There are two principal groups of nonvoting members, "advisory" (largely from Federal agencies) and "associate" (largely representatives of manufacturers of weighing and measuring equipment). The Executive Secretary of the Conference is a member of the staff of the National Bureau of Standards, through whom counsel, assistance, and services are supplied by the Bureau to the Conference. From the organization of the Conference in 1905 it has been sponsored by the Bureau, and close liaison between Bureau and Conference is maintained at all times.

Cooperation of the National Bureau of Standards. In the matter of special investigations that may be necessary to develop certain technical facts or experimental data essential to the intelligent consideration of some question, the National Bureau of Standards is always willing to cooperate with the Conference and is frequently called upon in this connection.

Conference Decisions. The decisions of the National Conference on Weights and Measures are purely recommendatory. A code of specifications and tolerances, for example, or a model law that has been adopted by the Conference, can have no effect in any given jurisdiction until it is promulgated or enacted by competent authority within and for that jurisdiction. However, the reputation of the Conference for making only reasonable and proper recommendations is so well established that even many jurisdictions that never find it possible to be represented by delegates at the sessions of the Conference accept the conclusions of the Conference as expressing the best thought upon a given subject, and, at the earliest convenient opportunity, take the necessary steps to put those conclusions into effect. In some States provision has been made for the automatic acceptance of specification material adopted by the Conference, unless this is specifically modified or rejected by the State. Thus, through voluntary cooperative effort on the part of weights and measures officials, both those who find it possible regularly to attend the Conference sessions and those who are prevented from attending, the National Conference on Weights and Measures is, in fact, effective in realizing its objectives.

Bureau Relations with Individuals. In addition to its contacts with the National Conference on Weights and Measures, the Bureau maintains direct relations with individual State and local weights and measures agencies and officers in technical areas where information or assistance is sought from the Bureau by these groups or individuals. Requests range from the U.S. equivalent of some foreign unit of weight or measure to the drafting of a regulation or the design of a new piece of testing apparatus. Every effort is made to be of maximum practical help to the regulatory official. Not infrequently similar services are rendered to equipment manufacturers, often in the interpretation of technical requirements and in resolving problems arising from regulatory controls.

In its role as a service agency for weights and measures officials, the Office of Weights and Measures often finds itself engaged in extensive engineering studies in the laboratory or in the field or both, to develop the underlying facts or performance data needed for the solution of some seemingly simple problem of statistical treatment, examination procedure, or specification language. Such studies may lead to the evolution, design, and pilot construction of some new piece of testing apparatus, satisfying a need not otherwise met or doing some job more effectively, more economically, more simply, more safely, or easier than before.

Requests for Assistance. Through the meetings of the National Conference and through its publications, as well as by word of mouth, the Office of Weights and Measures tries to publicize the results of such studies as are discussed immediately above. However, it is not practicable to reach every ear and eye, and memories are short. It is urged, therefore that when technical problems arise, when new testing apparatus is to be procured, when new programs are to be undertaken, the regulatory officer get in touch with the Office of Weights and Measures. Information already on hand, designs already drawn, patterns already established—all available to him on request—may save the official time, money, effort, and perhaps even a few headaches.

Correspondence is welcomed, and every effort is made to supply helpful information on specific questions and to suggest remedies for particular problems. Not infrequently the assistance rendered by correspondence lies in citing publications or other sources from which the desired information may be obtained. At times publications of the Bureau can be supplied, particularly to new officials, some of these (such as the weights and measures Handbooks) having been specially prepared as training manuals.

It is from the background outlined that there have evolved the EPO's presented earlier herein.

Training Provided by OWM. The Office of Weights and Measures has specialized in the development of a training program for State and local officials. The program has two prime objectives: (1) To increase the technical efficiency of the regulatory officer and thus to increase the effectiveness of his official activities. (2) To promote uniformity of procedures among State and local jurisdictions.

Depending upon circumstances, training may be brief or extended, it may be provided upon an individual or group basis, it may be conducted in Washington or at some field location, and it may be planned and conducted by OWM personnel or OWM may merely advise with a

State Director on the details and agenda of a school to be conducted by him.

Individual Instruction at Washington. New officials, both administrators and technicians, may come to the Office of Weights and Measures in Washington for limited periods for a series of discussions or laboratory sessions covering the entire field of weights and measures supervision or any particular phase thereof on which help is desired. These programs of instruction are flexible and informal and are adapted to the need in each particular case; they are especially helpful to newly appointed heads of weights and measures units and their principal assistants, and to specialists such as laboratory technicians and field supervisors. However, it is necessary to restrict the number of persons receiving training at any one time, and the programs must be fitted into the general schedule of activities of the Bureau personnel at such times as to avoid undue interference with or interruption of the regular work of the Bureau. Neither facilities nor personnel are available for a large program of this kind.

Instruction Within the State. Within the limitations of available funds and of other commitments of its limited personnel, the Office of Weights and Measures will arrange, upon request, for a representative to spend one or several days in a State office discussing with a newly appointed chief and his principal assistants (or, for that matter, with any such officials, whether or not newly appointed) any matters with regard to which it is felt that the Bureau representative can be helpful. Within the same limitations, the Office of Weights and Measures will, upon request, arrange to conduct a training school at some suitable location within a State, to be attended by all of the weights and measures officials of the State. Depending upon the particular need, such a school may be planned to cover the highlights of the entire area of weights and measures supervision, to be followed by subsequent schools devoted to the intensive and detailed study of special phases of mechanical or supervisory activity; or the curriculum of the school may be directed to some form of activity about to be undertaken or to some one or more matters of special current concern or interest to the jurisdiction in question.

Again within the stated limitations, it is possible for the Office of Weights and Measures, upon request, to arrange for field demonstrations of testing equipment and techniques for particular classes of commercial devices or even to conduct general field training for small groups of inspectors.

Training Schools at Washington. Finally there is the one-week or two-week formal school conducted by OWM on the Bureau premises for senior personnel in groups of 10 to 15 participants. Prerequisites to registration are set up, a heavy schedule is adhered to, oral and written examinations are prescribed, student participation in practical exercises is required, and concentration and hard work are the daily order.

State Training Schools. Useful training schools can also be conducted successfully under State auspices alone with (if deemed advisable) guidance from OWM as to school content, training aids, and the like. A systematic program of training schools, planned and carried out under the direction of the State weights and measures office, is highly desirable. Such schools can be utilized for instructing new officials in the fundamentals of their jobs and in the performance of their daily tasks. They can also be utilized for the instruction of old and new officials in new techniques, new laws, new regulations, new forms, special surveys and investigations, and for the consideration of any new procedures or any program, instruction, or interpretation that is new to the group. Another very important purpose of the training school is the periodic review of prescribed procedures that presumably are in effect but with respect to which deviations have gradually and inadvertently grown up among the officials; this sort of retraining will restore uniformity throughout the jurisdiction, a consideration of major importance. It is here that training manuals such as the present publication should prove to be particularly valuable.

Some Observations on Training Schools. The more technical the subject matter on the agenda of a particular training school, the more important is it that the school group be kept small. For technical sessions, twenty is suggested as a maximum number for best results; it is considered far more effective to hold several schools with identical subject coverage for groups of reasonably small size than to attempt to handle these technical subjects in a single large class.

The distinction between a training school and the sessions of an ordinary meeting of a weights and measures association lies partly in the character of the subject matter offered to those in attendance and very emphatically in the manner in which that subject matter is offered. In the association meeting the speakers deliver their papers or present their talks, usually treating the broader aspects of their subjects and avoiding mathematical and other technical details. There may (and should) be enough discussion following the speaker's presentation to clear up pertinent questions and leave the audience with a clear conception of the speaker's ideas; however, the audience normally is present merely to listen, to get new ideas, to be introduced to new and interesting subjects related to their professional field, and to receive general instruction.

In the school, however, the primary effort is to *teach*, to *train*, to make certain that each member of the class not only understands what is being taught but acquires competence to *do* what is taught, in the manner prescribed, when he returns to his normal sphere of independent activity. The school demands of the instructor clear initial presentation, repetition of explanation and instruction from different viewpoints and in varied terms, demonstration whenever appropriate, meticulous attention to detail, patience in dealing with those slow to understand, and ingenuity in devising methods of drilling the students so that the lesson may be fixed in their minds by their actually doing, perhaps over and over, whatever is being taught. Obviously, all of this requires on the part of the instructor careful technical preparation and teaching ability and knowledge.

Chapter 6.—Reference and Field Standards and Field Equipment

The Variety of Standards. The character of the various weights and measures standards, the materials of which they are constructed, their design, their finish, differ according to the use intended for them. In their material aspects these standards range from the finest that science can design and that the best workmen can produce, as demanded for the primary standards of a nation, to the relatively crude examples of commercial weights and measures that adequately meet the demands of ordinary trade. Thus the primary standard of mass (or weight, as it is commonly called) of the United States is a cylinder of specially prepared platinum-iridium alloy; the primary "working" standard of length is a bar of similar material and of unusual cross section, the defining lines being so finely engraved that a microscope is required for observing them. From standards of this high order there extends a long sequence of standards of successively lesser refinement, until finally we reach the cast-iron weight and the sheetmetal measures of trade.

Throughout this long succession of standards of varying classes, however, there is maintained an unbroken sequence of contact from the highest to the lowest. Were this not true, were there any points where the line of official contact became broken, no one could say that the pound at the merchant's counter was actually a pound, or that the yard was actually a yard. It will be appropriate here to review the many steps necessary before a fundamental National standard is translated into a quantity of merchandise in the hands of the consumer.

Federal Standards. Taking the standard of mass as an example, the sequence begins with the *primary standard of the United States,* the prototype kilogram preserved at the National Bureau of Standards, the value of which, in terms of the International Standard Kilogram, is known with high precision. (There is a recognized relation between the kilogram and avoirdupois-pound units. As published in the Federal Register of June 30, 1959, the National Bureau of Standards announced that effective July 1, 1959, calibrations carried out by NBS would be based on the exact equivalent, 1 pound (avoirdupois)=0.453 592 37 kilogram.)

The national primary standard is used but rarely, and then only to standardize the *laboratory standards of the mass laboratory of the Bureau.* The laboratory standards of the Bureau are used in the frequent checking of the values of the *Bureau's working standards,* which in turn are used in the testing of weights submitted to the Bureau for examination.

State and Local Standards. One of the important classes of weights submitted to the National Bureau of Standards for test comprises the *primary standards of the several States,* and when these are tested their corrections are determined and reported to the State. Returned to the custody of a State, the State primary weights are expected to be used, with their corrections, within the State in a manner corresponding to that followed at the National Bureau of Standards with respect to the national primary standard; that is, they should be used occasionally to test the *laboratory standards of the State.* These latter standards should, in turn, be used to prove the *State working standards,* including the field standards of the State inspectors, and the *laboratory or the working standards of the cities and counties* throughout the State. In addition to their use for the testing performed in the field, the working standards of the State are available for use in the laboratory for testing commercial apparatus, and in other laboratory work not demanding a very high degree of precision.

In addition to its laboratory standards if these are provided, the city or county department of weights and measures will have its field equipment, or *working standards,* which, on account of the hard service to which they are subjected, will frequently be checked against the local reference standards, or will be returned to the State department for reverification in case local reference standards are lacking. The field equipment, of the State or local department is carried to the establishments of industry and trade, there to be used directly in the testing of the *weights and weighing devices in commercial use.* The last step is the use of this commercial equipment by the trader in the buying and selling of merchandise.

Considering the foregoing, it must be apparent to even the most casual observer that the variations that may safely be permitted upon any test throughout the long list given are small, and that the greatest care must be exercised at all points to preserve the integrity of the standards themselves.

Specifications and Tolerances for Standards. Specifications and tolerances are issued by the National Bureau of Standards for the standards of weight and measure of the States, and when procuring weights and measures to serve as State standards, compliance with these specifications and tolerances should be demanded. (Manufacturers of standards are entirely familiar with these requirements, which are of a technical character. Anyone having need to know the details of these requirements should communicate with the National Bureau of Standards, specifying the types of standards in which he is interested.) Similarly, the State office should prescribe the specifications and tolerances to be met by the laboratory and working standards of the local jurisdictions under its control. Preferably, local laboratory standards should conform to the requirements for State laboratory standards, and local working or field standards should, of course, conform to the requirements for State working or field standards. It should be unnecessary to say that all standards should be thoroughly examined periodically to insure that they meet the requirements that have been set up.

Sealing and Certification of Standards. The fact that a standard or a particular set of standards has been found to conform to the requirements applicable to it should always be attested in a suitable manner. For standards of the lower orders this attestation may properly be limited to marking or "sealing" the standards themselves, especially in those cases in which the design of the standard is such as to provide an appropriate surface to receive the mark or seal. For standards of the higher orders, such as reference and laboratory standards or other standards of high precision, the issuance of informative certificates is recommended, and it is suggested that certificates can be used to advantage clear down to field standards. In the case of reference and laboratory standards, the availability of a specific certificate or other written record covering each periodic determination of the value and overall suitability of the standard or set of standards may be especially valuable in quickly resolving formal questions on the validity or legality of the standards. And even the field inspector may from time to time have opportunity to make impressive use of a certificate covering his working standards, when he is asked the pointed question, "How do you know that your standards are accurate?"

Calibration of Standards. The National Bureau of Standards calibrates the primary reference standards of the States without charge. After the initial calibration of State primary standards, these should be returned to the National Bureau of Standards for recalibration at regular intervals of about 10 years; the law of the State usually specifies this interval, and the provisions of the law should, of course, be observed. The periodic retesting of standards of lower order, of both State and local offices, is of no less importance, and should be carried out by the State or local office at frequent intervals; the frequency of these tests will be determined by the design and material of the standards and the amount and character of use to which the various standards are subjected. It may be mentioned here that in the case of any standard, a retest before further use should be made whenever any accident occurs or other condition develops that casts any suspicion upon the accuracy of the standard.

Examinations of the standards of cities and counties are supposed to be made by the State office, and this course should always be followed whenever the State is in a position to do this work. In those States where there is no State office equipped to do the testing, it will be necessary, in order to establish the authenticity of the local standards, that they be sent to the National Bureau of Standards for test. (In the case of cities and counties, the organic act creating the National Bureau of Standards requires that a reasonable fee be charged for the work of verifying standards. A schedule of the fees may be obtained upon request.)

Recommended Standards and Equipment. A schedule of weights and measures standards and equipment advisable for a particular class of weights and measures office and under a stated set of fiscal and administrative circumstances may be obtained from the Office of Weights and Measures of the National Bureau of Standards. Certain items of standards and equipment are somewhat less essential than others, particularly for a newly organized department or office. This distinction is made because frequently funds for complete equipment are not available at the time of the organization of an office, and it is desirable for the new official to be informed as to what items of equipment are most necessary; moreover, the new office is usually fully occupied for a time with taking care of the mechanical condition of the more common types of weighing and measuring devices, and does not have the time fully to cover the entire weights and measures field. However, if funds are available for completely equipping an office with all of the standards and equipment recommended, this should be done by all means, so that the office may at once be in a position to render complete weights and measures service.

Since weights and measures supervision is a highly specialized service, specialized equipment is demanded. Furthermore, the fundamental character of this service and its great importance to all elements of a community require that this equipment be of unquestioned good quality. By reason of its special character and the limited market for it, and because of the precision required in its manufacture, weights and measures equipment of good quality is necessarily expensive; this fact should not, however, cause officials to purchase such equipment purely on a price basis, sacrificing quality on the altar of a false economy. It is far better for a weights and measures office to have a slightly smaller amount of the best equipment than to be fully equipped with standards and apparatus of doubtful quality and permanence.

Special Equipment. It should also be borne in mind that, while certain special classes of the official's work may be carried on with regular equipment designed primarily for other purposes, not infrequently such work may be performed in a much more satisfactory and efficient, and, perhaps, in a much more precise manner, with special equipment designed for that particular purpose. Another consideration in support of adequate equipment for every purpose is the very unfavorable impression created in the minds of the public if the weights and measures officer must resort to makeshift methods every time a slightly unusual situation develops, and the contrary impression created by well-designed equipment of

Field set of "cube" weights.

The kit contains fourteen 2-pound weights, two 1-pound weights, and a box containing fractional-pound weights ranging from 8 ounces to 1/16 ounce. It is designed particularly for the general testing of scales of small capacity, but is a pivotal standards item for the entire testing and checking program.

good appearance, obviously well suited to perform the particular service in which it is being employed.

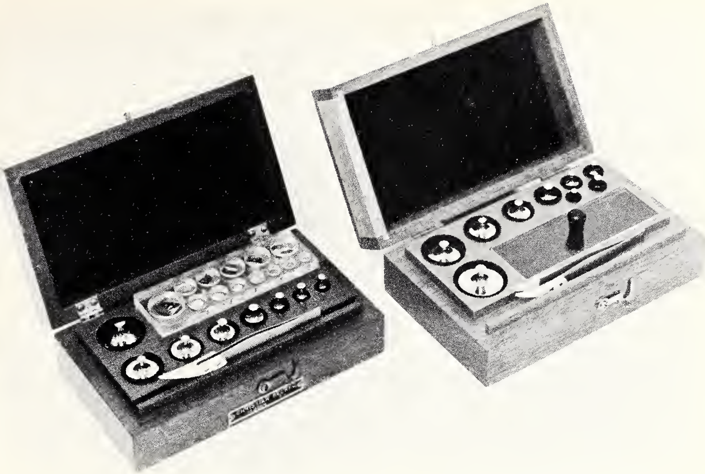
With respect to certain major items of special equipment (such as vehicle-scale testing units, for example) a special procurement problem may arise in that the item cannot be bought "from stock" or even on the basis of "stock" or standardized designs and specifications. Faced thus with the necessity of having his equipment built to

Sets of standard weights in denominations of decimal subdivisions of the pound.

In each set the denominations are 0.3, 0.2, 0.1, 0.05, 0.03, 0.02, 0.01, 0.005, 0.003, 0.002, 0.001, and 0.001 pound. These are especially designed for use in the ratio-testing of scales, the testing of scales graduated in decimal fractions of the pound, and the checking of packaged commodities.

special order, the official may proceed largely on the basis of his own knowledge alone, to design and engineer the equipment; not infrequently it happens that the resulting piece of equipment would have been materially improved, or its cost materially reduced, if the official had had the benefit of experience developed in other jurisdictions with equipment for a similar purpose. Since the Office of Weights and Measures of the National Bureau of Standards is, in general, well informed on the activities of weights and measures departments throughout the country, it is in a good position to make helpful suggestions on the design and construction of special testing equipment for weights and measures purposes. It is urged, therefore, that officials planning to procure new items of special equipment consult with the Office of Weights and Measures before deciding on the design for such items.

Adequacy of Testing Equipment. Proper testing equipment is obviously a prerequisite to the proper testing of



Sets of grain and metric standard weights for testing small scales of special design (prescription, jewelers, etc.) and weights.

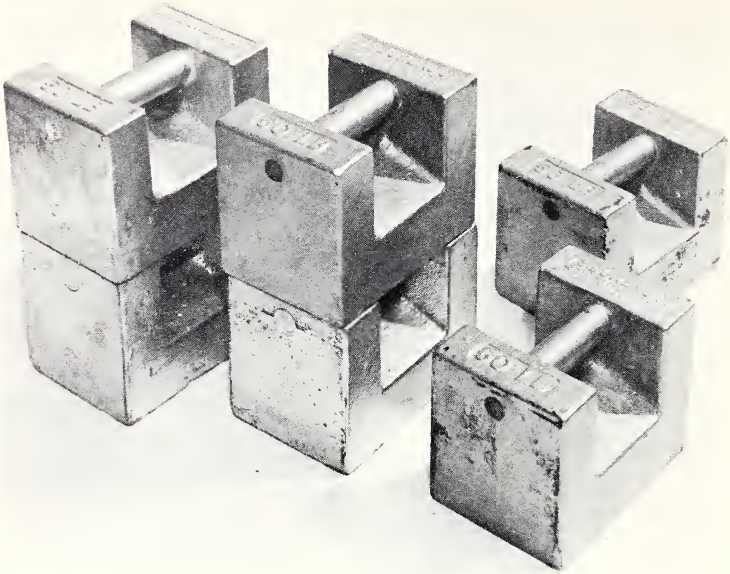
The grain set (left) ranges from 0.1 to 1000 grains; the metric set ranges from 1 milligram to 100 grams.

scales. Such equipment can be considered to be proper and adequate only if it is suitably designed for testing purposes, sufficiently accurate for the class of service in which it is being used, and adequate in amount to permit ready realization of testing objectives and to facilitate testing procedures. It should be so constructed that it will retain its characteristics for a reasonable period under conditions of normal use, it should be available in denominations and types appropriate for the determination of the value or performance of the device under test, and it should have been accurately calibrated.

Inadequacy of testing equipment is by no 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.

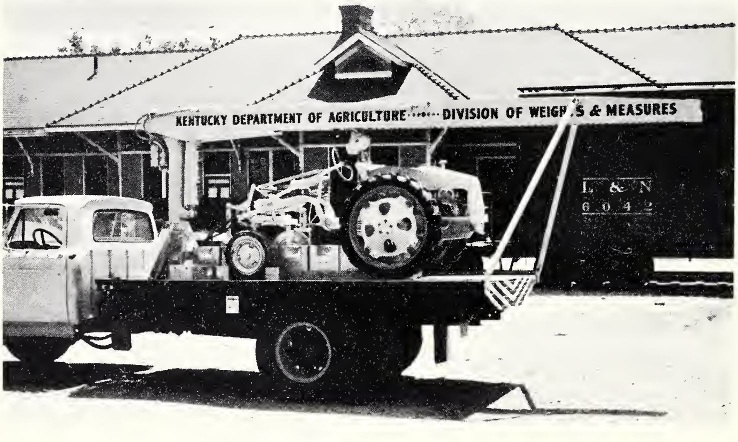
The needs of the case may be stated briefly as follows:

1. Standard weights should be provided:
   (a) In suitable denominations to permit of (1) the direct testing with test weights of all desired



50-pound cast-iron test weights.

The handles are hollow and provide space for adjusting material. The closure of the adjusting cavity is a screw plug covered by a lead cap, on which the approval seal is stamped.



A livestock-scale testing unit.

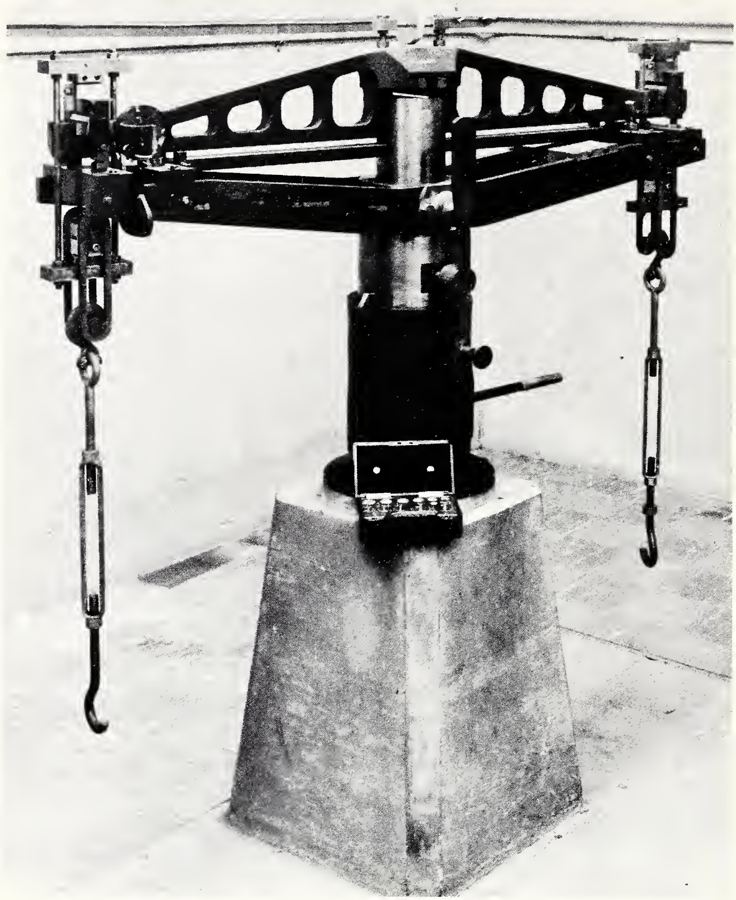
This unit has a telescoping boom, a power-operated hoist that handles two 1000-pound weights at a time, and a special tractor unit for moving weights after unloading from the truck.

A vehicle-scale testing unit.

This is a fully power-operated unit utilizing 2500-pound (and smaller denomination) test weights. The battery-powered dolly is for positioning test loads on a scale platform, and is itself standardized at 2500 pounds.

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 20,000 pounds capacity.



1000-pound equal-arm balance designed by H. H. Russell, NBS, for calibrating test weights.

Loads may be reversed for transposition weighing by rotating the balance through 180°. Loads are applied by raising the fulcrum support by means of a hydraulic jack.

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 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 deemed proper (by appropriate authority) for the inspector to make.

Accuracy of and Corrections for Standards. It has long been accepted as a general principle that the error on a standard used by a weights and measures official should either be known and corrected for when the standard is used or, if the standard is to be used "without correction," its error should be not greater than 25 percent of the smallest tolerance to be applied when the standard is used. The reason for this is to keep at a minimum the proportion of the tolerance on the item being tested that will be "used up" by the error of the standard. Expressed differently, the reason is to give the item being tested as nearly as practicable the full benefit of its own tolerance.

Field testing operations are complicated to some degree when corrections to standards are applied, and except for work of relatively high precision it is recommended that the accuracy of standards used in testing commercial weighing and measuring equipment be so established and maintained that the use of corrections is not necessary. Also, whenever it can readily be done, it will be desirable to reduce the error on a standard below the 25-percent point previously mentioned.

The accuracy of testing apparatus should invariably be verified prior to the initial use of the apparatus and should be checked periodically thereafter, particularly following an accident involving the apparatus.

Maintenance and Use of Testing Equipment. Having procured suitable and adequate equipment, it becomes the continuing duty of the official to maintain that equipment in proper condition. There are three kinds of maintenance—maintenance of accuracy, maintenance of good operating condition (in the case of mechanical equipment), and maintenance of appearance. As to the first, there should never be any doubt of the accuracy of the weights and measures standards used by the official; this is fundamental. If there be any suspicion of inaccuracy, immediate steps should be taken to resolve the doubt, and if the suspicion proves to have been well founded, adjustment, repair, or replacement, as the case may require, should promptly be made.

Weights are made from or coated with metals selected for resistance to corrosion and wear that might affect their masses. Nevertheless, special precautions should be observed in handling and using standard weights, for every effort should be made to guard against even very slight changes in their values, changes that may be multiplied manyfold before the final effect is reached, and that may be reflected in a departure from standard throughout an entire community. It follows that the higher the class of the weight the greater protection it should be accorded. Specifically, State primary standards and State and local laboratory standards should never be touched with the hands, but should always be handled by means of the special lifters provided for that purpose; the accumulation of dust or other foreign material should be prevented; moisture and corroding gases should be excluded from contact with these standards; and the greatest care should be exercised to prevent any abrasion or scratching of the bottom or any other surface. Such weights should always be kept under glass or in a closed cabinet when not in use, and in use they should be handled most carefully and should rest upon a freshly cleaned surface. Should there be required any cleaning of these standards, the greatest care should be exercised to avoid any damage to the surfaces being cleaned; any accumulation of dust should be gently removed with a soft camel's-hair brush, and if rubbing with gauze or cotton is a necessity, gauze or cotton should be moistened with alcohol or distilled water and the rubbing pressures should be kept at a minimum.

Similar precautions should be observed in the case of laboratory standards, although the requirements are not so strict. It is advisable to avoid handling these standards (except those reserved for testing commercial scales and weights) with the bare hands, the use of the special lifters being recommended in all cases.

Field standards must, as a matter of expediency, be handled without lifters, but care should be exercised to avoid any accumulation of moisture, dirt, or other foreign material on the weights, and cleaning should be performed without abrading or scratching the weights in any way. Particular attention should also be given to avoiding any tendency to slide the weights about, for this will cause wear and consequent loss of material; when it becomes necessary to move a weight it should be lifted and set down gently in its new position. To avoid heavy condensation of moisture on small weights used by field inspectors during winter months in cold climates, it is suggested that steps be taken to keep the temperature of the weights reasonably close to indoor working temperatures; this can be accomplished if the weights are stored indoors whenever they are not in use for several hours or more.

It should always be borne in mind that when any standard is being used it represents, for the moment at least, the last word in precision, and that everything that may be done to preserve the accuracy of that standard should be done.

Standards and Equipment of Service Agencies. As a corollary to the preceding discussion, there may be noted the lack of attention to the accuracy and adequacy of their working standards and equipment that is displayed by some repair agencies and servicemen. Accurate and dependable results cannot be obtained with faulty and inadequate standards, and if the servicemen is inadequately equipped, it cannot be expected that his work will be wholly satisfactory or that his results will check consistently with those of the properly equipped weights and measures official. Disagreements between serviceman and official can often be avoided, and the servicing of commercial equipment can usually be expedited and improved, if servicemen and officials give equal attention to the adequacy and maintenance of their testing apparatus.

Appearance of Testing Equipment. As to maintenance by the official of the good appearance of his equipment, this is considered to be second only to the maintenance of accuracy. The standards of the weights and measure officer, his balances, his tools and carrying cases, in brief, his entire equipment, should be of such appearance as to inspire confidence in the minds of all, not only with relation to the integrity of the standards, but also with relation to the ability and carefulness of the official himself as disclosed by the appearance of his testing equipment.

Chapter 7.—A Further Look at Inspection and Testing

In this further look at the two main branches of the mechanical examination of weighing equipment, numerous points merely mentioned or given brief treatment heretofore will be considered in some detail.

General Considerations. Inspection and testing are closely allied, and at times the line of demarcation is very indefinite; but, in general, inspection may be defined as that portion of the examination of a piece of apparatus conducted independently of the physical standards of weight, while testing is that portion of the examination involving the use of such standards. Or, in other terms, inspection is largely directed to determining compliance with the requirements of the "specifications" and the "regulations" of the official codes, whereas testing is specifically directed to determining compliance with the "performance requirements" and the application of the "tolerances" of those codes. This distinction is recognized by the codes themselves; a commercial device is said to be "accurate" if it "conforms to the standard within the applicable tolerances and other performance requirements," and is said to be "correct" only "when, in addition to being accurate, it meets all applicable specification requirements." The loose usage whereby the term "inspection" is understood to embrace everything that the official has to do in connection with commercial equipment is rather common and is to be discouraged, and consistent discrimination between inspection and testing is recommended. To assist in this discrimination, the overall operation is called "examination" in this publication, leaving "inspection" for use in its limited meaning, as here set forth.

Inspection is particularly important, and should be carried out with unusual thoroughness, whenever the official examines a type of equipment not previously encountered. But even a type of device with which the official is thoroughly familiar and which he has previously found to be in agreement with the specifications should not be accepted entirely "on faith." Some part may have become damaged, or some detail of design may have been changed by the manufacturer, or the owner or operator may have removed an essential element or made an objectionable addition. Such conditions may be learned only by inspection. Some degree of inspection is, therefore, an essential part of the official examination of every piece of weighing equipment.

The Purposes of Inspection. The principal purposes of inspection may be enumerated as follows:

1. To insure that the requirements of the code of specifications are met (design, construction, materials, finish, marking, and the like) ; and, in the case of apparatus previously examined, to insure that no additions or alterations that might adversely affect official approval have been made by the operator since the preceding inspection.

2. To insure that working parts are in the proper condition to function as intended, to determine whether or not there are indications of abuse or of a lack of proper attention on the part of the operator, and to establish the facts upon which to base any needed recommendations for improved maintenance designed to improve performance or prolong the useful life of the equipment.

3. In the case of unfavorable test results, to aid the official in determining the source or underlying cause of the trouble, thus enabling him to discuss more intelligently with the operator the steps necessary to a proper remedy.

4. To insure that there exists no unusual condition external to the apparatus that may be conducive to inaccuracy or to the perpetration of fraud.

5. To assist the official in checking compliance with applicable regulations (as distinguished from specifications).

Inspection for Specification Compliance. The necessity for inspection for the first purpose mentioned must be at once apparent. The specifications set up certain standards, and it is the duty of the official to require that these standards be met by the apparatus in his jurisdiction. In the case of a new type of device—as, for instance, a new model of a weighing scale—the inspection will naturally be made much more carefully and thoroughly than in the case of devices of a type that has previously been examined. If the new device in question has been submitted for examination to the office of the weights and measures official, the inspection can be made more conveniently and probably more effectively than a similar inspection in the field; but if the new device is encountered in the field for the first time, the inconvenience of making a thorough inspection should not be permitted to influence the official to slight this important duty. Should the device prove to be unsatisfactory, it will be found much easier to control the situation if this fact is discovered promptly and suitable action taken before the devices have secured a foothold by reason of numbers of them having been put into use in the territory in question.

In making a first inspection of a new type of device, the official should consider first what specifications are applicable to it; then, with the written specifications before him, he should examine the device with reference to the provisions of each paragraph of the specifications referred to. A record should be made of the results of the inspection, with detailed notations in relation to any points of noncompliance with the requirements. This record should be preserved as the basis for any future actions of the official with respect to the device.

It is sometimes felt by weights and measures officials that, once having made a thorough examination of a certain type of device, no further inspection of similar devices will be necessary when these are encountered in the field. It is true that subsequent inspections need not be so detailed in character as the first one, but by no means should they be omitted entirely. In the first place, conditions of use may bring out objectionable features of design, poor workmanship, or faulty materials that were not apparent upon first inspection, however carefully it may have been made. In the second place, manufacturers find it expedient from time to time to make modifications in the devices that they manufacture, and the devices so modified may or may not conform to specification requirements. Again, the user of a device may make or cause to be made changes that may create very unsatisfactory conditions; whether such changes are made with good intentions or, as may rarely happen, with a desire to provide a means to defraud, the official should become advised of the situation. In each of these cases, regular inspection of the devices examined offers the official the means of keeping informed on the general mechanical condition of the equipment so that corrective action can be taken whenever needed.

It should be emphasized that when an unscrupulous operator sets out to modify a piece of equipment so as to make it easier for him to practice fraud or so as to enable him to obtain a greater advantage than he could otherwise obtain, he is very apt to display considerable ingenuity in concealing traces of his attachment or modification; it therefore behooves the official to observe the greatest care in making his inspections whenever he has any suspicion that fraud is being practiced. It should also be mentioned that changes in or additions to a piece of apparatus may sometimes be made with the best of intentions and for a perfectly legitimate purpose by persons who do not understand the equipment or appreciate all the effects of doing certain things to that equipment. Such alterations are frequently found to have a most serious effect upon the accuracy of the apparatus and its suitability for commercial use.

Inspection should be extended beyond the weighing or measuring device itself to include any auxiliary equipment the performance of which has a bearing upon the performance characteristics of the instrument under examination or that has any weights and measures significance in relation to the operation of that instrument.

Inspection for Operating Condition. In relation to the second purpose of inspection, it should be borne in mind that a weighing scale is but a machine, and that it requires intelligent care if it is to continue to discharge its intended functions; similarly, that even a weight cannot retain its accuracy if subject to abuse. There are occasions when for particular purposes, an inspector will wish to determine the value or performance of a piece of equipment that is not in proper condition for use but is, nevertheless, being used commercially in that condition; however, in the course of normal routine examinations it would be foolish for the official to spend his time testing a device the parts of which were disarranged, broken, or otherwise out of operating condition. If these conditions were the result of lack of attention or of misdirected effort on the part of the owner or operator, the official would be remiss if he did not caution the careless man and instruct the ignorant one. Inspection becomes necessary, therefore, to enable the official to discover any improper maintenance conditions that may exist, and to take the necessary steps to have such conditions corrected and prevent their development in the future. Moreover, an important service may be rendered to those equipment owners who, through ignorance of proper maintenance measures, suffer their equipment to deteriorate at a rapid rate, by giving them instructions in maintenance methods and thus assisting them to prolong the useful life of their equipment.

Inspection to Locate Cause of Inaccuracy. In relation to the third purpose, it has been said that in the case of unfavorable test results inspection is made to aid the official in determining the source of underlying cause of the trouble so that he may intelligently discuss remedial measures with the operator. Here, again, is met the much-discussed problem of how far the official should go in the direction indicated. Many officials are inclined to take the stand that their statutory duty is to test commercial equipment, approve it if it is found accurate, and reject it if it is found inaccurate, and that to go further that this is unnecessary and inadvisable. Notwithstanding this statutory provision, however, it is submitted that the official who stops with the mere statement to an operator that his equipment is inaccurate, with an unwillingness to discuss with him the probable sources of the inaccuracy, is not doing all that may properly be expected of him, and certainly is not capitalizing upon all of his opportunities to be of service to his community. The conscientious official will not be completely satisfied until he has made a reasonable effort to be of maximum assistance to the operator, even to the extent of discovering for himself the underlying reasons for the faults that his examination has disclosed and discussing with the operator ways of avoiding their recurrence.

Inspection of Environment. The fourth purpose of inspection—to insure that there exists no unusual condition external to the apparatus that may be conducive to inaccuracy or to the perpetration of fraud—is to disclose external conditions that may be equally as important as faulty conditions in parts of the mechanism under test. Currents of air upon the under or upper sides of a scale platform, insecure supports for a counter scale, and conditions in a scale pit, are some examples of the factors entering into the ultimate performance of commercial weighing devices that must be learned through inspection and that the efficient official should take into consideration in connection with his examination of the apparatus that is under his control.

Inspection for Regulation Compliance. The final purpose of inspection has been said to be to assist the official in checking compliance with applicable "regulations," that is, those requirements that are directed to the owner and operator rather than to the commercial equipment itself. During the inspection of the equipment and its environment, clues may be discovered or definite evidence found that will point the way to establishing a violation of regulations that might not otherwise be brought to the attention of the official.

Misuse of Equipment. Inspection, coupled with judicious inquiry, will sometimes disclose that equipment is being improperly used, either through ignorance of the proper method of operation or because some other method is preferred by the operator. Equipment should be operated only in the manner that is obviously indicated by its construction or that is indicated by instructions on the equipment, and operation in any other manner should be prohibited.

Recommendations Based on Inspection. A comprehensive knowledge of each installation will enable the official to give to the owner constructive suggestions regarding the proper use and maintenance of his equipment and its suitability for the purposes for which it is being used or for which it is proposed that it be used. Such recommendations are always in order and may be very helpful. The official should, of course, avoid showing any partiality toward or against equipment of a particular manufacturer or a particular service agency, and should be very careful to confine his recommendations to matters upon which he is qualified, by knowledge and experience, to make suggestions of practical merit.

Inspection Details. The inspection of scales having now been discussed in rather general terms, there follows below a more detailed discussion (with limited repetition of items mentioned heretofore), presented largely as a sort of checklist.

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 here 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 condition.—
- 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, 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

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 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 of 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 that 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. (Except for scales designed for "dead beat" operation—that is operation without indicator oscillation—the adjustment should be such that when any load is applied, the indicator will swing from three to seven times before coming to rest; 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.)

The operations of application and removal of unit weights (drop weights) on automatic-indicating scales are positive, and that the value of the unit weights in place at any time is clearly indicated on the reading face.

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 or regulation 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.

The Purpose of Testing. 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 conditions of average use. The official will, therefore, try in his test to approximate service conditions of operation, and any method of use that may reasonably be employed in service may, with propriety, be duplicated in the test.

Check Observations. In general, the official should not base his finding upon single observations under the different conditions or at the different stages of his test. Replicate 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.

Outside Influences. During the progress of a test a constant effort should be made to eliminate the effect of outside influences. Otherwise, a result due to some external condition may be ascribed to imperfection in the device under test. Thus, for example, the effects of wind upon a platform scale might seriously prejudice the test results of the official who is not alert to such a possibility.

Analysis of Test Results. The official should also be cautioned against "jumping to conclusions" before he has made a careful analysis of the test results and of any other facts that 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 doubt, for example, that 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. The unfortunate part of this 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 symptom may well be borne in mind in this connection. In short, the adjustable features of a weighing device should never be used 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 disclosed by the test.

An exception to the foregoing recommendation for complete test data and analysis of test results is made when, on routine examination, some serious condition is found on either inspection or test that makes it imperative that the scale be rejected for reconditioning or repair regardless of what might be disclosed if the examination were to be carried to completion. In this case the examination can properly be terminated at once, with a saving of time and effort—unless it is felt that complete test results are needed to prove the sort of performance that the scale has been giving prior to the inspector's visit, for possible court action or for some other reason.

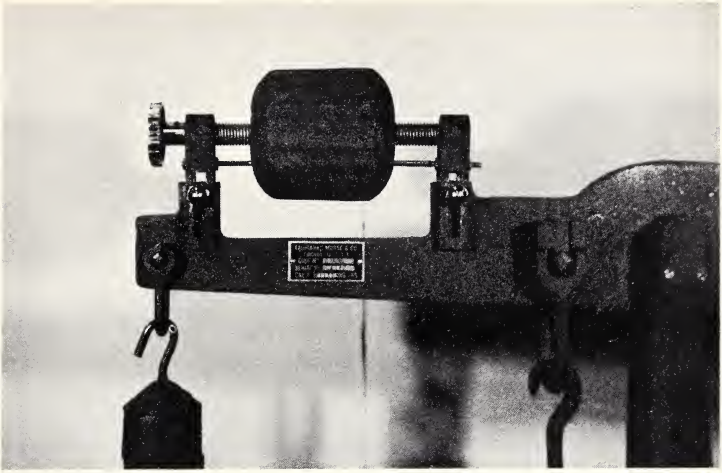
Recording Results. Theoretically, the official should record the results of every test for two reasons: First, so that he may have the data at hand to study the performance of the device that has developed inaccuracies and, to the extent indicated, to determine the reasons therefor.

Second, so that he may have a complete record for his files of the work that he has done and of the performance of the devices that he has examined; such a record may prove invaluable at some future time. As a practical matter, however, written records of the details of test results are seldom needed for the simpler types of scales, and may safely be omitted on routine tests. This does not hold true for referee tests of any kind or for routine tests of vehicle and livestock scales; in all these cases full test data should be recorded and filed.

Accurate and Correct Equipment. The weights and measures official is reminded that commercial equipment may be "accurate" without being "correct." A device is deemed "accurate" when its performance or value—that is, its indications, its capacity, its deliveries, its registrations, its actual value, etc., as determined by tests made with suitable standards—conforms to the standard within the applicable tolerances and other performance requirements. Equipment that fails so to conform is "inaccurate." A device is "correct" only when in addition to being accurate, it meets all applicable specification requirements; and if it fails to meet any of the requirements for correct equipment it is "incorrect." Only equipment that is "correct" should be sealed and approved for commercial use.

Testing Details. Certain generalities of testing having now been discussed, there follows below a discussion (with limited repetition of items treated heretofore) of a number of technical details associated with testing procedures.

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 plus 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 incorrect zero-load balance. Before a test is started, therefore, it is essential that the scale be in correct balance at zero load, that is, that it correctly give a weight



A weighbeam balance-ball assembly.

The nonrotatable ball is moved by the manually-operable screw. The assembly is vertically adjustable. In this view are shown, from left to right, the butt-balance pivot and bearing loop, the load pivot and bearing loop, the fulcrum stand, and one fulcrum-pivot anti-friction end cap.

indication of zero when there is no load on the platform, plate, or other load-receiving element. (There is a special case of scales designed to be "back-balanced" a certain amount.)

A lever scale of the nonautomatic-indicating type not having an indicator and a graduated scale is correctly balanced when the weighbeam comes to rest at, or oscillates through approximately equal arcs above and 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 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. 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 that can be duplicated with exactness on subsequent observations. 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 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 procedure. (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 instaces 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.)

The release of the weighbeam without impulse is of importance in the balancing procedure here recommended. 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 beam is stroked from the butt to the tip.

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 dislodge 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 desribed 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.

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 that 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.

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.

Parallax Effects. 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 that moves across a graduated chart, or a chart that 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.

Zero-Load Balance Errors. 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 be considered unsatisfactory because of instability of the zero-load balance condition. Such a conclusion 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 is suggested as a maximum allowance for permissable zero-load "balance shift," although as yet no limiting value has been adopted nor has any such value been generally agreed upon by the scale industry.

As previously indicated, 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. (An exception to these generalities is found in the scale designed to be "back-balanced" a fixed amount; but here the accurate pre-use back-balancing corresponds to the accurate zero-load balancing of the conventional scale, and this can be verified through the use of the back-balancing butt weight provided, in combination with standard weights on the load-receiving element.)

When "error weights" are used to facilitate the accurate determination of scale errors or to permit the ready application of tolerances where performance errors develop, these are to be "balanced in" when the zero-load balance condition is established. That is to say, the error weights are not "load," and "zero-load balance" means in this case zero balance indication with the error weights on the scale. The same rule applies when hooks, chains, slings, or other forms of special gear are required for the application of the test weights to the scale mechanism; all such gear required for the complete test of the scale is to be balanced in when the initial zero-load balance condition is established, and this remains in position through the step of checking for zero-load balance change at the end of the test. When this check for balance change is made, the value of the error weights in position must, of course, correspond to that of the original complement of such weights when the zero-load balance of the scale was initially established.

The Parts of a Test. The test of a scale comprises several distinct parts, although all of these are not applicable to the test of every scale. For the nonautomatic-indicating scale these parts are (1) the SR determination, (2) the shift test, (3) the increasing-load test, (4) the ratio test, and (5) the test of the loose weights used with the scale. For the automatic-indicating scale these parts are (1) the shift test, (2) the increasing-load test, (3) the decreasing-load test, (4) the test of the unit weights, and (5) the checking of the money-value indications.

SR determinations are made at zero load and at capacity load (or at maximum test load if the test cannot be carried to the capacity of the scale).

The shift test is made with off-center loads under certain prescribed conditions.

The increasing-load test is normally made with the test loads centered on or uniformly distributed over the load-receiving element.

The decreasing-load test is a continuation of the increasing-load test, in that observations are made at several points as the test load is being removed from the load-receiving element. The decreasing-load test is regularly made on automatic-indicating scales but is not made on nonautomatic-indicating scales.

The ratio test is made on any scale on which counterpoise weights are utilized, its purpose being to verify the multiplying power of the lever system.

Determination of SR (Sensitivity Requirement). The determination of SR, or sensitivity requirement, is made on all scales not of the automatic-indicating type to demonstrate whether or not the mechanism will respond to sufficiently small load changes to permit determinations of weight to be made (during normal operation of the scale) with reasonable precision. (No "sensitiveness" requirements are specified for automatic-indicating scales as it is difficult to differentiate between the effects of inaccuracy and insensitiveness in this type of scale.) It is essential that the inspector have a very clear understanding of the definition of SR and of the precise manner in which an SR determination is to be made. SR may be broadly defined as the change in load required to change the position of rest of the indicating element or elements of a nonautomatic-indicating scale a definite amount at any load. NBS Handbook 44 gives technical details regarding SR requirements for specific types of scales, and it is essential that the inspector be thoroughly familiar with these requirements.

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, however, a scale is not loaded to capacity during the test an SR determination is made at the maximum applied load. 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 stipulated change in the indication of the scale as specified 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 stipulated change of indication.

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.

SR 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 that 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.

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

Shift Test. The shift test 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. Under center or distributed lading, the reactions of the several elements are blended into a single effect, and the contribution of each separate element is masked and indeterminate. In the shift test, while it is impossible to block off all contributions to the observed effect from elements other than the one under particular study, such contributions are definitely reduced and the effect from the element under study is made to predominate. On scales of relatively small capacity the shift test is regularly made with a load corresponding to one-half the nominal capacity of the scale. On such 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 possible over points halfway 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 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 possible over the center of each quarter of the platform.

On scales of larger capacities—that is, portable, warehouse, 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 possible over each main load bearing in turn; if the shift-test load exceeds one-quarter of the scale capacity, then it should be positioned as in the case of a small platform scale—that is, centered in each quarter of the platform.

In the case of motor-truck scales having main levers that 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 that has been disclosed, or in those 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. Normally, 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 of a very large percentage of the total weight of a motor truck on the rear axle and the possible high end-loading of the scale that 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 it 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 on a motor-truck scale, the test-weight load should be equally divided between the two corners at one end, and the load should be concentrated as close to the end as is practicable. If the scale has four sections, the load should be positioned, in turn, across the platform along the pivot line of the second and third sections and across the second end of the platform. In a two-section scale the test should be made at each end.

In the matter of the size of the test-weight load used for end testing, it should be remembered that a motor-truck scale is designed for end loading up to the nominal scale capacity, and may properly be tested at the ends and sections up to this amount.

On a conventional computing scale having two main load bearings, a load may be centered front-to-back on the platter but displaced to right or left of center in order to point up the arm-length effect of the right or left load arm of the main lever or to focus attention on the right or left main load bearing assembly. If the load is centered right-to-left on the platter but displaced forward or back of center, it points up the correctness (or otherwise) of the adjustment of the lever stabilizing linkage.

On an equal-arm scale having the pans above the lever, transverse displacement of the load on one pan (the load on the other pan being centered) provides a check on the correctness of position of the two load pivots on that end of the lever, and displacement to right or left provides a check on the adjustment of the lever stabilizing linkage on that side of the fulcrum. Corresponding observations are needed with load displacement on the other pan.

On a four-main-load-bearing platform scale, observations with the test-weight loads concentrated near each corner of the platform focus attention, in turn, on each of the four principal elements of the lever system and on each of the main load bearings. Center lading on a long-platform scale is useful to develop any adverse effects resulting from weighbridge deflection.

In the multiple-section vehicle or livestock scale, test-weight loads concentrated successively along the transverse main-load-pivot line of each section will develop information on the performance of each section, the contribution of other sections to any observed result being reduced to a minimum by this pattern of test-load application.

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.

Increasing-Load Test. The increasing-load test is made to develop the performance characteristics of the scale when loads are reasonably well centered or evenly distributed over the load-receiving element, with particular reference to the accuracy of weighbeam and reading-face indications. The central position or even distribution of the test load should be maintained throughout this test.

The test should be carried up to the nominal capacity of the scale or, in certain special cases, 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. 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 enough tests are made at intermediate points to establish with reasonable certainty the performance characteristics of the particular scale under examination, consideration being given to the probable manner of use of the scale and to any details of its construction that might affect its performance in certain parts of its weighing range. For example, on most small beam scales and automatic-indicating scales having fan-type reading faces, tests should be made at least at one-half and full capacity of the scale, and on small automatic-indicating scales having circular reading faces, tests should be made at least at each quarter of the reading face.

In the case of a computing scale it is felt that tests at the critical half-capacity and capacity points for a fan scale and the four quarter points for a cylinder scale should be supplemented by tests at numerous other points in order to develop all needed information about the weighing performance of the scale. Thus the EPO for computing scales calls for several test observations below 1 pound and at each even pound to the capacity of the scale. Because the observations are to be made as the increasing-load test of a computing scale progresses, it may be noted here that the inspector should critically observe the appearance of the chart, particularly on a cylinder scale, as the test advances, to detect any abnormal chart conditions such as dented areas, distortion of any kind, out-of-roundness, or other physical damage. Such conditions are usually readily apparent, and if any are observed, a note, mental or otherwise, should be made of where they exist so that further observations may later be made when checking money-value indications, as explained later in this chapter. (See page 122.)

For the larger beam scales, test observations should be made at no less than two loads, half and full scale capacity if practicable, and if more test loads are utilized more information will be developed.

Testing Weighbeam Bars. With respect to a weighbeam bar, test observations should be made at not less than two or three points, including half and full capacity of the bar. If the bar is notched, test observations should also be made at any notches that appear to be worn or otherwise in poor condition, and if it is learned that the bar is largely used within a relatively small range, it will be useful to test at several notches in that range.

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 that in reality is the result of an improper setting of the poise by the inspector. (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 that is within tolerance) exceeds the tolerance for the combined load.

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. 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 any ratio test as such disappears and becomes merged with the test of the weighbeam.

When Test-Weight Load is Inadequate. In the test of a large-capacity scale where the amount of test weights available is less than the "used" or full 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 "buildup" 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.

Substitution Method of Testing. The principle of the substitution method of test is the successive substitution for the test-weight load of a load 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 40,000-pound vehicle scale that must be tested with only 10,000 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 10,000 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 that just fails to "bump" when released. Then the 10,000 pounds of test weights would be removed, great care being exercised not to disturb the scale mechanism in any way that would affect the balance condition, and any material available would be carefully added to the platform until the former condition of balance had been reproduced; assuming the scale under test to be capable of repeating its indications, it is apparent that there would now have been added to the platform just 10,000 pounds of material within that degree of accuracy determined by the ability of the scale to duplicate the original balance condition. In other words, there would now be available a 20,000-pound known load consisting of 10,000 pounds of test weights and 10,000 pounds of other material. If now any poise that had been moved were to be restored to its original position and any small weights that may have been utilized in establishing the reproducible balance condition were to be removed, the scale would be in just the same condition as though the test had been started with 20,000 pounds of test weights and had proceeded to the point where 10,000 pounds of that amount had been used.

The test would then proceed as before until the platform load reached 20,000 pounds, when another substitution would be made in the same manner as has been outlined. The substitution operation may be performed as many times as required.

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 that 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 several substitutions may reach serious proportions.

Another caution that must be observed during a substitution test is never to change the adjustment of the regular balancing means of the scale during the progress of the 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 that prevailed when the scale was originally balanced at zero after the substitution is completed and before proceeding with the test; this cannot 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 or weights added to platform or counterpoise hanger. When a full-capacity beam scale has an error of overregistration 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 the platform to produce the desired balance; when an automatic-indicating scale has a similar error, enough small weights may be added to the platform to bring the indicator into coincidence with the next forward graduation so that a precise reading can be made.

Strain-Load Method of Testing. 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 that 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. (The regular balancing means of the scale could be utilized 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; for this reason, use of the regular balancing means is not recommended here.) 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 indicated 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 would 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 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.

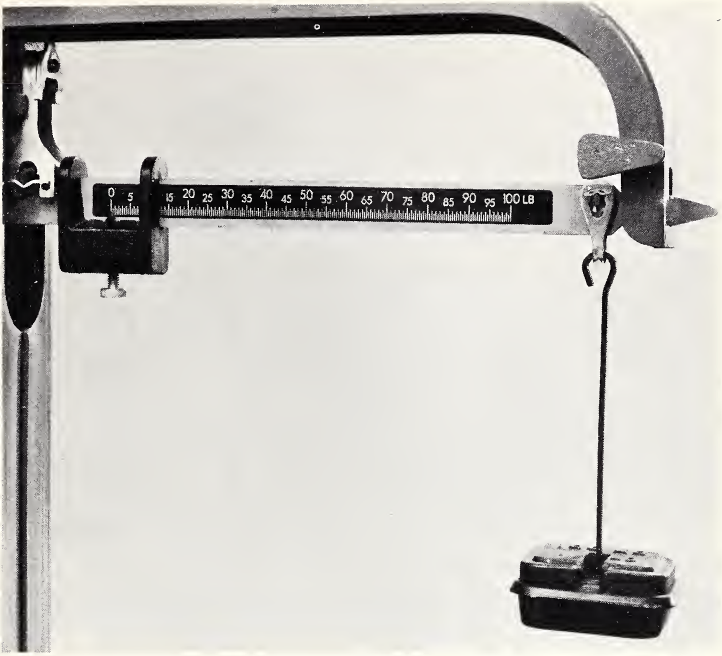
Tolerance Application on Substitution and Strain-Load Tests. There is an important difference between the substitution method and the strain-load method in the manner of applying the tolerances. In the substitution method, all of the load on the load-receiving element of the scale at the time of making 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.

Motor Vehicles as "Test Weights." The customary equipment for the testing of motor-truck scales is a power-operated unit carrying a load of large-denomination test weights. Inspectors have been known ill advisedly to use the loaded unit 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 a motor 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 in very grave doubt. The better 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 vehicle may, however, properly be utilized as a strain load in the course of the test of a vehicle scale.)

Poise and Trig Positions During Testing Operations. When testing any scale, regardless of method, it is advisable that all poises that 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 increasing-load test, but equally to all tests. Whenever a scale gives weight indications on two

A vehicle-scale testing unit.

This is a power-operated unit that carries nineteen 1000-pound and two 500-pound test weights that are handled three at a time. Controls for hoisting and placement of weights are shown at the left rear of the truck.



Weighbeam assembly of portable platform scale.

This view shows the weighbeam fulcrum loop, a poise with locking screw, the weighbeam locked down by the trig, and the counterpoise hanger with the "100-pound" counterpoise weight in place.

sides—that is, on the operator's side and the opposite or "customers" side—a sufficient number of check observations should be made to insure that the indications of the two sides are in agreement.

Decreasing-Load Tests. It is characteristic of mechanical systems to lag somewhat in their responses to stress. This results from looseness of fits, lost motion in linkages, lack of refinement of parts, inertia, and frictional effects. The condition is referred to as mechanical hysteresis. A similar characteristic is displayed by elastic bodies such as springs, and manifests itself by some failure to repeat on a series of downcoming or gradually reduced stresses the exact deformations that occurred on a corresponding series of upgoing or gradually increased stresses.

The purpose of a decreasing load test on an automatic-indicating scale is to determine that the effects of hysteresis, friction, poor fits of parts, loose connections, general lack of refinement of design and manufacture, poor finish of parts, careless workmanship, and wear are not present to a degree that would jeopardize accuracy of weighing results. The indications given by a scale that has been stressed (by the loading incident to an increasing-load test), as the stress is reduced (by the removal of the test load), provide some measure of the combined adverse effect of the factors enumerated.

Following the increasing-load test, observations should be made at not less than three or four points during the removal of the test weights, including (if practicable) the half-capacity point. (In the case of certain large-capacity scales where insufficient test weights are available for a test to the capacity of the scale, the decreasing-load test should include a test load equal to one-half the maximum test load applied during the increasing-load test.) During the decreasing-load test (and during an increasing-load test as well) the test weights should not be so gently removed (or applied) as to prevent any oscillation of the mechanism. (Such a test may sometimes be applied in the laboratory for some special purpose, but it should not be used in routine testing.) For regular testing the test weights should be handled in a normal manner, with no special effort to prevent or to increase ordinary oscillation of the mechanism.

(Decreasing-load tests are made *only* on automatic-indicating scales.)

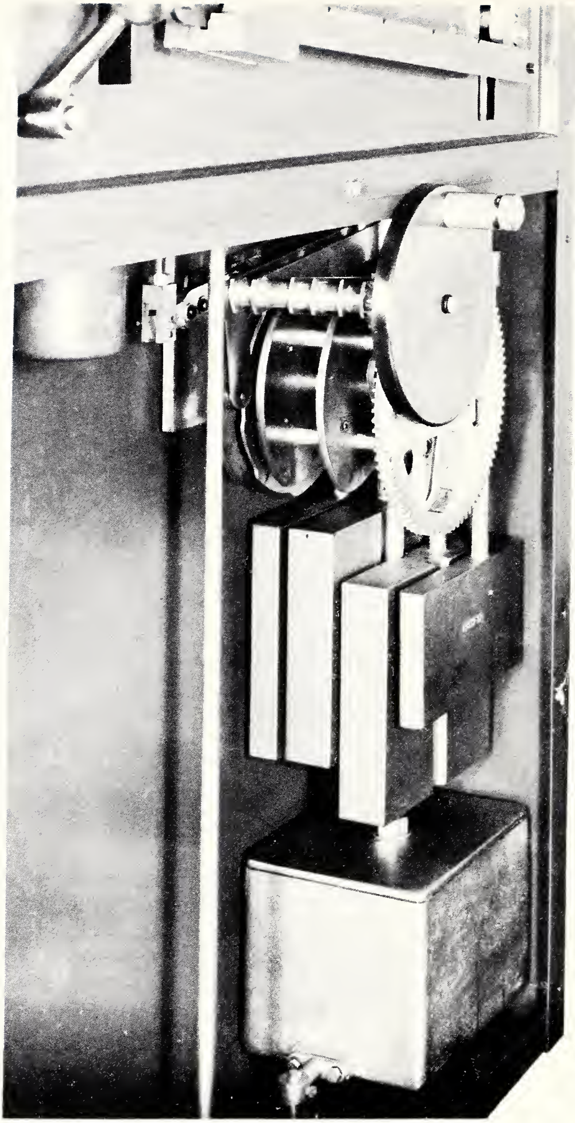
Ratio Test. A scale that employs levers in its construction is designed by the manufacturer to have a definite scale multiple or ratio resulting from the definite ratios of the lever components that make up the lever system. There is no rule requiring manufacturers to design a scale so that it will have a certain multiple, but as noted earlier there is a degree of conformity among manufacturers in this respect.

The weights and measures inspector makes scale-ratio tests only when manually removable weights are involved. Such weights—equal-arm, counterpoise, hanger, or bottle—are standardized and marked at definite values, usually some even multiple of the pound or some value involving only some simple fractional part of the pound, the actual values depending on the ratios of the scales with which they are intended to be used. With standard scale ratios and standard values for the removable weights, accurate weighing results may be obtained over a given scale whenever the loose weights "match" the scale ratio. Also, scales and weights may be separately manufactured to their respective standards, and accurate and suitable replacement weights may always be obtained by a scale operator.

The object of the ratio test of a scale is, then, to determine whether or not the actual scale ratio is close enough to the ratio that is standard for the scale under examination to meet the prescribed ratio tolerance requirements. In this test the test-weight load on the load-receiving element of the scale is counterpoised by *standard weights,* not by the weights belonging to the scale, which are separately tested and required to conform to their own tolerances. Obviously, if the test loads were to be counterpoised by the weights belonging to the scale, and if these weights were themselves in error by some unknown amount, the ratio test would fail to accomplish its intended purpose.

The ratio test is most conveniently performed if flat, slotted, standard weights are available for use on the counterpoise hanger; for example, a 1-, 2-, 2-, 2-pound set will be found suitable for portable platform and larger scales. Another approach is to provide for use on such scales a single, flat, slotted, 1-pound weight having a diameter of at least 5 inches; such a weight provides a large enough "shelf" to support safely additional standard weights, either cube or cylindrical as needed.

Test of Unit Weights. When an automatic-indicating scale is equipped with "unit" weights—that is, weights that are enclosed within the housing or cabinet and that 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



Unit weights.

One design of unit weights for a large automatic-indicating scale, shown mounted inside the cabinet together with the mechanism for applying and removing them.

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 coincide with the "zero" reading-face graduation, and if it does not, the amount by which it fails to do so 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 the two unit weights then in place, when the indicator should again coincide with the "zero" reading-face graduation; the amount, if any, by which coincidence fails represents 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 that 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.

Test of Back-Balance Weights. 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 that would be required if balancing weights were to be utilized on the platform. In such a case the inspector should 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 should verify the accuracy of these balancing weights (1) by comparison with standard test weights on the scale under examination or (2) 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." Tolerance testing is used when 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 that the weights and measures official is most frequently called upon to perform. If, 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.

Tolerance Testing. In tolerance testing, a known load is applied on the load-receiving element of the scale and this load is opposed by a weighbeam poise set to a corresponding value, by the theoretically correct 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 underregistering or by removing weight from the load-receiving element or adding weight on the counterpoise hanger if the scale is overregistering. Having made a change equivalent to 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 an error in the direction of overregistration 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 reading face and the value of the tolerance may be added to the platform, and the reading-face indication observed with respect to the first reading-face graduation in advance of the one originally under consideration. For example, assume a 10-pound reading face 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 reading face) 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. 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. (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.)

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 that, 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 that at some given load has an error in the direction of overregistration, the tolerance for that load being $\frac{1}{2}$ 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); 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. (The error in the multiple of the scale may safely be neglected in this computation, the designed multiple being used, as in the example.)

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

Estimation 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.

Error-Weight Testing. With respect to the application of tolerance to, and the precise determination of errors in, nonautomatic-indicating scales, the 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 errors of overregistration and to apply tolerances on scales having such 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 or of underregistration errors on scales of any type. 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. In the case of errors of underregistration the platform load can readily be increased by the addition of the necessary weights. However, since it is not ordinarily known in advance whether a scale is going to overregister or underregister 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 anticipated errors or the 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 smallest weight being equal to the minimum tolerance value, and the total of the weights being equal to the tolerance value at the maximum test load to be applied to the scale.

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 should 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 error 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.

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 underregistering, whereas if less than the original amount of error weights has been used, the scale is overregistering. If abnormally large errors of overregistration, 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 that 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.

Checking Money-Value Indications. In the case of each money-value computing scale examined, some attention should be given to the computed values. During the increasing-load test of such a scale attention will have been given to the physical condition of the chart. If any distortion, out-of-round condition, or other physical damage has been observed, the place or places on the chart where this occurred will have been noted. When the test of the scale for weighing accuracy has been concluded, the inspector should so load the scale as to bring into action the noted points of chart damage, and should then check, at several adjacent even-pound weight indications, and at closely spaced prices-per-pound across the entire price range, to discover if the chart damage has caused any error in computed money values.

Whether or not chart damage has been observed, when the weight-accuracy test of a computing scale has been completed the inspector should make a check on computed money values at several weights (1, 2, 10, 20 pounds are recommended because of the ease of computation for these weights) and for a random selection of three or more prices-per-pound. (The price-per-pound selection should vary with each successive computing scale examined, so as to avoid any fixed pattern.) The purpose of this check is to discover any instances of faulty chart manufacture; it is admitted that the recommended procedure is wholly inadequate for establishing the correctness of the entire chart, but it is quite out of the question for the inspector to make the thousands of computations necessary for a complete check, and what is recommended does provide a partial check.

A basic principle *must be observed* in *all* checking of computed money values. The objective is to examine the money values on the chart *with reference to the weight values on that chart,* and not with reference to certain loads applied to the scale pan or platter. The acceptability of the scale as a weighing machine has already been determined; now the effort is to learn whether or not the chart computes correctly, conformably to its own weight indications. Therefore, when checking computations at 1 pound, for example, the scale is first caused to indicate *precisely* 1 pound, and then the money values are checked. Similarly, when checking at 20 pounds, for example, a precise scale indication of 20 pounds is first obtained by whatever means may be most convenient—thus eliminating any weighing error that might exist at that point—and then the money values are checked. When this method is followed—and it is the only method acceptable—it is to be required that there be complete accuracy of the money value graduations within the precision of observation; no failure of proportional agreement *on the chart* between weight and money-value graduations is permissible.

Agreement Between Visual Indications and Recorded Representations. When a commercial scale advertises itself as capable of performing a specific service, it is proper that it be examined with respect to that promised capability. Thus if the promise be to indicate weight values and also to print weights on tickets or otherwise to record weight values, the inspector should take whatever steps are needed to establish accuracy of performance in respect to both indicating and recording of values. Acceptability of the scale must be predicated upon accuracy in both functions.

The Examination of a Prototype. In this discussion, "prototype" is used not in its exact sense of the original or model after which something is copied, but rather in the associated weights and measures sense. In this special sense the prototype is a typical example of the commercial copies of the manufacturer's basic pattern for a particular design, and represents the product as it will be manufactured, or as it is proposed that it be manufactured, for commercial use. Such a "prototype" is submitted by the manufacturer to a weights and measures agency for examination prior to its sale in the jurisdiction, in the expectation that its design and construction will be found to conform to official requirements and that accordingly it will be accepted as satisfactory, or will be officially approved as to pattern, according to the rules in effect in the jurisdiction.

It may be considered for purposes of this discussion that what is said about the examination of a prototype applies, insofar as application is practicable, to the first example of a new pattern encountered in the course of routine field examinations by any representative of a weights and measures agency.

The general theory of the examination of a prototype is: Here is something new, it may or may not meet official requirements, whether or not it does meet those requirements can be determined only by a very thorough and critical examination, and such an examination is immediately in order. Of particular importance in the examination are matters of design, construction, materials, finish, and workmanship, and compliance with all applicable specification requirements. Performance is not neglected, but this is secondary in a prototype examination on the theory that the accuracy of a device can be controlled by the manufacturer and that the accuracy of each device is an individual characteristic that will be individually evaluated in the test of the device when offered for or actually placed in commercial service.

A prototype examination is best performed in the laboratory, where it is to be presumed there are available all facilities needed for a complete examination. When a prototype examination must be made in the field, the effort should be to approximate as closely as may be the thoroughness and precision of the laboratory examination.

Even when good examination facilities are available and great care is exercised in making the examination, doubt may occasionally remain as to the suitability of some design innovation, or the durability of some material utilized in the construction, or the susceptibility of the device to misuse under service conditions, or some other matter of possible significance. In such cases, approval or acceptance can be tentative, final action being contingent on the results of a field trial of reasonable duration.

Reverting to the theory of the prototype or pattern examination, this serves, when competently performed, to keep out of service in a jurisdiction those devices that fail to meet specification requirements, and to simplify the field examinations of those devices the patterns of which have been found acceptable.

Application of Basic Testing Principles. Finally, it should be emphasized that the weights and measures official should thoroughly understand the principles of testing and be able to adapt these principles to the needs of the devices that he meets in the field. New types will be encountered from time to time, and rule-of-thumb methods will be found inadequate. The routine of testing must frequently be varied to conform to the peculiar design and construction of a particular device. But if the official knows what his test should develop, if he understands the effects of the various testing operations and if able to choose the proper operation to bring out the desired facts, if he familiarizes himself with the mechanical principles of the device under examination, and if his equipment is adequate, he should be able to carry on with entire success the testing of any device that he is called upon to examine.

Chapter 8.—Reports and Report Forms

General Considerations. It is a basic principle in regulatory work that an informative record should be preserved of every official act. By an informative record it is meant that the recorded data should be sufficiently detailed in character and should be so presented that they will fully answer all questions, whenever in the future it may become necessary to seek information in the files.

In setting up a system of weights and measures records it is advisable to avoid unnecessary clerical work—copying, cross-indexing, etc.—because this is inefficient and expensive and constitutes an irritating burden on the staff responsible for record keeping. Excessive clerical work can probably best be eliminated by a systematic utilization of *original* records—that is, field reports—as the official office records of equipment examination. Such a plan is now widely followed in weights and measures jurisdictions; its success depends largely, however, upon two factors, (1) the design of the report forms and (2) the care exercised by field personnel in using the forms.

The Inspector's Responsibilities. Brief comment on the design of forms will be offered at the end of this chapter. But first it is desired to emphasize the importance of the part played in the record system by the field inspector, and to suggest some ways in which the value of his contribution may be enhanced.

It will be assumed, then, that the inspector is provided with forms well designed for reporting upon his examinations of weighing equipment. How can he make the best use of them?

Perhaps the most important thought for the inspector to keep in mind is that human memory may fail and that future knowledge of what he has done and what he has found in the course of his equipment examinations will of necessity be based on the written reports he has made when the examinations were conducted. If that knowledge is to be complete, and thus useful, the field reports must be fully informative.

To satisfy the requirements of the situation the inspector should take full advantage of the report forms with which he is provided, and should execute fully the form or forms appropriate to each individual examination. The name, address, and business of the equipment owner, the location of the equipment, the description and identification of the equipment and its condition and performance, the official action taken following the examination, and official recommendations made or orders issued to the equipment owner or operator are all of obvious importance as matters of official record. If the provision for entry of data on the form is inadequate for the reporting of some significant circumstance or observation, a supplementary entry should be made elsewhere on the form or a supplementary report should be prepared so that the ultimate official record may be complete.

Entries on report forms should be neatly made and all should be readily legible. Numerical values on a report may be of prime importance, and figures should be carefully formed so that they will be unmistakable. A report that is carelessly prepared not only may not be informative, it is almost certain to raise a doubt about the technical competence of the inspector who made it.

A well-planned examination report form will call for a description of the equipment examined—kind, make, serial number, capacity, and probably some construction details. The inspector should be careful to supply all desired data, in strict conformance with whatever criteria, rules, or definitions may have been prescribed for his guidance.

The condition of a weighing device "as found" by the inspector may be of considerable significance, and may form a basis for forceful recommendations to owner or operator. When of importance, the as-found condition should be carefully reported.

In the case of vehicle and livestock scales, test reports can only be properly informative if they include detailed test results. Special report forms for such scales should be provided, and all test data called for should be entered as the test observations are made. On these scales the information gathered during the inspection—as distinguished from the test—of the device may be of considerable importance, and the report form should make provision for the entry of such information. (It is a good form of insurance against forgetting some items of importance, for the inspector to make informal written notes during the progress of his inspection of large, complicated, or unusual scale installations, for later transfer to the report form.)

In the case of scales of the smaller capacities and simple construction, it is normally unnecessary, in the course of routine examinations, to record in detail the results of the test. The inspector should not hesitate to do this, however, in any case where he feels that such details are of special significance, using any convenient form of supplementary report.

It is always required that the report show the final results of the examination—that the device has been approved, rejected, or condemned. If prior to the final result any alteration—such as cleaning, relieving of binding conditions, change of or addition to dash-pot liquid, and the like—or any adjustment has been made, this should be noted on the report. If a scale is confiscated or destroyed incident to its condemnation, this fact should be noted on the report.

When a device is rejected, an action that anticipates that some sort of corrective action will be taken by the owner to bring the device into "correct" condition, it is recommended that use be made of a special rejection report, supplementary to the regular examination report, to set forth in some detail the reasons for the rejection and give whatever official instructions are appropriate in the premises. This special report should be made out with the same care as is observed in making out the regular examination report, and should be specific and explicit in its terms.

The examination report form should provide space for the entry by the inspector of official recommendations or orders, based on official regulations and conditions disclosed by the inspector's examination. Although any such recommendations or orders should always be discussed orally with the device owner or his representative, they should invariably be succinctly and definitely expressed in written form on the examination report.

Finally, the inspector should obtain the signature, on the report, of the device owner or his representative, to identify the person to whom a copy of the report and any instructions, orders, or warnings were given, and he should authenticate the report with his own signature.

Design of Forms. Supplementing the foregoing comments (which are directed particularly to the field inspector) a few suggestions are offered below to the person required to design the examination-report forms for his jurisdiction.

Attention is invited to Part IV—System of Records, pages 177 to 190, inclusive, of National Bureau of Standards Handbook 82, Weights and Measures Administration, for a general discussion of weights and measures report forms and records.

Essential Forms. With specific reference to weighing devices, it is recommended that as a minimum the following forms be provided:

1. *Field Examination Report.* For use by the field inspector for weighing devices other than vehicle and livestock scales. A size of 5×8 inches is suggested for this form.
2. *Vehicle and Livestock Scale Examination Report.* A combination form for use by the field inspector, specially designed for reporting examinations—including detailed test results—of vehicle and livestock scales. To provide adequate room for entering test and inspection results, it is recommended that this form be 8½×11 inches in size.
3. *Equipment Rejection Report.* It is suggested that this form be 5×8 inches in size, printed front and back. The front is for use by the inspector in identifying a rejected scale, giving the reasons for the rejection, and issuing the official instruction regarding non-use until after repairs have been made. The reverse of the form is for use by the service mechanic in notifying the weights and measures office that repairs have been completed, or by the owner in notifying the office that the scale has been discarded and replaced.
4. *Temporary Use Permit.* A postcard form for use by the weights and measures office after receiving notice that a rejected scale has been repaired or that a new scale is awaiting examination, so that the scale may be put in service by the owner pending an official examination.
5. *Notice of Equipment Installation.* A postcard form for use by scale sales and service personnel to notify the weights and measures office that a scale (other than one for which there is an Equipment Rejection Report) has been installed and is ready for official examination.

Essential Elements of Forms. Mention is made below, but without discussion, of elements and characteristics considered essential for weights and measures forms.

Every form should be headed with a clear statement of the name, mailing address, and telephone number of the weights and measures office.

Every form should make provision for entry of the date and of the signature of the person executing the form.

On equipment examination and rejection report forms, provision should be made for entry of the signature of the equipment owner or his representative below a statement acknowledging receipt of the report.

On all forms, standard items of desired information should be clearly identified by printed captions.

On all forms, provision should be made, where appropriate, for a reasonable use of check-mark entries.

On equipment report forms, provision should be made for the *positive* identification of the equipment involved.

On equipment examination report forms, adequate provision should be made for entry by the inspector of special comments or conditions found and of warnings, instructions, and orders issued to the equipment owner.

On all forms, *adequate* writing space should be provided wherever hand-written entries are to be anticipated.

For all equipment report forms, provision should be made (padded sheets or carbon-insert sets of sheets) for preparation of reports in duplicate (or triplicate if the inspector is to retain personal copies).

Every form should be kept as simple as practicable, but should demand all *needed* information.

Clerical effort demanded of the field inspector should be held to the practicable minimum.

Color coding by use of tinted papers is suggested to differentiate forms of different kinds or to identify the several copies of a single form intended for different persons.

Sample Forms. Patterns have been worked out by the NBS Office of Weights and Measures for the five forms recommended above, and sample copies of these may be obtained without cost upon application to OWM.

Chapter 9.—The Official Action Resulting From the Examination

When the weights and measures officer has finished his examination of a commercial weighing device, he is ready to take some kind of official action on the device. His legal authority for such action is derived from the basic weights and measures statute under which he operates. The Model State Law on Weights and Measures reads in part: "The director shall approve for use and seal or mark with appropriate devices such weights and measures as he finds upon inspection and test to be 'correct' as defined . . . and shall reject and mark or tag as 'rejected' such weights and measures as he finds, upon inspection or test, to be 'incorrect' as defined . . . but which in his best judgment are susceptible of satisfactory repair. . . . The director shall condemn, and may seize and may destroy, weights and measures found to be incorrect that, in his best judgment, are not susceptible of satisfactory repair . . . ." Under this authority, four possible actions may be taken by the weights and measures officer:

1. If the device is found to be correct—meeting all specification and performance requirements—"approval" of the device is in order.

2. If the device is found to require only some minor attention to put it into "correct" condition, and if it is found appropriate that the inspector provide that attention, "approval" of the device is in order following whatever service is rendered.

3. If the device is found to be "incorrect" and to require repair or adjustment beyond such simple matters as the inspector can appropriately attend to, the device being considered by the official to be susceptible of satisfactory reconditioning, "rejection" of the device is in order.

4. If the device is found to be "incorrect" and, in the best judgment of the official, to be not susceptible of satisfactory reconditioning or modification, "condemnation" is in order, with possible confiscation or destruction of the faulty device.

Approval and Sealing. It is traditional that when the weights and measures officer leaves a commercial device in correct condition, he places thereon his approval "seal," a mark showing that the device is then in a condition such that it is satisfactory for use in commercial transactions.

Location of Approval Seals. For each type of weighing scale a location should be selected for placing the approval seal, so that there may be uniformity in the location of the seals on similar types of equipment. Such uniformity will be useful to the official when checking equipment in service, and will encourage the public to become familiar with the seal and to look for it on commercially-used devices.

Rejection Tags. Rejection is a temporary expedient to remove incorrect equipment from service until it has been reconditioned and found to be "correct" upon reexamination. When equipment is rejected it is suitably marked by the official to indicate this fact—unless the repairs are to be begun immediately. The customary mark is a tag (occasionally an adhesive label) of distinctive color, usually red, setting forth (1) the fact of rejection, (2) the reasons therefor, (3) the penalty for commercial use before repairs have been made and the device has been reexamined and sealed, and (4) the time limit set for making of repairs.

Discarded Rejected Equipment. It frequently happens that when a device is rejected the owner prefers to buy new equipment rather than to have the old equipment repaired. In such cases the rejected device is often turned in as part payment on the new equipment and so passes into the hands of a dealer in weighing or measuring devices. When this occurs the interest of the weights and measures official in the equipment in question does not cease; he should be just as careful in seeing that proper repairs are made before the device is again placed in commercial use as though it had remained in the hands of the original owner, and he should exercise strict control over all reconditioned equipment handled in his territory.

Seizure of Equipment. Authority to "seize and destroy" is customarily granted to the official by his law not only with respect to equipment that he condemns but also with respect to equipment that he has rejected but that the owner has not had properly repaired within the specified time limit. This authority should be exercised by the official with discretion. He should keep always in mind the property rights of an equipment owner, and cooperate in working out suitable arrangements whenever it is thought practicable for an owner to realize at least something from equipment that has been condemned. In cases of doubt the official should initially reject rather than condemn. Destruction of equipment is a harsh procedure, as is also confiscation; power to seize and destroy is necessary for adequate control of extreme conditions, but seizure and destruction should be resorted to only when clearly justified. In the case of the more expensive and complicated weighing scales, suitable repair is usually possible when these are found to be incorrect, even though repair may be economically unsound; so rejection is the customary procedure. Seizure of these items may occasionally be justified, but in the majority of instances confiscation should be unnecessary. Even in the case of worn-out equipment, some salvage is usually possible, and this should be permitted under proper safeguards.

The practice of merely marking as "condemned" equipment that is not proper for use and that cannot be repaired and leaving this equipment in the hands of the owner is to be discouraged if there is any other way in which the equipment can definitely be put out of service; such equipment should be removed from the channels of trade so as to eliminate the possibility of its again being used commercially. Of course, it will not be practicable for the official to confiscate a large item such as a complete vehicle scale; if such an item must be condemned, the official should see to it that the unit is so dismantled that it is effectively put out of use or that its indicating mechanism is so "sealed" that the scale cannot be used. But in the case of small devices, which comprise the majority of the units that it is necessary to condemn, dismantling when practicable and removal (by the owner) from the premises, confiscation (by the official) and subsequent destruction, or destruction by the official at the time of test, is the proper method of procedure.

Records. As in the case of equipment approved for use, the official should keep complete records of all equipment rejected or condemned, the reasons for the action taken, and the ultimate disposition of the equipment.

Chapter 10.—Tolerances

A Definition. A succinct answer to the question, What is a tolerance? is found in the technical weights and measures regulation of practically every State: A value fixing the limit of allowable error or departure from true performance or value. The official tolerances prescribed by a weights and measures jurisdiction for commercial equipment thus become the limits of inaccuracy officially permissible within that jurisdiction.

Why tolerances? It is recognized that errorless value or performance of mechanical equipment is unattainable. Tolerances are established, therefore, to fix the range of inaccuracy within which equipment will be officially approved for commercial use. In the case of classes of equipment on which the magnitude of the errors of value or performance may be expected to change as a result of use, two sets of tolerances are established, "acceptance" tolerances and "maintenance" tolerances. Acceptance tolerances are applied to new or newly reconditioned equipment and are smaller than (usually one-half of) the maintenance tolerances. Maintenance tolerances thus provide an additional range of inaccuracy within which equipment will be approved on subsequent tests, permitting a limited amount of "deterioration" before the equipment will be officially rejected for inaccuracy, and before reconditioning or adjustment will be required. In effect, there is assured a reasonable period of use for equipment after it is placed in service before reconditioning will be officially required. The foregoing comments do not apply, of course, when only a single set of tolerance values is established, as is the case with such equipment as, for example, glass milk bottles and graduates, which maintain their original accuracy regardless of use, and paperboard measure-containers, which are used only once.

Basic Theory of Tolerances. A condensed statement of the theory underlying the establishment of equipment tolerances is that their values are so fixed that, on the one hand, permissible errors are kept so small that neither party to a commercial transaction involving the equipment in question will be seriously injured, and that, on the other hand, such a high order of accuracy is not required as to make manufacturing or maintenance costs disproportionately high. Quite obviously, the equipment manufacturer must know what tolerances his product will be required to meet, so that he can manufacture economically. The commercial product must be required to be good enough to satisfy commercial needs, but it should not be required to be made unreasonably costly, complicated, or delicate in order to insure a reduction of its errors to unnecessarily small values. Manufacturing is simplified and the level of equipment prices is lowered in proportion to the degree of uniformity among weights and measures jurisdictions in their tolerance requirements and in their specifications for commercial devices.

Tolerances and Adjustments. There is another aspect of tolerances that merits careful thought; this is the extent to which tolerances should be considered by those persons engaged in the actual adjustment for accuracy of commercial equipment. The ideal situation would be for equipment to be without error. Since it is not practical to require errorless value or performance, a reasonable approximation of this is fixed for enforcement purposes. But, when equipment is being adjusted for accuracy, either initially or following repair or official rejection, the effort should be to adjust as closely as practicable to zero error. Tolerances are primarily accuracy criteria *for use by the regulatory official.* Equipment owners should never be permitted to take advantage of tolerances by deliberately adjusting their equipment to have a value or to give performance at or close to the tolerance limit. Nor should the repairman or serviceman be permitted to bring equipment merely within tolerance range when, by the exercise of reasonable skill and with the expenditure of a reasonable amount of time and effort, adjustment closer to zero error can be accomplished.

Commodity Tolerances. A class of tolerances other than equipment tolerances may be discussed briefly. These are known as "commodity tolerances," and prescribe either general or numerical limits of permissible variations in the amounts of commodities packed or delivered, as compared with the amounts represented by the packer or seller. While such variations are, of course, inevitable and must be recognized, neither the National

Conference on Weights and Measures nor the National Bureau of Standards has ever recommended any general list of numerical commodity tolerances.

The principal objection that has been urged against the publication of numerical commodity tolerances, and one that seems to have much merit, is that the publication in numerical terms of permissible variations in amounts of commodity to be packed or delivered may have a tendency to cause packers and dealers to try to take advantage of the tolerances by deliberately packing to, or trying to deliver, the minimum amounts permitted by the tolerances, rather than the full amounts represented. Specifically, there may be a tendency to "aim" not at the full amount, but instead at the lower limit of the tolerance.

Since fixed numerical commodity tolerances are by no means invariably equitable, it is recommended that numerical commodity tolerances be not promulgated at all if it is practical to avoid doing so. In lieu thereof, tolerances stated in general terms are recommended whenever it may become necessary to publish commodity tolerances; an example of this form of treatment is found in the regulations under the Federal Food, Drug, and Cosmetic Act (and in different language in the Model State Regulation Pertaining to Packages; Exemptions, Marking Requirements, Variations), where the statement of tolerances reads as follows:

> Variations from the stated weight or measure shall be permitted when caused by ordinary and customary exposure, after the commodity is sold and delivered by the manufacturer, packer, or distributor, to conditions that normally occur in good distribution practice and that unavoidably result in change of weight or measure.
>
> Variations from the stated weight, measure, or numerical count shall be permitted when caused by unavoidable deviations in weighing, measuring, or counting the contents of individual packages, that occur in good packing practice; but these variations shall not be permitted to such extent that the average of the quantities in the packages of a particular commodity comprising either a shipment or other delivery of the commodity or a lot of the commodity that is kept, offered, or exposed for sale, or sold, is below the quantity stated; and no unreasonable shortage in any package shall be permitted, even though overages in other packages in the same shipment, delivery, or lot compensate for such shortage.

It must be recognized, of course, that even under the "general" treatment of commodity tolerances discussed immediately above, it is necessary for officials, as a matter of practical administrative procedure, to operate under certain limited numerical criteria. However, if these criteria are not published they are not open to the objections previously cited to straight numerical tolerance lists.

SR and Tolerances. SR requirements and tolerances should not be confused. An SR requirement is *not* a tolerance. It is the maximum permissible value for a definitely measurable characteristic of a nonautomatic-indicating weighing scale. When the sensitiveness response of a particular scale is determined according to the precise rules laid down, this response, in terms of weight units, may not exceed the value of the maximum SR prescribed in the code; if the actual SR should exceed the prescribed maximum value for SR, the scale fails to meet performance requirements.

Lower and Upper Tolerance Limits. There are several important questions that must be considered in arriving at proper numerical values to be included in a table of tolerances. First is the question of what field standards or other testing equipment may be available, or what can be developed, for the test of the device. It is a general principle in weights and measures testing that the error of a standard either should be known and corrected for or, if the standard is to be used without correction, should be not greater than 25 percent of the smallest tolerance to be applied when the standard is used. Next is the question of how small the errors of proper commercial equipment of the best type available may reasonably be kept. The answer to this question will establish the limits below which the tolerance values cannot go. In reaching that answer thought must be given to the probable cost of added refinements that may be made necessary by the tolerance values proposed, to the probable character of the commercial service to which the equipment in question will be subjected, to the justification of the smallness of the proposed values by the service anticipated, and to the readability of the proposed values on the equipment in question or by external means. Finally, how large may the errors safely be permitted to be? Here again attention must be directed to the character of service anticipated for the apparatus in question; another important consideration is the possibility of the presence in the use of the equipment of errors that would be additive to the purely instrumental errors, resulting from unskilled operation by the user or from moderate carelessness or abuse. If tolerance values are too great, the tolerances fail of their purpose by failing to keep errors on approved equipment so small that no one's rights are jeopardized; if tolerance values are so small that they cannot be justified or that they cannot be read, they become unsound or merely foolish, as the case may be.

Tolerances Established Through Planned Study. In establishing a series of numerical tolerance values, two definite steps are taken: (1) The testing equipment and testing procedure are agreed to. (2) A statistical plan is devised that will, through a series of tests utilizing the agreed-upon equipment and procedure, permit identification (for purposes of study and analysis) of the errors that must be anticipated in the standards, the procedure, and the device to be tested.

At this point it usually is found helpful to study the matter first from the standpoint of percentages. Having arrived at a tentative percentage that represents a reasonable allowable error, the next step is to use this percentage in building up a tentative table of values for as many different conditions, capacities, and loads as may be dictated by the type of equipment under consideration; in this tentative table, the tolerances probably will be proportional throughout and should be expressed in terms of a unit that it will be convenient to use in regular work. Tolerance values are now "rounded off" to get rid of inconveniently small fractional parts of a unit; if the differences between successive tabular values are slight, the table can with advantage be simplified by grouping the tabulated conditions, capacities, and loads and assigning to each group a single tolerance value representing approximately the mean for that group. The tolerance values so far arrived at are then studied within themselves, and are also compared with such tolerances as may exist for somewhat similar devices. If it be found that the values seem unnecessarily large, this may lead to a revision resulting in a departure from the original percentage figure, or in some cases from the straight percentage plan; it will probably then be found that the lower values are too small, at least for some of the equipment to be covered by the tolerances, and this may make it necessary to establish a minimum tolerance value somewhat higher than the value arrived at by straight application of the percentage believed to be generally satisfactory. Throughout this analysis and comparison, the two questions previously mentioned—how small may the tolerances reasonably be kept, and how large may they safely be permitted to be—have, of necessity, continually been kept in mind, and the tolerances eventually decided upon will inevitably lie within the limits thus defined.

Uniformity of Tolerances on Both Sides of Zero Error. Depending upon the character of the equipment and upon the uses for which it is designed, tolerance values may be differently arranged with reference to their respective standards; the apparatus may be permitted to be in error an equal amount in excess and in deficiency, the tolerances in one direction may be greater than in the other, or the permissible variations may even all be in one direction, with no tolerances at all allowed in the opposite direction. Normally it is considered that a device may properly vary as much above the standard as below it, and in the absence of special reasons to the contrary, tolerances are ordinarily so arranged. Familiar examples of such tolerances are those for scales and weights.

If, however, when the equipment is in use there is a consistent tendency for the instrumental error to increase in the direction of underregistration, coupled with a probability that the errors of use will tend in the same direction, then the tolerances on underregistration may properly be considerably larger than those on overregistration.

Need for Tolerances on Underregistration. One more point remains to be mentioned—the necessity for tolerances on underregistration. Officials have been known to entertain the belief that they need only concern themselves with errors of overregistration—that they should not object to a device having even very large errors in the direction of underregistration. In opposing this viewpoint let it be said, first, that the inspector's seal on a piece of commercial equipment should indicate reasonable accuracy, and not merely that if the error is against the interest of the buyer of commodity, it is a small one; second, that it is considered basic that it is the duty of the weights and measures official to protect equally the interests of both parties to a commercial transaction; and third, that the same piece of equipment may be used both for buying and for selling.

Part III.—BASIC WEIGHING PRINCIPLES AND ELEMENTS

An examination of the elementary principles of design, the patterns, and the performance of weighing equipment.

Chapter 11.—Weighing Principles

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 the U.S. 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. (This definition of the unit of force sets up an "absolute" unit; that is, one that 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.)

The actual gravitational force acting upon a given body varies with the geographical location of the body. Other conditions remaining unchanged, this force is measurably affected by changes in elevation—as from sea level to a mountain top, for example—and in latitude—as from the northern to the southern parts of the United States, for example. However, if the weight of the body is determined by the use of standard weights, either directly on an equal-arm scale, or indirectly on a scale utilizing weighbeam poise and counterpoise weights, the observed value of the weight of the body will not be affected by changes in either the elevation or the latitude of the body (other conditions remaining unchanged) because the resulting changes in gravitational force will react equally upon the body being weighed and the standard weights being utilized, and the observed weight of the body in terms of the standard weights will therefore remain the same. (In this discussion, variations that result from changes in air density—which are commercially unimportant—have been disregarded. Moreover, the general matter 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 National Bureau of Standards.)

In commercial transactions involving quantity determinations and in most industrial weighings, 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 guantity 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, that 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.

Scales. As used herein, the word "scale" means a weighing scale, that is, an instrument for determining and indicating weight, and embraces all types from the simple equal-arm beam to the relatively complicated weighing machines designed to meet the special demands of modern commercial or industrial service. But whether simple or complex, the scale is a mechanism for opposing an unknown force with a known counterforce and thus producing the desired weight indication.

The majority of weighing 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 "load" and "power" points. (In this publication the word "power" is used in its specialized scale sense of denoting the counterforce opposing the load; the word is not to be understood in its engineering sense of the time rate of doing work.)

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

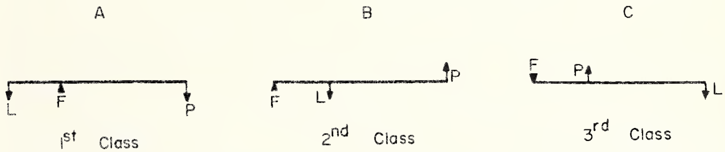


FIGURE 1. *Classes of levers.*
F = Fulcrum.
L = Load point.
P = Power point.

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. Homely examples of levers of the different classes are: 1st class, pliers, seesaw, crowbar used as a pry, walking beam; 2d class, nut crackers, oar, pump handle when fulcrumed at end; 3d class, tweezers, sugar or fire tongs.

Scale Levers. 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 or reading face assemblies 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 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." (In a scale lever, whenever the forces act along a line—as along the knife-edge of a pivot—the power and load arms are measured at 90° to the line of action of the force, that is, perpendicular to the line of the knife-edge.)

Lever Multiple or Ratio. The ratio between the power arm and the load arm of a lever is its "multiple" or "ratio." (The multiple of a lever may be called by the physicist its "mechanical advantage.") If a lever has power and load arms that are equal, its ratio 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.)

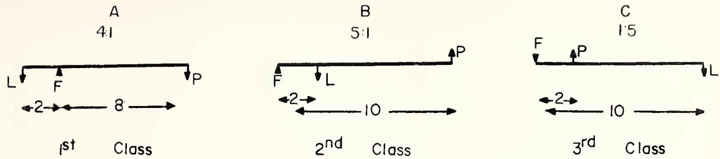


FIGURE 2. *Arm lengths of levers.*
F = Fulcrum.
L = Load point.
P = Power point.

Let it be assumed that three levers of different class have the arm lengths indicated in the diagrams in figure 2. Lever A is seen to have a ratio of 8:2 or 4:1; 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 $\frac{1}{5}$ 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. 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.

Multiple of a Lever Train. 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 diagrammatically in figure 3; in each case the multiple of the system is 20.

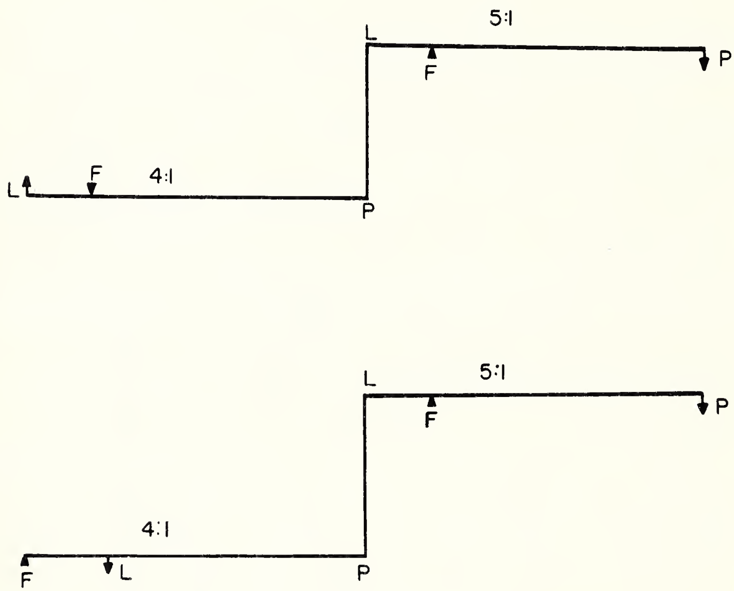


FIGURE 3. *Combinations (trains) of levers.*

F = Fulcrum.
L = Load point.
P = Power point.

Multiple of a Scale. In scale construction, the multiples of the levers used are not always integral numbers; multiples such as 2.9, 3.4, $2\frac{2}{3}$, $3\frac{1}{3}$, 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 on any scale that utilizes counterpoise weights, 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 are the multiples of individual levers. Portable platform scales using counterpoise weights usually have tip multiples of 100 or 200. Similar platform scales of larger capacity usually have tip multiples of 500, 1000, or 2000. Counter scales may have tip multiples ranging from 2 to 66⅔.

When a scale is said to have a tip 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 hanger 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.

The butt multiple of a scale 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.

Equilibrium and Center of Gravity. 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 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 that prevails is the effect that 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 that 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 that 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 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 oscillation 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 12.—Basic Weighing Elements and Some Simple Scales

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,

A Chinese steelyard.

This small-capacity type was intended for the weighing of precious metals or other valuable items. The steelyard shown is of ivory, with three silk-cord fulcrums, a brass poise sliding on a cord loop, and a cord pan suspension. The banjo-shaped wooden case is for storing the steelyard when not in use. [From the museum of W & T Avery, Ltd., Birmingham, England.]

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 fixed in 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.

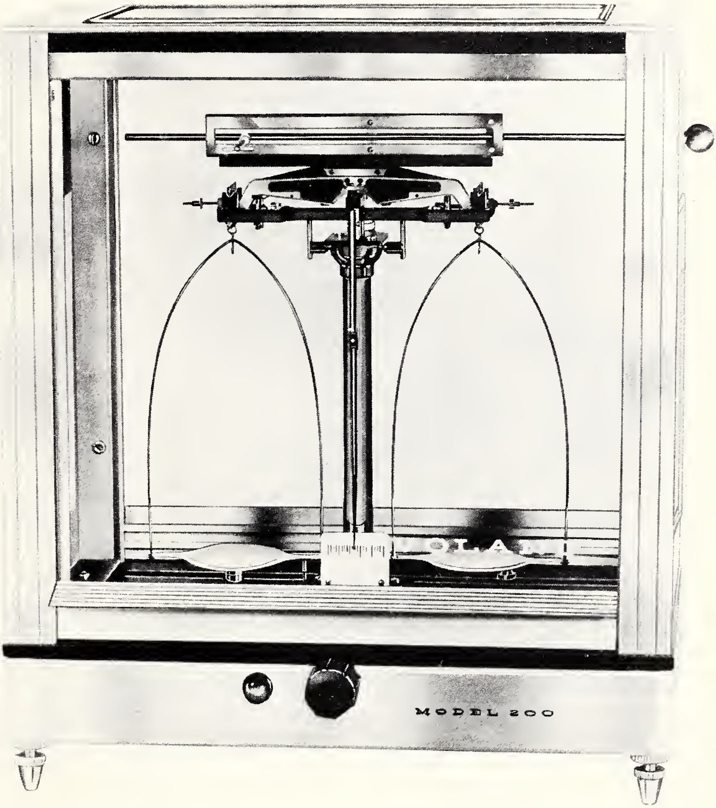
Sometimes instead of being shaped to a knife-edge, a pivot is shaped to a point; such "point pivots" or "cone pivots" are made use of in certain cases where levers join at an angle or where a very flexible connection is needed, and are satisfactory where the transmitted forces are not too great.

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 be made of 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. In still another development a small assembly utilizing an element known as a "load cell" substitutes not only for pivots and bearings but for the lever as well; this will be discussed at a later point (pages 178–9) in this chapter.

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 that is still used for a wide variety of weighings, ranging from commercial operations to scientific weighings of the highest precision.



A simple equal-arm balance.
This type of balance is used for laboratory work that does not demand high precision, and is sometimes used in pharmacies for "class A" prescription duty and in jewelry establishments for the weighing of gems and precious metals.

This type of weighing device 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 device 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.

Both the simple balance and the steelyard are 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; 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 that 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 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

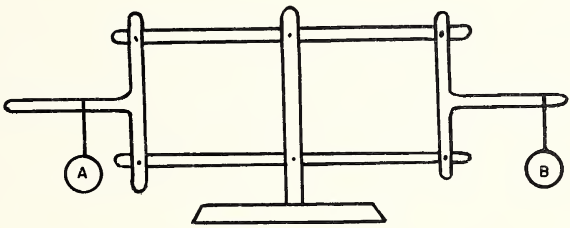


FIGURE 5. *The Roberval principle.*
Diagrammatic sketch of the device by which the principle was originally demonstrated.

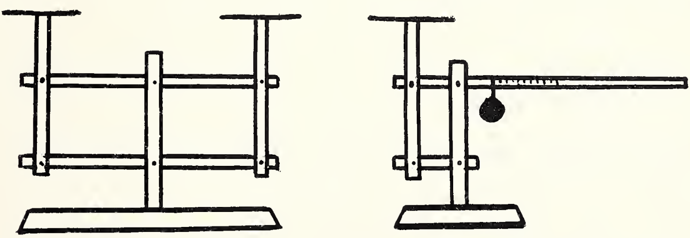


FIGURE 6. *Application of the Roberval principle to weighing scales.*
Diagrammatic sketches of stabilized-pan scales of the simple equal-arm and unequal-arm types.

essential condition in scales of the type illustrated is that 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 sometimes located above the main levers rather than below them, in order to obtain certain advantages in the operation of this element.

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 livestock 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 "payload" they are designed to carry has necessitated a corresponding increase in the strength and weighing capacity of vehicle scales, until now 50-ton "motortruck" scales are being generally installed for vehicle weighing, and motor-truck scales having capacities of 60 and 70 tons are also available. A comparable development has also taken place in the platform size of scales intended for weighing highway vehicles and vehicle combinations; platforms 60 feet or more in length are now by no means uncommon.

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 levers may be mounted one above the other, and combined by connecting the power pivot of the lower one

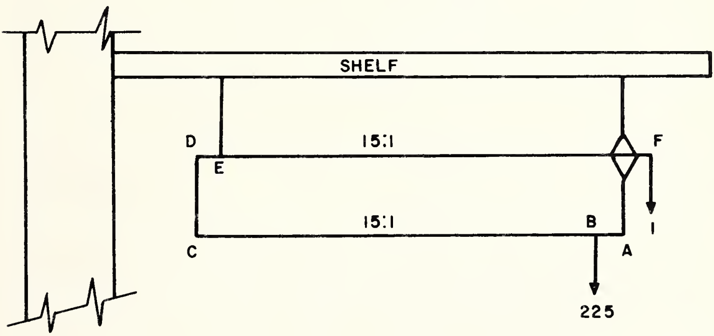


FIGURE 7. *The "butcher's meat beam."*

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.

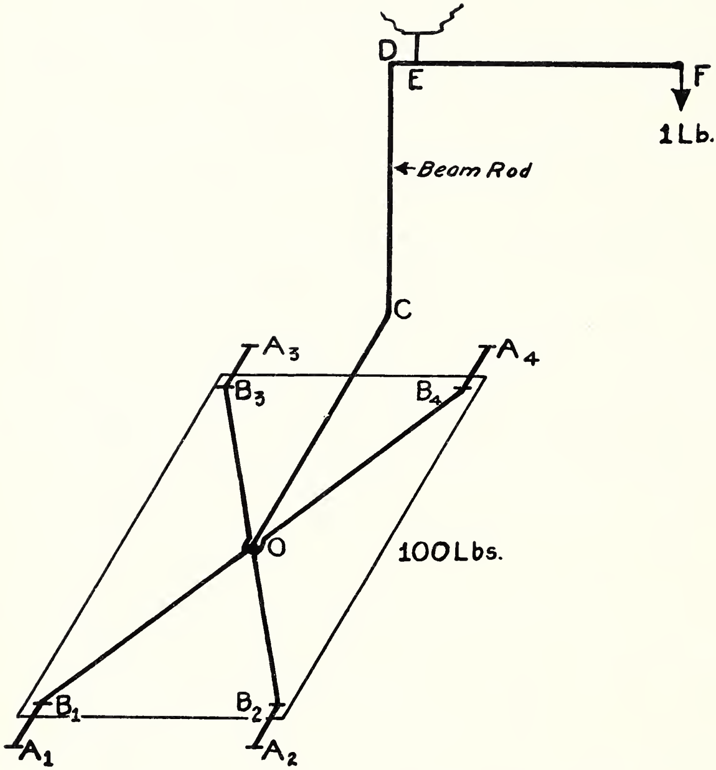


FIGURE 8.—*The "portable platform" scale.*

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.

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 designed to be 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 designed to be 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 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 and in figure 7. 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.)

To repeat, 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 8.

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 the following chapter.

Nose-irons. Scale levers and weighbeams 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 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 levers of the system, adjustable with

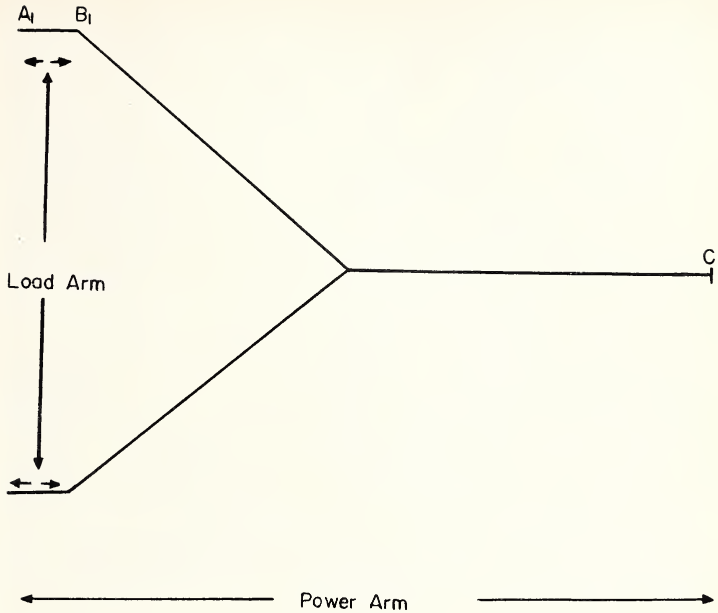
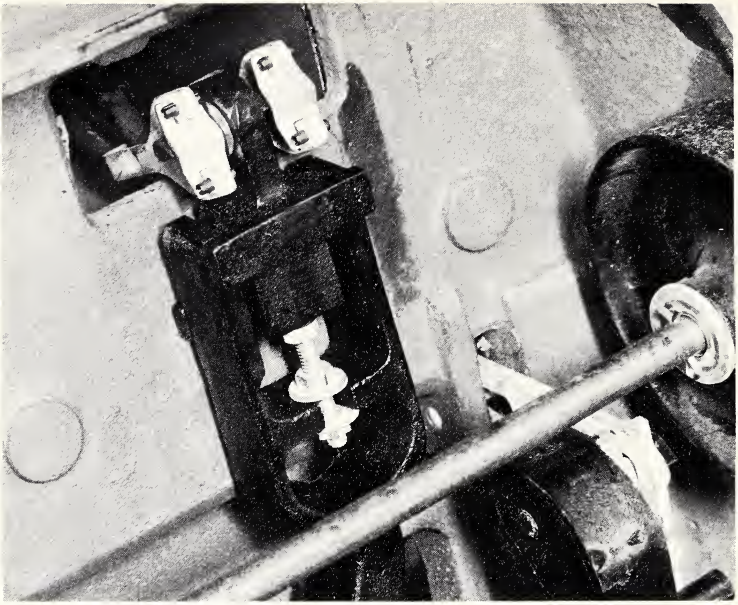


FIGURE 9. *The "arms" of the long lever of a portable platform scale.*
A_1 A_2 = Fulcrum knife-edges.
B_1, B_2 = Load knife-edges.
C = Power knife-edge.

respect to their distances from their respective fulcrums. (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.) 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.

Range. 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



Detail of a portable-platform scale nose-iron.
The push-pull adjustable element carries the tip (power) pivot of the long lever and connects, by means of a bearing loop, with the beam rod.

knife-edge relative to a line joining the load and power knife-edges. In figure 9 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 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

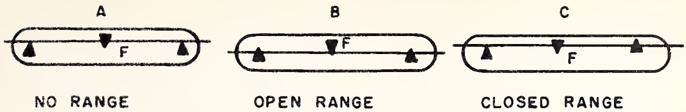


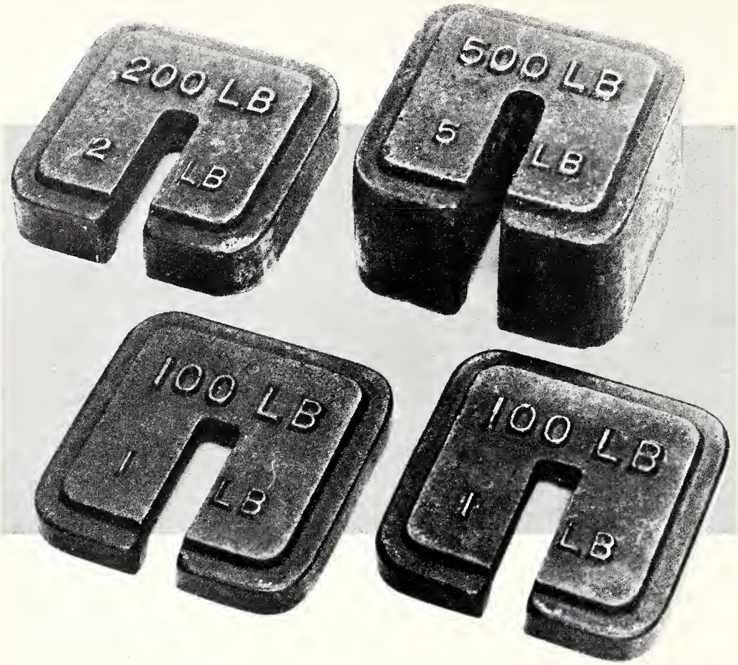
FIGURE 10. *Range of pivots.*
Diagrammatic sketches of equal-arm levers to illustrate the three kinds of range.
F = Fulcrum.

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 that 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 that 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."



Full complement of counterpoise weights for a 1000-pound portable platform scale having a 100-pound weighbeam and a multiple of 100:1.

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 that 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 and Poises. 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 values 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. 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 "trig 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 of 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. 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 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, that 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.

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:

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

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.

An automatic-indicating scale may be defined as one on which the weights of applied loads of various magnitudes are automatically indicated throughout all or a portion of the weighing range of the scale. A "full-automatic-indicating" scale is one on which the capacity of the automatic-indicating elements equals the nominal capacity of the scale. A "semi-automatic-indicating" scale is one on which the capacity of the automatic-indicating elements is less than the nominal capacity of the scale. (A scale that automatically weighs out commodity in predetermined drafts, such as an automatic grain hopper scale, a packaging scale, and the like, is not an "automatic-indicating" scale.)

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 is automatically 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 may be employed in platform scales of either class.

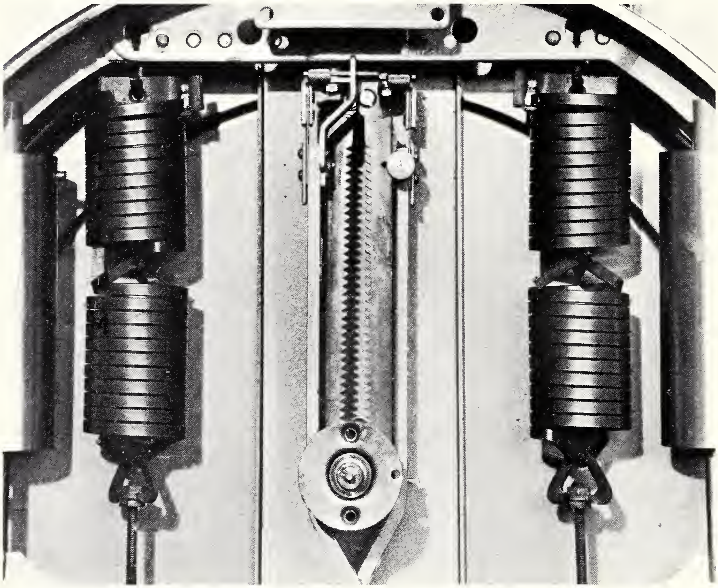
The Spring. "Elasticity" is that property of a body by which it is capable of recovering its original size and shape after it has been forcibly deformed. With reference to a given body, the "elastic limit" is the greatest stress (force per unit area) to which the body may be subjected without preventing its recovery of its original form after the deforming 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 that, when released after having been forcibly deformed (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 principle is the basis for the use of springs in scale construction to supply counterforce.

For many years "weighing" springs were made of high-carbon steel, hardened to the proper point, and were 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. (It may be noted that for such springs the extension under a given load will be greater the greater the number of turns in the coil, the greater the diameter of the coil, and the smaller the diameter of the wire.)

Simple springs such as have been described have one characteristic of particular importance to their use in scale construction—they are affected by temperature changes. If the temperature is increased the spring grows "weaker" and under a given load will extend a greater amount than at a lower temperature. If the temperature is decreased, the opposite effect is produced. In the past, many of the more elaborate spring scales were equipped with automatic, thermostatically controlled adjusting devices designed to compensate for variations in the resistance or elasticity of the springs that resulted from changes of temperature.

Special alloys have now been developed as materials for spring manufacture, 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. Further improvements in the performance of coiled springs when used in scale construction have been brought about by special heat treatment and by the use of flat stock rather than wire of circular cross section. The improved springs are now widely utilized in spring-scale manufacture. It may be noted, however, that in spring scales of simple design and inexpensive construction, simple, high-carbon-steel springs are still extensively utilized.



Interior mechanism of hanging, double-spring, circular-reading-face scale.

The indicator and reading-face have been removed from the side facing the camera. Each rack actuates one pinion-and-indicator combination. Each "spring" comprises two coils wound in opposite directions. There are two pneumatic dash-pots, one at either side.

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 bent lever of the first class, with the distinguishing and very useful characteristic of having, in effect, arms of variable length that 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 "pen-

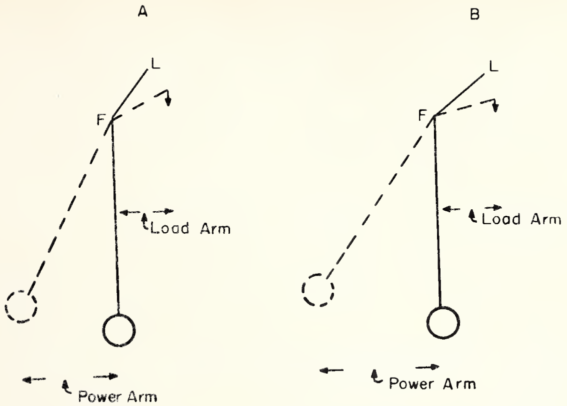


FIGURE 11. *The pendulum as a counterforce.*
Diagrammatic sketches illustrating the varying "power" of a pendulum.

dulum weight" or "pendulum ball," secured at or near the free end of the long arm. Without attempting to picture the actual details of customary scale design, the diagrammatic sketches shown in figure 10 illustrate the characteristics 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 10. 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. 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.

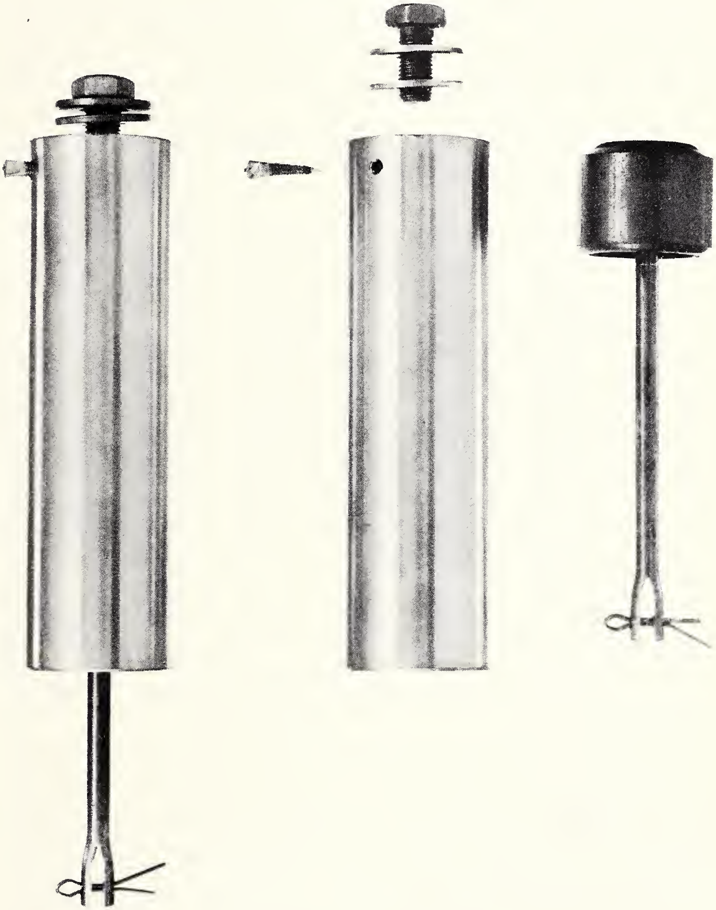
The amount of counterforce that a pendulum is capable of exerting depends upon the effective lengths of its load and power arms and upon the mass of the pendulum ball. Other factors remaining constant, the counterforce that may be exerted by a given pendulum will increase as the weight of the pendulum 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.

Pendulum assemblies for scales are frequently of the double-pendulum variety, two opposed pendulum-and-cam units being jointly and simultaneously actuated when a load is applied to the scale.

The Dash Pot. By reason of the very characteristic of the counterforce mechanism that makes the automatic-indicating scale possible—that is, its readiness to respond automatically, completely, and rapidly to changes in the amount of applied load, within the designed range—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 very 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



A pneumatic dash-pot.

The view at the left shows the dash-pot assembled. The disassembly illustrated at the right shows the piston and stem, the cylinder, and the needle valve that controls the damping effect. The top of the stem is the point of connection to the weighing mechanism.

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 dual capacity through the resistance that it offers to rapid movement of the scale mechanism; in other words, it acts as an effective brake. Dash pots have been of two general kinds, liquid dash pots and pneumatic dash pots, the former very much more widely used than the latter. Recently some use is being made of dash pots that operate on the magnetic principle.

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 that are externally adjustable as to size. The piston adjustment provides a ready means of controlling 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 now used in liquid dash pots is usually a fairly light petroleum oil, silicone fluid, or, for scales of large capacity, kerosene, although other liquids and mixtures have been used. The damping effect of a liquid dash pot depends upon such factors as the viscosity of the liquid used, the clearances around the piston, the area of the piston ports, the range of adjustment of the ports, and the area of the piston. In addition to his consideration of these factors, the scale designer seeks 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, and one that is in chemical harmony with the metals exposed to it in dash-pot service. It is important that the weights and measures official and the operator of any scale equipment with a liquid dash pot respect the judgment of the scale designer, and never add to the dash pot of such a scale any liquid that is not recommended for that specific use by the manufacturer 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 that 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 or, sometimes, by means of a digital indicator—that is, a "straight-reading" counter, as in an automobile odometer. 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 that 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. 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, a commercial straight-face spring scale is not susceptible of the precision of indication that may be obtained in other automatic-indicating types of scales 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.

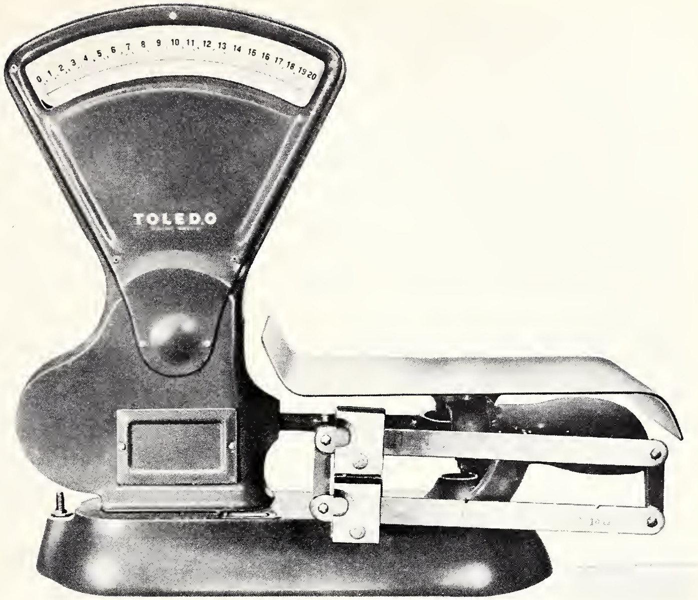
If in the preceding example it were possible to increase or magnify the travel of the indicator, indications corresponding to spring elongations caused by loads much smaller than quarter-pounds could be read. This is exactly what is accomplished in the "dial" type of scale, which has a circular "reading 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 that meshes with a straight rack that 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 diameter of 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 earlier, 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.

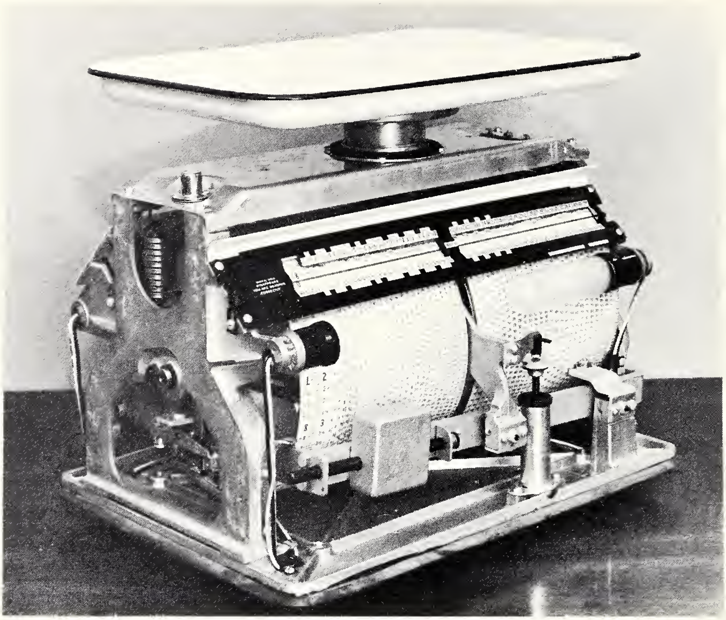
A "fan" scale is so called because the indicator, in traveling from its position at zero load to its position at capacity load, describes a path shaped like an opened folding fan; that is, a sector of a circle. The application of load to such a scale causes the indicator arm, which is relatively long, to rotate on its axis and to pass across



An automatic-indicating unequal-arm bench scale.
This scale has a 20-pound × 2-ounce, fan-shaped, noncomputing reading face, and is equipped with a double-bar weighbeam, one smooth bar graduated to 10 pounds by 1-ounce subdivisions, and one 10-pound notched capacity bar having a single (5-pound) subdivision. The post can be seen extending downward through the opening in the base to connect with the stabilizing linkage within the base.

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 stretched horizontally across the face of the chart. Obviously, only a small portion of the surface



A "box-type" computing scale with housing removed.
This view shows the dealer's side of the scale. (One of the chart lamps has been removed.) A part of the lever system, with fulcrum and load bearings, and connection to hydraulic dash-pot are shown in foreground.

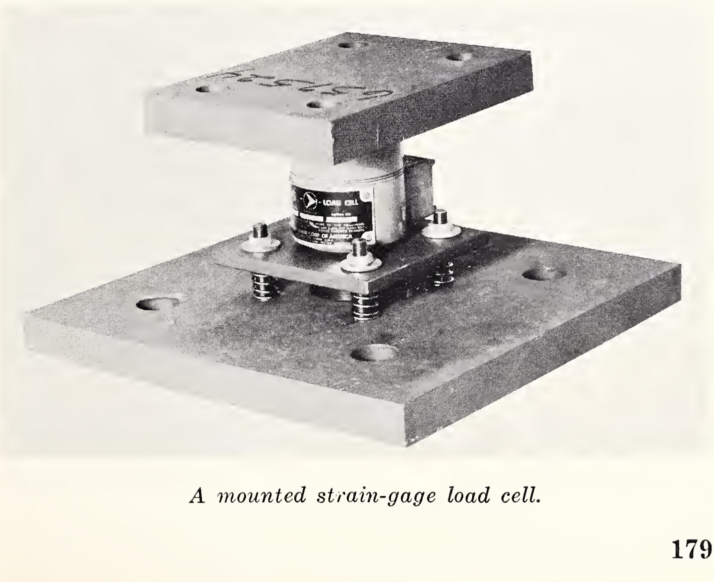
of the cylinder is required for the single series of weight graduations; the reason for building a cylinder scale is to provide room for a plurality of series of value computations giving the money values for various weights at different prices per pound. A scale equipped with a price-computing chart is called a "computing" scale; this type will be discussed in the succeeding chapter.

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 the weighing 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.

Load-Cell Scales. Automatic indication of weight may also be obtained from systems in which the forces of applied loads are measured by means of elements known as "force transducers" or "load cells." These devices may involve strain-gage, hydraulic, or pneumatic components.

The strain-gage load cell, together with its electrical-electronic instrumentation, converts the applied force into weight units. Hydraulic and pneumatic load cells may actuate some form of mechanism that converts the pressure directly into weight units.

Load cells may be utilized in scales in two ways. (1) The load-receiving element of the scale may be mounted directly on load cells. (2) The scale may employ a conventional platform lever system, but have a load cell introduced at some suitable point beyond the platform lever system (usually under the transverse-extension lever or in the steelyard rod that is connected to this lever). In either location, the load cell converts the load forces into electrical signals for transmission to the readout unit. The "readout" may be provided in any one or more of a variety of ways. This readout may be accomplished by



A mounted strain-gage load cell.

an automatic-indicating device, automatic adding machines, automatic typewriters, teletypewriters, tape punch machines, or card punch machines. It may also be converted from analog to digital form for transmission purposes. The readout element may be installed at a considerable distance from the weighing site, and may serve more than one weighing unit. Likewise, a single weighing device may read out at two or more indicating elements.

"Electronic" Scales. The most frequently encountered load-cell scale is the so-called "electronic" scale in which are employed strain-gage load cells. The operation of the strain-gage load cell can best be explained by examining, in fairly simple terms, the two main principles that form the basis of the electronic weighing systems. The first principle concerns the load-receiving supports, which are generally small upright steel columns mounted on a rigid base. The steel columns respond to a law which states that the strain or deformation of the column will be proportional to the stress or load applied to the column, provided, of course, that the load does not exceed the elastic limit of the column. The column actually behaves as a true spring, but the strain or deformation is so slight that it is imperceptible to observation by the naked eye. A load of fifty pounds on a column may cause a compression of twenty-five millionths of an inch.

The second principle concerns the change in electrical resistance of a conductor when subjected to a stress. An electrical conductor strained by tension will provide an increase in resistance, while a compressive stress will provide a decrease in resistance. A strain gage is constructed of approximately 5 inches of very fine (one-thousandth of an inch in diameter) resistance wire, which is formed into a grid no larger than the size of a postage stamp. This grid, cemented between two pieces of thin paper, is very sensitive to strains and to changes in strain. A well designed strain gage will be capable of detecting movements as small as a millionth of an inch.

These two main principles are combined in the strain-gage load cell as the strain gage, bonded to a steel column, responds to a stress or applied load by changing in electrical resistance in an amount proportional to the applied load. Generally, four strain gages are used in a single load cell, depending, of course, on the type of load to be sensed. This combination of gages provides a degree of temperature compensation and increases the electrical output.

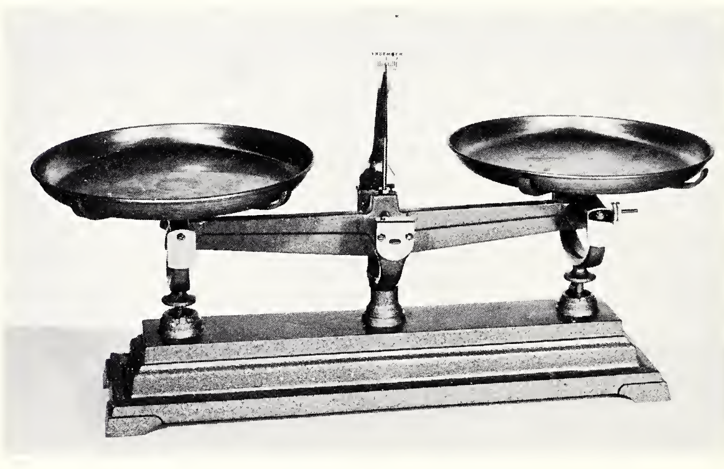
The change in resistance of this load-cell circuit, resulting from an applied load, is precisely measured by a complex electronic instrumentation, which involves an amplifier, a Wheatstone bridge for balancing purposes, and a readout device. The amplifier, composed of electronic circuitry, amplifies or increases the power of the original electrical impulse from the load-cell circuit to provide sufficient voltage and current to actuate the readout device.

The gages bonded to the steel column are enclosed in a hermetically sealed steel housing to reduce the effects of temperature and humidity changes. The housing provides for the connection of wires through a junction box from the strain gages to the instrumentation.

Chapter 13.—Ordinary and Special-Purpose Scales

Scope of Treatment. It is the purpose of this chapter to describe briefly the more usual types of ordinary and special-purpose scales that the weights and measures officer may encounter in the course of his official duties. Ordinary scales, as distinguished from special-purpose scales, are grouped according to their design and construction and are treated under the designations (1) bench or counter (embracing equal-arm, unequal-arm, and four-bearing), (2) suspended, (3) portable platform, (4) warehouse, (5) overhead, and (6) motor truck. Railway track scales are not discussed in detail, because almost all weights and measures jurisdictions are without the specialized and expensive equipment necessary for the proper testing of these scales. Wagon scales are not discussed because this type has been completely outmoded, being replaced by the motor-truck scale.

Bench or Counter Types. The classification of bench or counter scales embraces, in general, all scales that are especially adapted, on account of their compactness, light weight, moderate capacity, and arrangements of parts, for use upon a counter, table, or bench. (Computing scales are excluded because of their special character.)



An equal-arm counter scale.

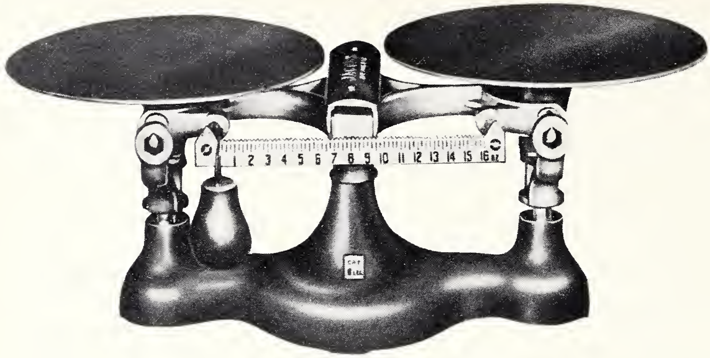
This type is frequently used as a druggists' counter scale. The view shows the balance-indicating elements, the anti-friction end caps for fulcrum and load pivots, and, at the right, a balance-adjusting element.

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 four-bearing scales. These three groups will be separately considered under their respective headings.

From the standpoint of similarity of capacity, type of indications, and character of use, many bench and counter scales and many "suspended" or "hanging" scales 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 encountered 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.

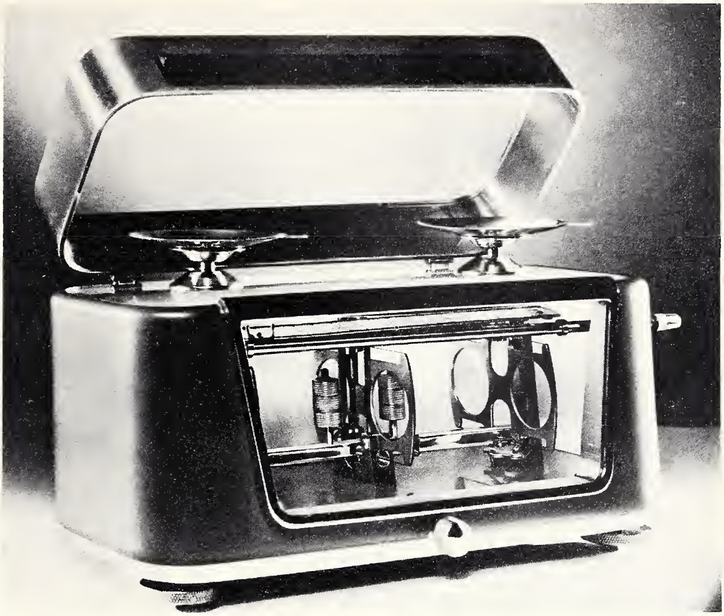
The type of equal-arm scale in which the pans are supported above the beam and are stabilized by a linkage on the Roberval principle, will be found in general use in many lines of business and industry. Certain patterns of equal-arm scales are commonly spoken of as "trip" scales. The simplest variety 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 trip scales in denominations down to the smallest value that 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



A nonautomatic-indicating equal-arm counter scale.
This 8-pound "trip" scale has flat circular plates as load-receiving elements, and is equipped with a 16-ounce × 1/4-ounce notched side-bar having a hanging poise. The two posts can be seen extending downward from the bearing yokes to connect with the stabilizing linkage within the base.

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 balance indicator 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 that employs a long upright pointer in combination with a flexural 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 reading face. On such a scale 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. If weight values are assigned, the scale is classed as an automatic-indicating scale, even though the range through which weight values are indicated automatically is relatively very small. This type is commonly spoken of as an "over-and-under" scale, and the chart may be 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



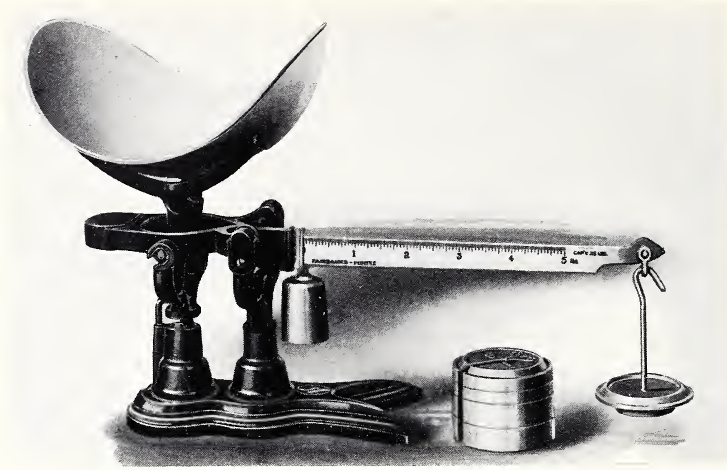
A "class A" prescription scale.

This scale employs steel bands under tension instead of conventional pivots and bearings. The parallelogram formed by the beam, stabilizing bar, and torsion-band grids is well illustrated. The poise on the graduated weighbeam bar is positioned by means of the sliding rod with fork end that projects through the housing at the right.

commodity pan will not be confused with the weight pan.

In another type, a semiautomatic-indicating 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 bar 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



A 35-pound, unequal-arm, beam, counter scale, with hanging poise and counterpoise weights.

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 or other hard "stone."

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 commerical 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 reading faces 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.

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 at a later point. 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.

Four-Bearing Types. A "four-bearing scale," as the term is used herein, is one in which the load-receiving element, normally a platform, has four lines of support comprised in bearings that contact the knife-edges of pivots in the levers. A bench or counter four-bearing scale is one in which the weighbeam or other reading element is located at an elevation sufficiently low in relation to the load-receiving element 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 four-bearing scales. However, there are numerous automatic-indicating computing scales that do not differ much in outward appearance from four-bearing scales, but in which the platform or platter has a two-point support—that is, only 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. These scales may be identified by the term "stabilized platform"; it is necessary that they be distinguished from four-bearing scales because of the difference in the positions of the test load during the shift test for the two types. For the two-bearing (stabilized-platform) type the four shift-test positions are to the right, left, front, and rear of the load-receiving element, halfway between center and edge. For the four-bearing type the four-shift-test positions are points near each platform bearing in turn, at the four "corners" of the load-receiving element.

The ordinary counter, four-bearing, platform, beam scale conforms in general principles of design to portable platform and warehouse 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. Such 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 $66\frac{2}{3}$:1, $53\frac{1}{3}$:1, and 50:1 being common.

A modification of the ordinary counter platform scale that may be encountered is one that 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 four-bearing 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 as "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 four-bearing automatic-indicating scales may run from 10 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.

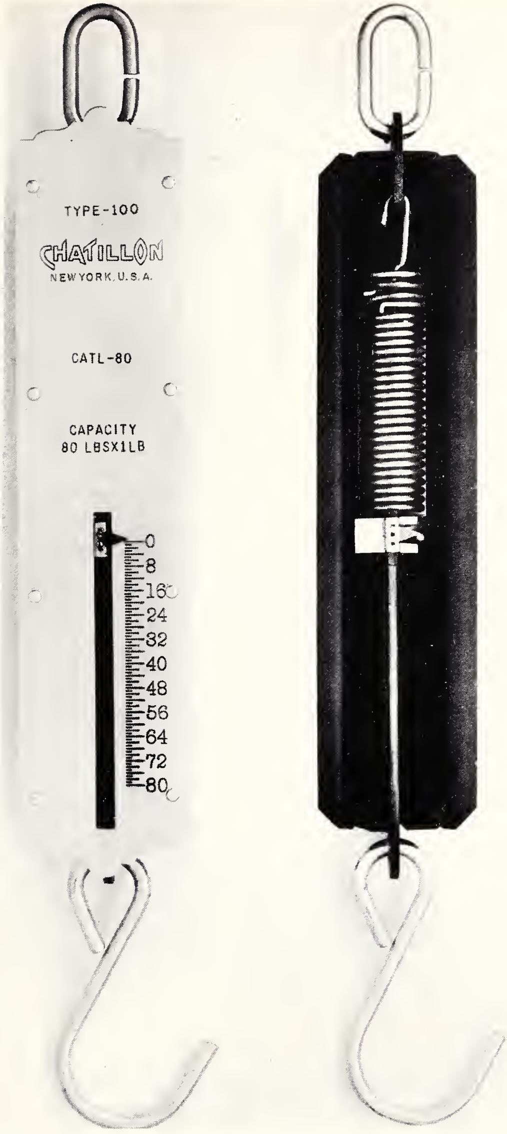
Suspended Types. A suspended, or "hanging," scale is a self-contained scale that is designed to be suspended from an overhead support. There are many suspended scales that are used for the same purposes as counter scales and that are identical in some respects, such as capacity, character of indicating elements, etc., with some scales of the counter type. Again, certain suspended scales correspond in capacity, use, and character of indications 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.

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 of 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 reading faces 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 reading face; 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.

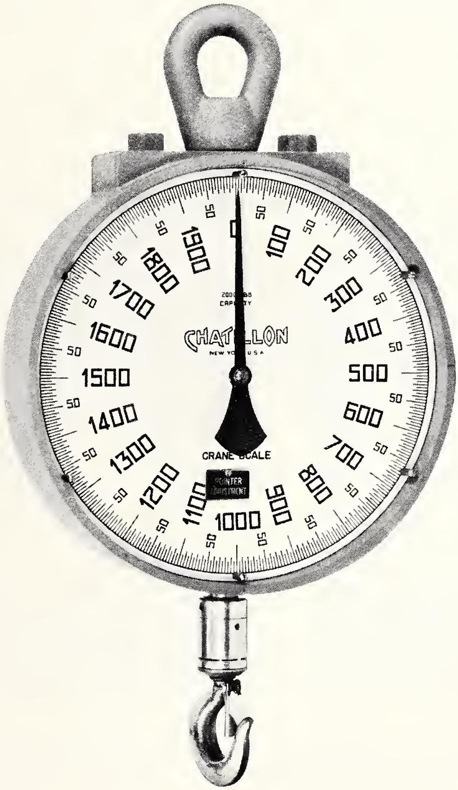
The simplest form of suspended beam scale that will be found in commercial use is the steelyard, and this will be encountered comparatively rarely except in the regions where cotton is weighed. The steelyard for weighing baled cotton is usually referred to as a "cotton beam" or, when used by a public weigher, as a "weighmaster's 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



A straight-face spring scale.
The view at the left shows this 80-pound × 1-pound scale completely assembled. The right-hand view shows the same scale with the face removed to expose the simple mechanism.

A hanging, circular-reading-face, spring scale, with deep pan.

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 that 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 opera-

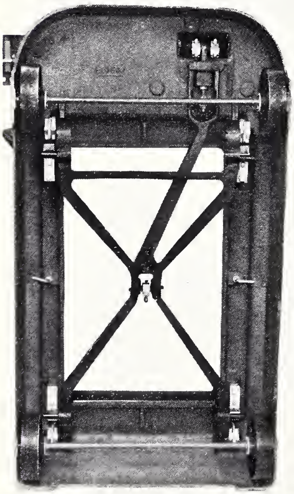


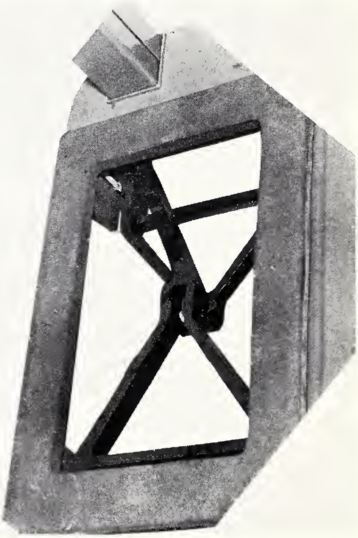
An automatic-indicating crane scale.

tion 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" that 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 many 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, may comprise a lever system connected with an automatic-indicating head, or may be of the load-cell type.

Portable Platform Types. The platform scale designed





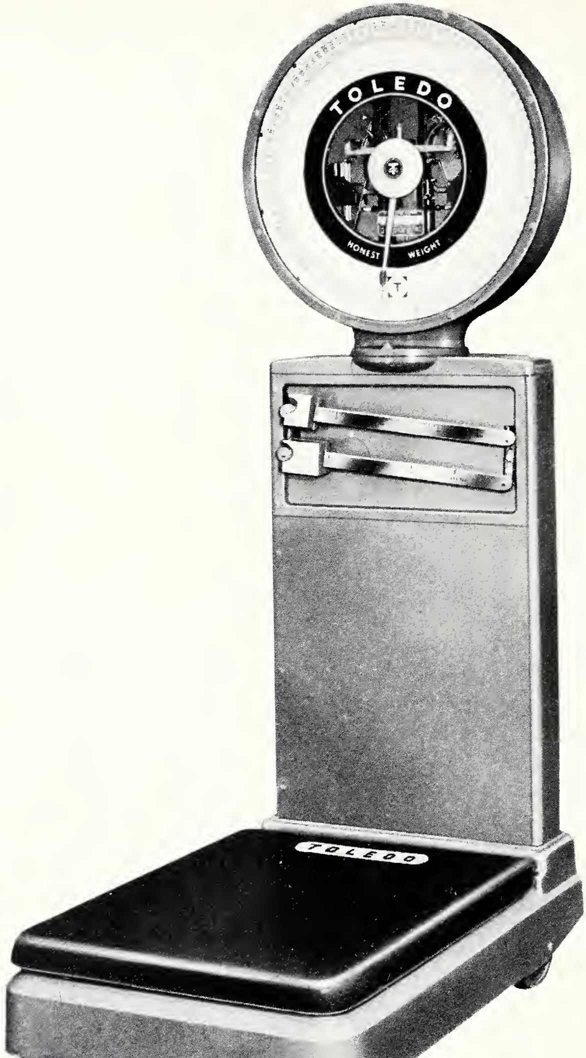
Lever system of a portable platform scale.
The metal cap that forms the load-receiving surface has been removed from the platform frame. In the right-hand view one looks downward through the opening in the frame; the "long" lever (above) and the "short" lever (below) are connected by a bearing ring at center. In the left-hand view one looks upward from the under side of the scale; at the upper right are shown the nose-iron of the long lever and the connection to the beam rod.

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 weighbeam or reading face 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 sometimes incorporated a relieving device (on beam scales) or a locking device (on automatic-indicating scales).

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 designed ratio is uniformly 100:1; in scales of larger capacities the designed ratio is frequently 200:1.

General-purpose automatic-indicating scales of the portable type have dials or other indicating means that are ordinarily graduated to one one-thousandth or less of their capacity; that is, there are usually not more than



An automatic-indicating portable platform scale.

The reading face, graduated to 500 pounds by 1-pound subdivisions, is supplemented by a double-bar weighbeam. A portion of the double-pendulum mechanism in the head is visible.

A portable platform beam scale with balance indicator.

In this view the trig is turned down to lock the weighbeam at the bottom of the trig loop, thus throwing the balance indicator to the "under" side. (With the trig released, proper "balance" is shown when the indicator is alined with the black arrow.)

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.

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."

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 that are primarily designed to be installed in a fixed position inside a building. (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.")

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.

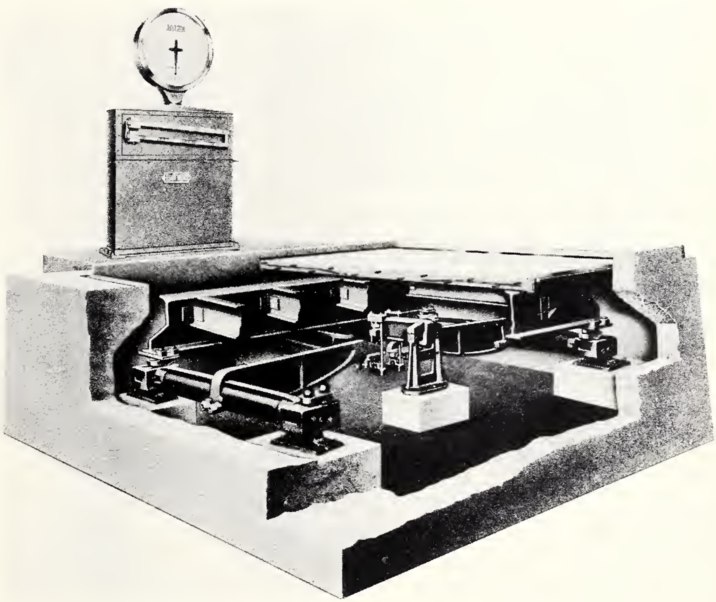
It is not uncommon to encounter a self-contained warehouse scale in use resting on the floor—like a portable scale without wheels. If the floor is level and provides a solid support for the scale, and if the height of the platform—10 or 12 inches above the floor—is not conducive to abuse of the scale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

There are numerous elements of general design and construction that are common to built-in warehouse scales and to motor-truck scales (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 forces transmitted from the power pivot of some other lever in the assembly.

The distinguishing characteristic of the torsion lever is 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



An automatic-indicating, built-in, 2-section industrial platform scale.

This cut-away view illustrates a torsion-lever (pipe-lever) system with ball checks.

which is attached, usually at a right angle, an extension arm carrying at its tip end the power pivot of the lever. 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 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.

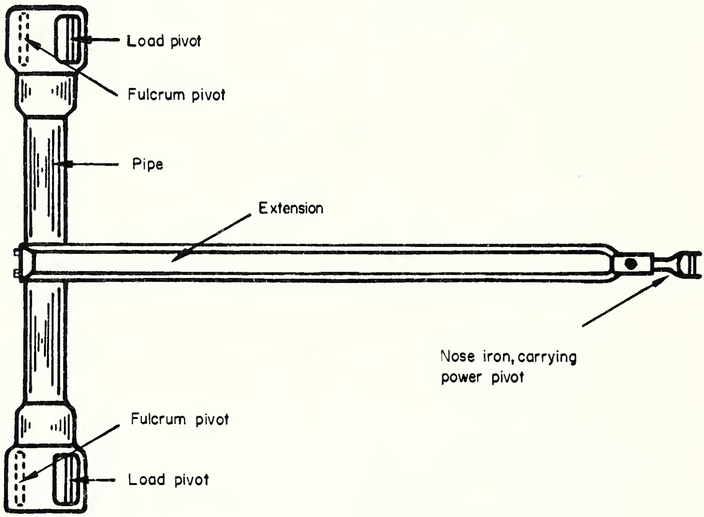


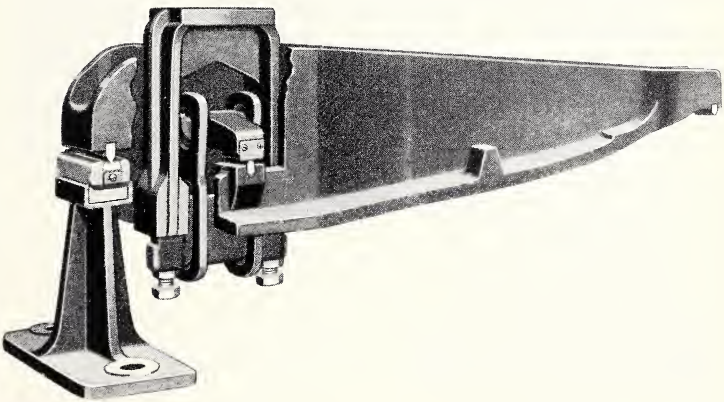
FIGURE 12. *A "pipe" or "torsion" lever.*
Diagrammatic sketch of a typical lever.

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 types); the forces may be transmitted from the main levers through one or more "extension" levers; and there may be a "shelf" lever. Extension levers, when they are included in the original design of the platform lever system, and shelf levers, may be 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), 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."

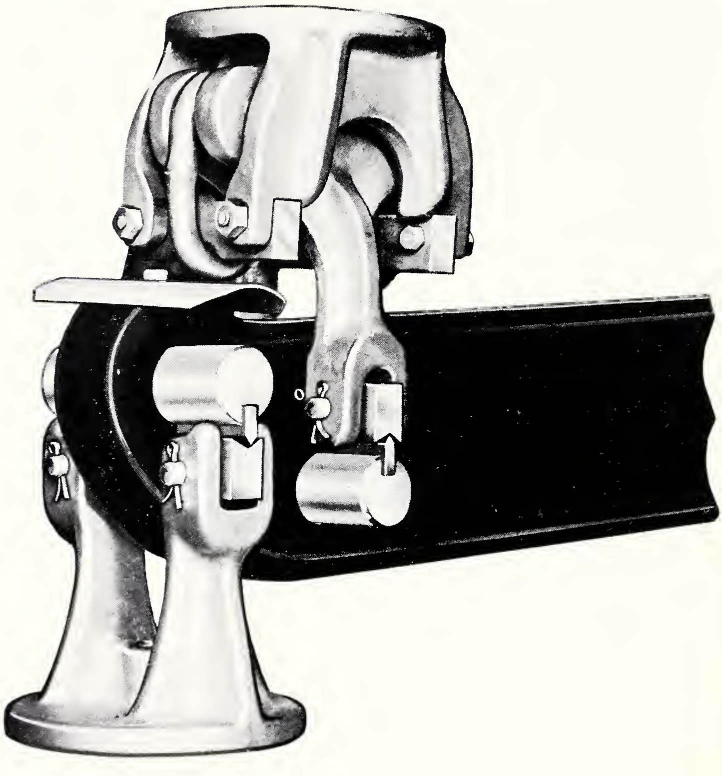
When the platform is provided with bearing feet that rest directly on the knife-edges of the load pivots of the main levers, this type of construction is known as the



Straight-lever main-lever suspension load bearing assembly.
This cut-away view illustrates a design in which the suspension elements are largely below the pivot knife-edge.

"rigid bearing" type. When load loops, or other linkages from the bearing blocks (that 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



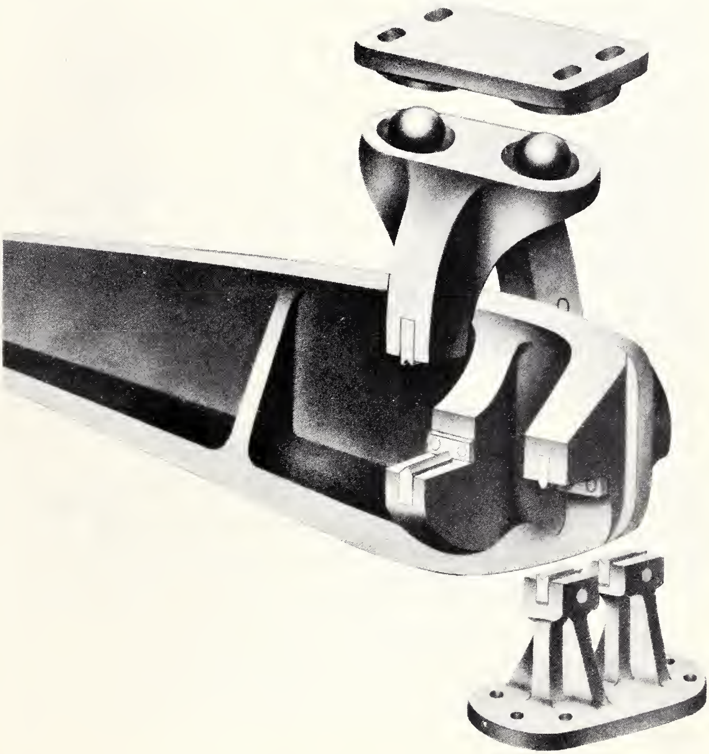
A suspension load-bearing assembly on a straight lever.

In this design the complete suspension assembly is mounted above the load pivot. Fulcrum pivot and fulcrum-bearing stand are illustrated, as are also the self-alining bearing blocks.

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 that 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.

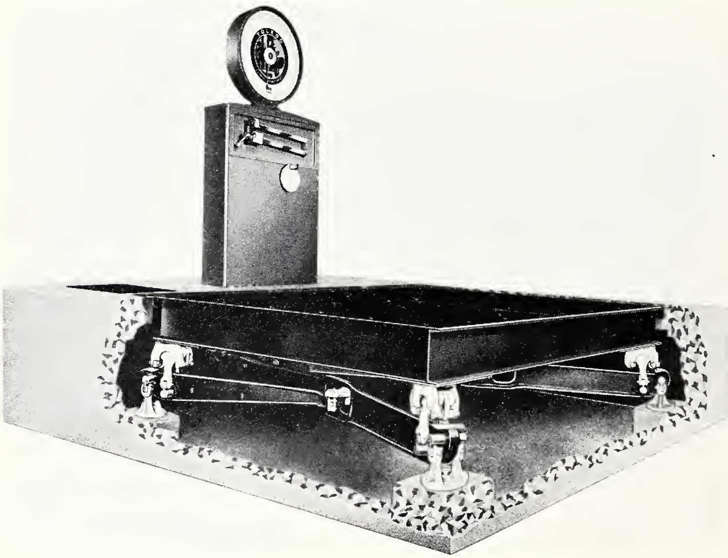
In another type of construction known as the "ball check" type, steel balls rest in iron cups directly above rigid bearing feet, and similar cups are fastened to the under side of the weighbridge supporting the platform;



A ball-check assembly.
This separated view shows the top ball plate, the load bearing with balls and ball sockets, load and fulcrum pivots, and fulcrum stand.

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 may be 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 ad-



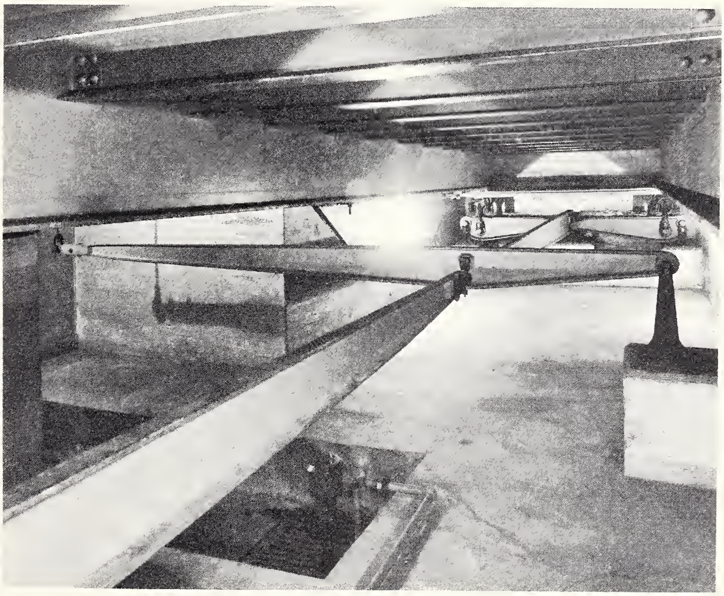
A built-in straight-lever system.

This cut-away view illustrates a concrete pit and piers; main-lever fulcrum stands; the two long main levers; one of the two short main levers and its connection to a long lever; the suspension load-bearing assemblies; and the frame for the scale platform.

justed 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 actually to prevent horizontal platform motion.

Scale 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, waterproofed, lighted, drained, ventilated, and heated, and 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-bar or multiple-bar,



A vehicle-scale pit designed for accessibility for inspection and maintenance.

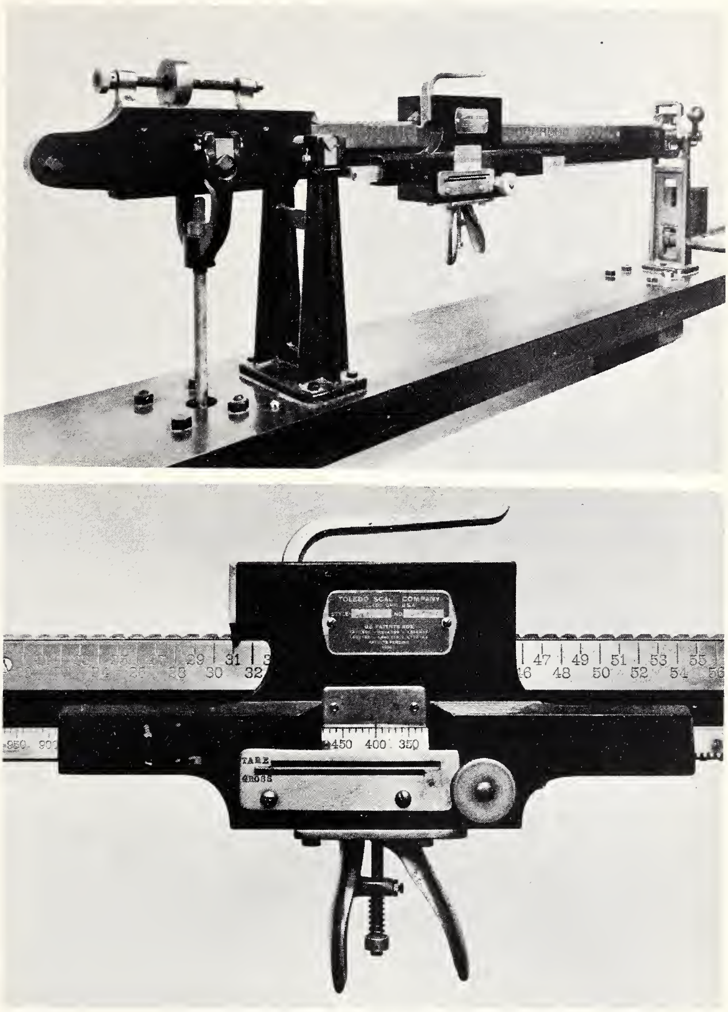
Entrance to pit is by stairway at left. Pit is lighted, and drains to sump furnished with automatic cellar drainer. (Scale has 40 ft × 10 ft platform.)

they may or may not be full-capacity, and they may or may not be type-registering. The ordinary type-registering weighbeam is a full-capacity weighbeam that has a row of type figures on the underside 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.

Automatic-indicating elements may be of any of the usual types already discussed, and 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 that 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.

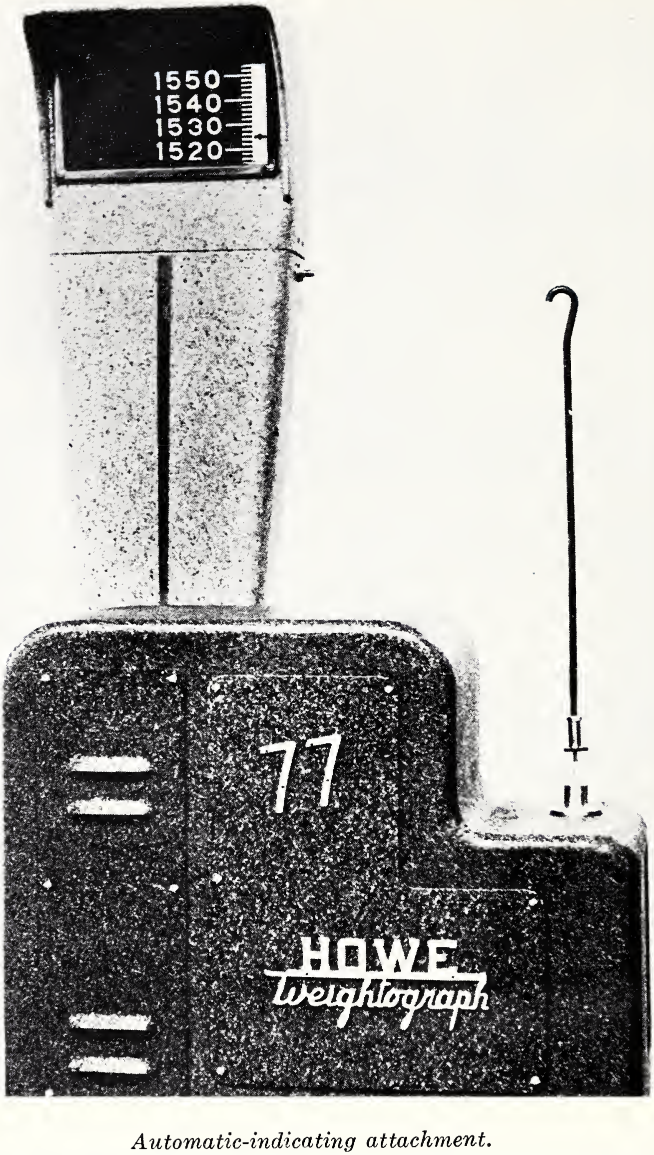
Automatic-indicating attachments may be connected to warehouse or motor-truck scales of the beam type; a familiar example of this is the unit in which the weight indications are projected upon a ground-glass screen. Balance indicators similar to those made for use on portable scales are also designed for installation on beam scales of large capacity. There are also "printing" scales or attachments, such that the weights of loads may be recorded on individual cards or otherwise.

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 1000-pounds capacity, very similar to the ordinary portable scale, may occasionally be found set into the floor.



Full-capacity, type-recording, weighbeam assembly of a vehicle scale.

Upper view: The complete weighbeam assembly.
Lower view: Detail of poise assembly.
Handle at top terminates in pawl that engages weighbeam notches. Grips at bottom are for imprinting weight indication on weigh ticket. Knob at right is for positioning fractional poise.



Automatic-indicating attachment.

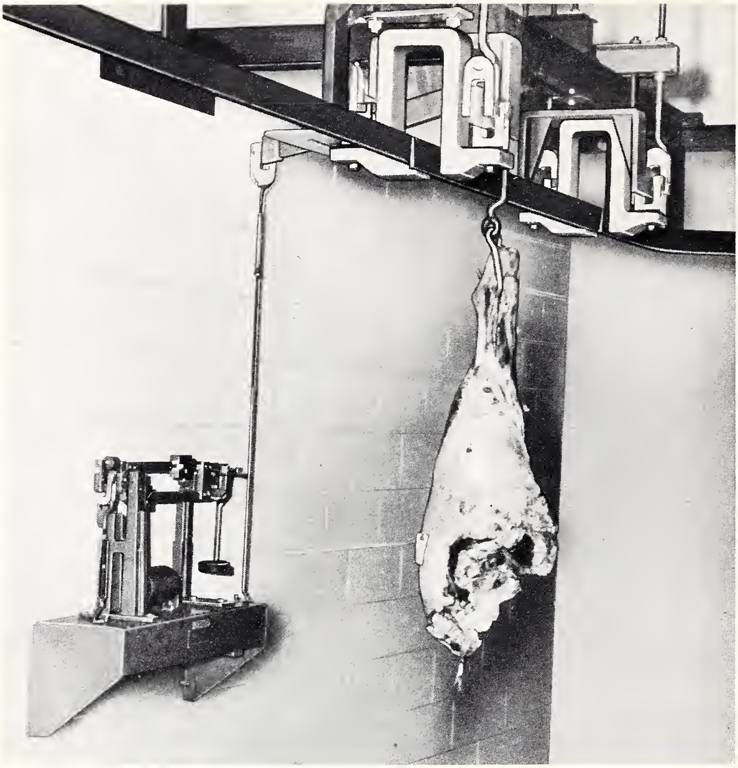
In this type the optical system projects on the hooded screen an image of a portion of a graduated scale, which cooperates with the fixed arrow-head indicator.

True warehouse types ranging in capacity above 1000 pounds 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 that normally are permanently installed in one location and that 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.

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

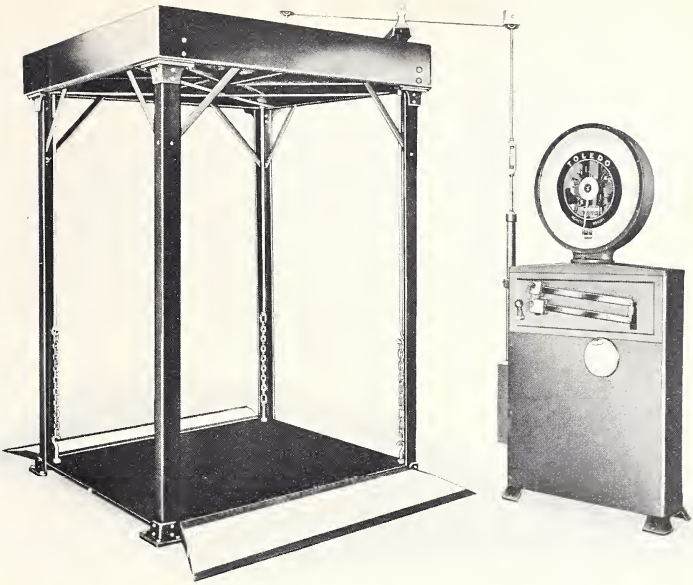


A monorail scale.

This view shows a roller and hook on the weigh rail, that is, the section of the overhead rail that is connected to the lever system. The weighbeam assembly is mounted on the wall.

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 cutout 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



A floor-supported, overhead-lever, automatic-indicating, platform scale.

On the cabinet there are shown the "crank" for applying and removing unit weights and, at the left of the weighbeam, the handle for actuating the locking mechanism.

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.

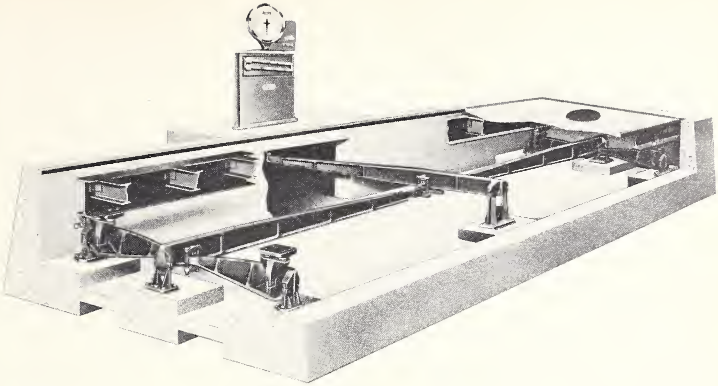
Scales of the Pitless, Animal, Livestock, and Dump Types. Scales of the so-called "pitless" type are designed for temporary installation in connection with construction projects. These scales may be said to be semi-self-contained; they have shallow-type levers and supports, so as to reduce to a minimum 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.

An "animal" or "livestock" scale is one 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. These 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, motor-truck, or railway track scales.

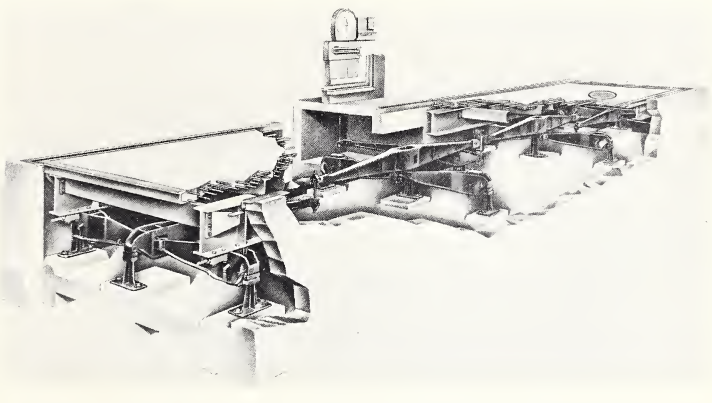
Another modification of a vehicle scale is known as a "dump" scale; the name is derived from the fact that the platform or a portion thereof may be tilted while a loaded vehicle is in place, and the load dumped from the tail gate into a receiving bin beneath the platform. The lever system is arranged 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 may range in capacity from 15 to 40 tons.

Vehicle Types. The vehicle 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 are of unusually rugged construction, 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 impact incident to truck movement across the platform.

In a typical two-section, straight-lever, vehicle-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 installations having platform lengths in excess of 40 feet, four-section design is customary. Here the platform lever system will comprise (1) in the straight-lever pattern, four pairs of main levers, two end extension levers, and one transverse extension lever, and (2) in the torsion-lever pattern, four main levers and one extension lever. Vehicle 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



A two-section, straight-lever, built in, automatic-indicating scale. This cut-away view shows concrete deck with manhole for access to pit, angle-iron protection for pit coping and deck, main girders and transverse deck beams, main levers, end extension levers, transverse extension lever, lever-fulcrum stands, and pit construction.



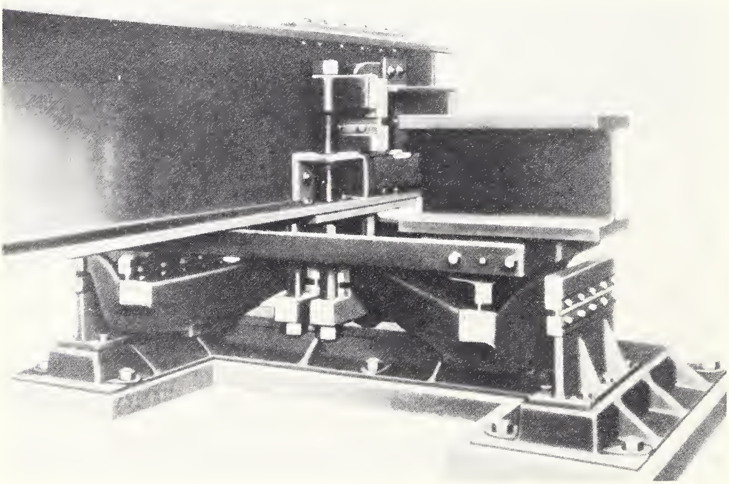
A four-section, straight-lever, automatic-indicating, motor-truck scale.

20 to 70 tons; platform sizes normally range from 20 by 8 feet to 100 by 10 feet.

Railway Track Types. 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 cutout 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 (as is also the case with vehicle scales) 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, but two-section scales are also in use.

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 that are rigidly secured in place. Thus at the fulcrum of a lever, one



Flexure-plate connections.
The view shows clearly the flexure plates at the main-lever fulcrum and load points of this railway-track-scale lever system.

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.

Reference should be made to chapter 12 (p. 179) for a discussion of load-cell scales. Present use of load cells is essentially confined to large-capacity scales.

Special-Purpose Scales. Any scale assembly that performs some service in addition to weighing, or that is designed for some special, restricted use, may be considered to be a "special-purpose" scale. Some of the more common types of such scales found in commercial use are discussed briefly here. Reference will also be made to some types that are not strictly commercial and that the official may rarely be called upon to examine, but that present interesting variations from conventional design; occasionally a type that 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-purpose 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, notwithstanding the fact that in its broad sense the term "computing" might reasonably be applied to any scale that is capable of indicating the result of some computation in addition to indicating weight. Scales other than the restricted class of "comput-

A testing scale.
A special-purpose design incorporating an optical system that projects an image of the indicator on the ground-glass screen.

ing scales" just defined, but that 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

An "upright", cylinder, computing scale.

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.

The weighing mechanisms of computing scales are largely conventional in design and construction with the exception of the "overhead checks" now customarily utilized on cylinder scales having only two main load supports. (Many cylinder computing scales now being manufactured are of this "stabilized" design.) Cylinder scales are normally computing scales; there would be no useful purpose served in building a cylinder scale just to show a single series of weight graduations.

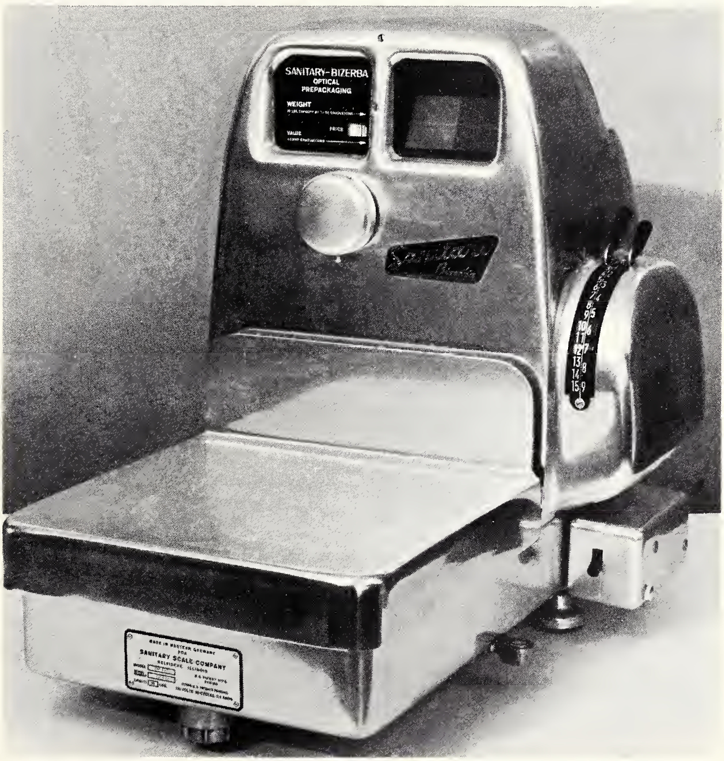
Usually in the fan chart the weight graduations are at the top along the wide edge of the chart, and the several series of value graduations corresponding to the various unit prices for which the chart is designed are arranged below, the series for the highest unit price being at the top. In the cylinder 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.

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 10, 12, 15, 18, 24, and 30 pounds and are 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 that utilize a fan chart, a weighbeam, and counterpoise weights.

Prepackaging Scales. The advent of the self-service method of merchandising fresh meat products in packages put up in advance of sale and displayed for sale in open refrigerated cases, has been responsible for the development of a variant of the ordinary computing scale that has come to be known as a "prepackaging" scale. The modifications incorporated in the prepackaging scale are directed primarily to the facilitation of the labeling of random-weight packages of commodity with statements of the net weight, price per pound, and total price of the package contents.

Initially the prepackaging scale had one principal distinguishing characteristic, a special element for the easy and rapid back-balancing of the scale to compensate for the tare weight of the package, so that the weight indicated by the scale would be the net weight of the package contents and the money value indicated would conform to that net weight. Soon the manufacturers of prepackaging scales placed a few graduations back of the zero graduation on the scale chart. The next development was to position these graduations accurately so that they could be assigned definite weight values, thus making it a simple matter to set the scale for various standardized tares without actually putting the tray and wrapping on the scale and balancing them off. With this simple apparatus the operator writes out the package labels by hand.

Makers of prepackaging equipment have now designed relatively elaborate units for large, random-weight, fresh-meat-packing operations. These include a label-printing element, and a selective mechanism such that the unit can be "set-up" to print repetitively on labels



A nonprinting, optical-projection type of prepackaging scale.
On this design, the indicator, for both weight and value, is the edge of a fixed colored band visible in the right-hand window; the image of weight and value graduations moves in a left-right direction as the load is changed. Only a single series of value graduations is visible at one time. The levers at the right of the housing set up the tens and units of the desired price per pound. The knob near the center of the housing is for balancing out the desired tare.

An automatic package-weighing and label-printing combination.

The weighing unit is at the left. The computing and label-printing unit is at the right; this unit reacts automatically to the indications of the weighing unit. At the right above is a rack holding a variety of inserts for the printing unit.

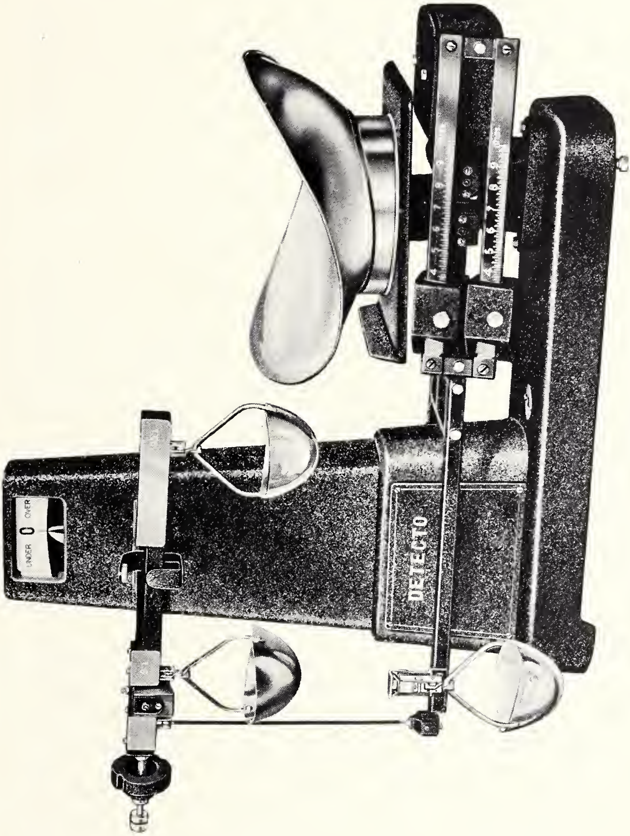
such items as the date, the variety or "cut" of meat, and the price per pound. The weighing element of the unit is connected with the printing element as is also a money-value-computing element, the latter being automatically "set" to compute at the particular price per pound for which the printer may be set. The weighing element can be back-balanced to offset the tare. When all these settings have been correctly made for a given product, a wrapped package of that product may be placed on the load-receiving element, the operation cycle of the unit may be started, and the unit will issue a label showing, in addition to the pre-set items—date, kind of product, price per pound, etc.—the net weight of the product and its total price. The actuation of the operating cycle may be automatic, being initiated as soon as the oscillation of the weighing mechanism has ceased. Also, the weight may be printed in terms of pounds and decimal fractions (hundredths) of a pound, instead of in pounds, ounces, and fractions of an ounce.

The test procedure for a simple type of prepackaging scale is practically the same as for an ordinary computing scale except for the added attention needed for the small graduated area back of zero. For the elaborate prepackaging units, recourse is available to the labels printed as the test loads are applied, the criterion of accurate performance being the issuance by the unit of labels that are accurate as to both weights and computed total prices.

Postage and Parcel-Post Scales. Scales designed for the determination of postage charges 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 a one-ounce basis, and on parcel-post packages they advance on a one-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. 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 weighbeam equilibrium is reestablished. Counting scales are equipped with small, convenient receptacles to receive the small counted number of articles that will counterpoise the articles that the scale is to "count." Frequently a second receptacle is provided, having a ratio to the small receptacle different from that of the principle 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 that can be accurately counted. It follows that the sensitiveness of the scale also determines the degree of accuracy of the count of articles that 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.



A counting scale.

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 that 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 that 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 reading face 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 reading face 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 earlier.

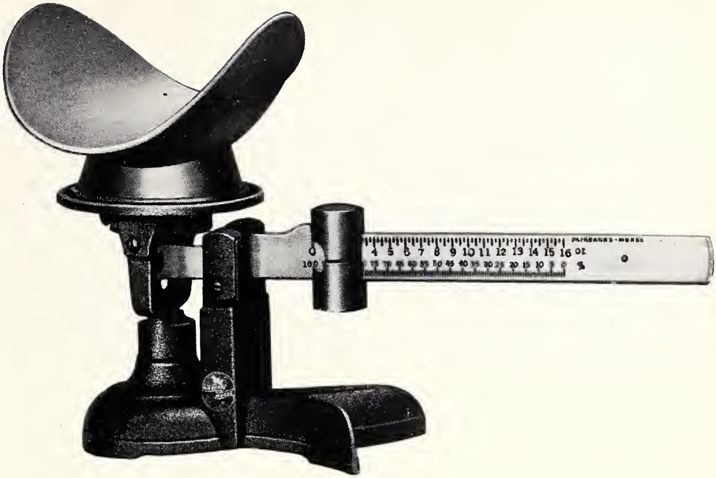
Another type of packing scale is an adaptation of the ordinary beam scale, having a self-locking poise. This type may be used for general weighing although the poise-locking feature that recommends it as a packing scale works against its use for general weighing purposes. Ordinary beam scales are not infrequently adapted for use as packing scales by equipping them with special counterpoise weights the counterpoise values of which correspond with the weights that it is desired to pack. For instance, flour-packing scales may have counterpoise weights with counterpoise values of 12½ pounds, 25 pounds, 50 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

A bucket-type grain tester.
The tester is supported by hand when in use.

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



An unequal-arm seed tester.

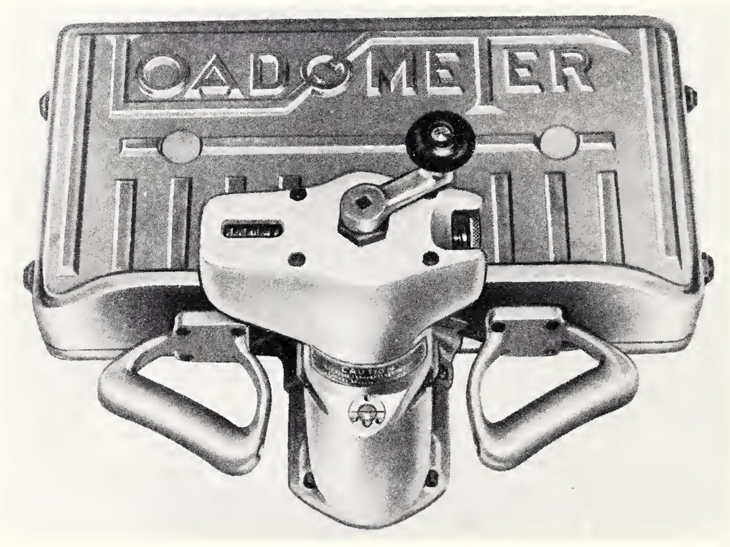
A 16-ounce sample is weighed out. The sample is then cleaned and the clean sample is reweighed. The percentage of foreign matter can then be read directly from the weighbeam.

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-Character-of-Load Scales. Many examples could be cited of scales that 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 griefly 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 ad-

Wheel-load weighers in use.
The view shows ramps in position on either side of each of the pair of weighers, and the truck wheels properly positioned on the weigher platforms.



A wheel-load weigher.
With no load on the platform, the knurled wheel at the top right of the column cap is used to establish a correct zero-load balance indication in the circular window visible on the side of the column, after the straight-reading (digital) counter at top left has been caused to read zero by turning the crank at top center the required amount in a backward direction. When the load is placed on the platform the crank is turned in a forward direction until the original balance indication (which disappears when the load comes on) is restored. The weight indication is then read on the counter at top left. The handles are for convenience in positioning and carrying the weigher.

justment 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 are provided with inclined approaches 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 that 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. 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. Hopper scales are not ordinarily equipped with full-capacity weighbeams, but utilize counterpoise weights.

Hopper scales for grain weighing may be 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.

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, as is the case in some of the scales already mentioned. 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 reading faces 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 that 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 that has passed across it.

Chapter 14.—Elements of Scale Performance

It is the purpose of this final chapter to discuss briefly and in general terms some of the more common elements that affect the performance of scales, so as to suggest possible sources of trouble when an examination discloses that a scale is not functioning as it should. No attempt will be made to include detailed instructions for adjustment or repair. Such instructions for particular makes of scales will sometimes 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 servicemen, repairmen, and erectors.

Adjustment and Repair of Scales. It is not to be presumed that the weights and measures official is expected regularly to undertake the repairs and adjustments that 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 that 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 within his legal rights. But if the official becomes competent to make minor adjustments, it is believed that there are times when he should do so.

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 expense of a return trip by the official to make a retest, and perhaps other factors, will guide the official in reaching his decision.

But whether or not adjustment is ever undertaken by the official, he should strive to perfect himself along mechanical lines and familiarize himself with all of the conditions that 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 discuss with 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 that the official should always render when it is possible for him to do so.

Conditions Affecting Scale Performance. There are numerous factors that enter into proper scale performance, and these are so interrelated that it is somewhat difficult to separate them. However, for purposes of discussion these may be grouped under the two general characteristics of sensitiveness and accuracy; under each, consideration will be given to those influences that are conducive or detrimental to satisfactory performance.

Sensitiveness. The sensitiveness of a scale is its response to relatively small changes 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 change of load, however small, would change the indication of the scale; as a practical matter, however, there is a limiting value for the load change 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 changes 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 changes of load, the observed condition is reasonably held to be "inaccuracy" rather than 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 scales 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 symbol SR has been adopted and defined in such a way that specification requirements in terms of SR have a very definite meaning for various types of commercial scales, and may be uniformly applied.

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 that have no direct relation to sensitiveness:

1. 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.

2. 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.

3. Knife-edges and bearing surfaces should be suitably hardened.

4. Knife-edges should be straight and sharp.

5. Bearing surfaces should be smooth and so designed or protected as to minimize the accumulation of foreign matter adjacent to a pivot.

6. 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.

7. The security of adjustable elements and of adjusting material should be insured.

8. The fit and alinement of parts should be good throughout.

9. Materials should have been selected throughout for permanence and wearing qualities and for their special fitness for the services demanded of them.

10. Simplicity of design and construction should not be sacrificed for complexity unless something worthwhile is gained.

11. Ease of operation, ease and precision of reading, and freedom from characteristics that might facilitate the perpetration of fraud in commercial use should be realized.

12. The surface treatment of parts should be such as will minimize deterioration in use.

13. In general, careful workmanship should be in evidence throughout the entire scale.

14. The factory assembly should be carefully performed, and the scale or its essential elements should have been tested before shipment.

15. Packing for shipment should be such as to minimize the probability of damage in transit, and all necessary instructions for unpacking and setting up or installing his scales should be furnished to the purchaser.

Proceeding to a consideration of the other sensitiveness 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 that 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 that 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 to 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 become rounded as a result of normal wear, corrosion, or excessive movement of knife-edges in 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 antifraction plates and caps, and flattened antifiriction points. Worn pivots and worn bearings should be reconditioned or renewed, but this work should be undertaken only 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 that 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. 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," "jerkey," or "lamb's-tail" motion, this is an almost certain indication of a direct bind against some live member of the mechansm—that 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 that 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 that 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. 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. 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 by a representative of the manufacturer 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 that has been bent, kinked, or twisted, a bearing that has been cracked, a chipped or crushed knife-edge, exposed parts (such as the linkage beneath an equal-arm counter scale) that have been bent or otherwise damaged, an indicator that 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 anti-friction 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 that may be adhering to the inner surface of a ribbon or to the surface of the cam that 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. Each 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 disclose 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 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 ball causes a decrease in the indication, and raising the ball causes an increase in the indication, for a given load. On all cylinder types of automatic-indicating scales, small "chart-balancing weights," mounted on the arms of the chart frame, are used to harmonize the indications at the quarter-capacity points. On pendulum-type automatic-indicating scales, adjustable cams are utilized to harmonize the indications at half and full capacity. 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 demonstrated that faulty adjustment of the elements in question is responsible for the errors found—and in addition the inspector should refrain from undertaking *any* of these adjustments unless he knows himself to be competent to make them successfully.

Scales that 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 is undertaken in a scale factory or shop by a competent mechanic 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 element; in this 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 that will seriously affect the accuracy of weighing. 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 that 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 cannot be made.

The reading face of an automatic-indicating scale may be so defaced that the indications cannot 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 dash-pot 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 a weighbeam or reading face, recutting of weighbeam notches, and similar jobs should be undertaken only in the specially equipped shop or in the scale factory.

When a scale is used with counterpoise weights that are too light, the scale indications will be too great, and when the weights are too heavy, the scale indications will be too small. Repair of inaccurate counterpoise weights is not recommended; such weights should be replaced with weights "correct" for the scale on which they are to be used.

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.

Appendix I.—SELECTION, INSTALLATION, AND MAINTENANCE OF VEHICLE SCALES

A recommendation of the National Conference on Weights and Measures.

I. SELECTION

An Adequate Specification. A basic consideration in the selection of a scale is compliance with an adequate specification. Scales in commercial service are subject to inspection and test by constituted weights and measures regulatory authorities. In the majority of jurisdictions in the United States, the codes of specifications, tolerances, and regulations adopted by the National Conference on Weights and Measures have been promulgated. It follows that the purchaser of a scale intended for commercial service should do no less than to specify compliance with the National Conference codes, and that the purchase contract should include a warranty by the seller that the scale furnished will conform fully to all applicable weights and measures requirements of the jurisdiction where it is to be installed. In the case of a scale to be purchased for noncommercial service (and so not subject to official controls), the same minimum requirement is recommended as for commercial scales, to the end that a satisfactory weighing machine may be obtained. If a scale is to be operated under unusually rigorous service conditions, or if other special or unusual demands will be made upon it, a competent scale engineer should be consulted; if it is found necessary to prescribe special requirements beyond the minimum requirements encompassed by the National Conference codes, these should be carefully worked out and explicitly set forth in the purchase contract for the scale.

Quality Versus Cost. Purchasers of scales intended for either commercial or noncommercial service will be well advised to avoid the false economy of sacrificing quality for low initial cost. A good scale, well installed and carefully maintained, will more than justify its cost by its long life and accurate weighing performance.

Individual Scale Characteristics. When selecting a particular scale, careful consideration should be given to (a) weighing capacity, (b) platform dimensions, and (c) the character of the indicating elements. In this relation, thought should be given not only to current needs, but also to needs anticipated for the succeeding 10 years or so.

(a) With respect to weighing capacity, it will probably be found to be economical in the long view to choose a scale with a nominal capacity of 20 percent or more in excess of the actual anticipated weighing requirements. This will promote longer life of scale parts, will be conducive to uninterrupted weighing service and reduction of maintenance expense, and will tend to avoid early obsolescence of the scale because of inadequacy of capacity to meet unanticipated weighing demands.

(b) It is contrary to good commercial weighing practice, as well as to a regulation of the National Conference Scale Code, to attempt to determine the total weight of a highway vehicle by weighing it one end or one axle at a time and adding the results. A value so derived may be seriously inaccurate. The same is true in the case of coupled vehicle combinations—for example, tractor-trailer units—when the several elements of the combination are individually weighed without first being disconnected from other elements of the combination. The length of a vehicle scale should be adequate to accommodate in its entirety the longest vehicle or vehicle combination that it is proposed to weigh on the scale. Since it is usually expensive and may prove to be unsatisfactory to undertake modification of an installed scale to increase its length, it is urged that, when deciding upon the length of a new scale, a liberal allowance be made over immediate needs to care for future developments. For vehicle scales, a platform length of at least 50 feet is recommended unless it is known that needs will be restricted to the weighing of relatively short-wheelbase vehicles. Scales of 60 feet, 100 feet, or even more in length are practical and are to be recommended when warranted by the character of the loads to be weighed. A minimum platform width of 10 feet is also recommended.

(c) The relative advantages and limitations of manual (weighbeam) and automatic means for indication of weight values, and the desirability or need for weight registration on tickets, tapes, and the like, should be carefully evaluated.

II. INSTALLATION

(Whenever, in what follows, reference is made to specific elements—as, for example, lever systems, load cells, weighbeams—the comment refers only to those scales that incorporate such elements.)

The vigilance of the purchaser may not safely be relaxed even when an excellent scale has been selected, since, if the scale is not properly installed, it may fail to produce the results of which it is susceptible—its weighing performance may be seriously inaccurate or may shortly become so, and it may deteriorate rapidly in service. Installations poorly planned or unskillfully executed too often result in new scales being turned over to their owners in improper or inaccurate condition. The purchaser will, therefore, do well to see to it that the following basic requirements are adhered to:

Site. The location of the scale should be such that smooth, straight, hard-surface approaches, level with the scale platform, may be provided for a reasonable distance (at least as long as the platform, if practicable) at each end of the scale, that surface water will drain away from the scale pit, and that nonweighing traffic need not go over the scale platform.

Installation Supervision. The entire installation should be made under the supervision of a competent scale erector, preferably an employee of the scale manufacturer, so that responsibility for the final accuracy of the scale and the suitability of the entire installation may be centered in a single agency.

Scale Pit. For proper scale maintenance—that is, protection against damage and deterioration of the scale parts and assurance of a continuance of accurate weighing performance—it is imperative that there be periodic cleaning and inspection of the understructure of the scale and, on occasion, that servicing operations and repairs be made to scale parts. For these reasons it is necessary that adequate room be provided so that an inspector or a repairman may move about the pit freely. Accordingly, the pit should be deep enough and access thereto should be such as to facilitate inspection, cleaning, and maintenance of scale parts.

Pit walls and floor, and piers for lever stands, should be of good quality concrete and should be poured as a unit.

Adequate means should be provided for pit drainage and ventilation.

Scale Elements in the Pit. All stands should be set directly on concrete without intervening supports, and should be securely anchored in correct position.

All parts of the scale should be so positioned as to bring them into proper relation with each other, with adequate working clearances around all live parts.

All levers or load cells should be installed accurately level and in proper alinement.

All bearing assemblies, connections between levers, the steelyard rod, the beam rod, and all other parts designed to be plumb, should be installed in accurate vertical alinement.

The pivots and bearings of the main levers and extension levers should be well packed with grease, to protect these parts against corrosion. Pivots and bearings of shelf levers, weighbeams, and of any extension or reversing levers installed between the transverse extension lever and the weighbeam or dial should be protected only by the film of oil remaining after these parts have been wiped with an oily (but unsaturated) cloth. Grease or an excessive amount of oil on these parts will affect the sensitiveness of the scale—that is, its response to small changes in platform load.

Weighbridge. The weighbridge should be of steel, adequately strong, and suitably braced for rigidity, and should include steel members providing adequate support for the platform. Adequate working clearances should be provided around the weighbridge.

Checking means should be provided and should be designed, installed, and adjusted to prevent excessive weighbridge movement without interfering with necessary weighbridge freedom during weighing operations. Ball or roller checks should be well packed with grease.

All structural steel should be painted to protect the metal against corrosion.

Platform. The platform should be of adequate strength and should be weathertight. The surface should be reasonably smooth and in surface alinement with the pit coping.

The opening between platform and coping should be established at approximately one-half inch at traffic level, and the edges of the platform should be undercut slightly to prevent lodgment of foreign matter between platform and pit wall.

Indicating elements. The indicating elements should be adequately protected from the weather.

The weighbeam or automatic-indicating elements should, if practicable, be so positioned as to avoid the use of added extension levers between indicating elements and the normal lever system, and the installation should be so arranged as to afford the weighmaster an unobstructed view of the entire platform.

Indicating elements should be installed level and plumb, and should be rigidly mounted upon firm foundations, preferably a part of the walls of the pit neck, but in any event independent of the scale house, weighing room, or other similar structure. A weighbeam should be horizontal when its tip is at the midpoint of its travel in the trig loop.

Adequate clearances should be provided around the indicating elements and the connections thereto.

Inspection and Test. During the progress of the installation, inspections should be made to insure compliance with specification and installation requirements.

When the installation is completed, final inspection should be made and the scale should be tested for accuracy and sensitiveness, "acceptance" requirements being applied. The test should, if practicable, be carried up to the nominal capacity of the scale, and in any event should be carried to that point in the weighing range corresponding to the largest gross load expected to be weighed on the scale. The test-weight load utilized should be as large as practicable up to the nominal capacity of the scale. Observations should be made at not less than three different test-weight loads. One or more strain loads should be utilized in combination with the available test weights when the amount of the test weights is less than the nominal scale capacity or the maximum anticipated gross lading.

III. MAINTENANCE

In order to prevent rapid deterioration of parts, to keep the scale in good mechanical condition, and to promote the continuance of accurate weighing results, the following instructions should be observed.

Regularly Clean the Following. The scale pit. This should be maintained in clean and dry condition.

The scale parts in the pit. When the protective grease around the pivots and bearings of the lever system becomes hard and dirty, clear the old grease away and repack the parts with fresh grease.

All structural steel in the pit. Keep this well painted to protect the metal. If rusting should start, thoroughly clean the metal before repainting.

The scale platform. Prevent all accumulations of dirt or foreign matter on or around the platform.

Scale Platform. Keep the surface in good repair.

Maintain an opening of approximately one-half inch between the coping and the edges of the platform.

Maintain surface alinement between the coping and the traffic surface of the platform.

Scale Approaches. Maintain in hard and smooth condition and in surface alinement with the scale coping.

Indicating Elements. Keep weighbeam notches and poises clean, and maintain weighbeam bars and face plates in clean and legible condition.

Keep automatic-indicating elements clean.

Keep dash pots properly filled and adjusted in strict conformance with the instructions of the manufacturer of the automatic-indicating device or attachment.

Handle all indicating elements with care, to avoid breakage of or damage to parts.

General. Keep the scale in correct zero-load balance, with any loose balancing material securely enclosed.

Do not overload the scale.

A vehicle scale is not well suited for precision weighing of gross loads of less than 1,000 pounds.

Keep indicating elements locked except when in actual use. To prevent inordinate wear of zero notch of weighbeam, the main poise should be positioned indiscriminately near the tip of the weighbeam when the scale is not in use.

Arrange for periodic inspection of the scale by a competent scale mechanic.

If scale parts become damaged or broken, arrange for prompt renewal or suitable repair by a competent scale mechanic.

Do not authorize or permit the grinding of pivots in the field; such work should only be performed in a scale shop furnished with the necessary specialized tools and equipment.

Contact the State or local weights and measures agency for additional information regarding the selection, installation, and maintenance of vehicle scales.

Appendix II.—GENERAL TABLES OF WEIGHTS AND MEASURES

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

*　　*　　*　　*　　*

6 076.115 49 feet (1 852 meters) = 1 international nautical mile.

The international nautical mile was adopted for use in the United States effective July 1, 1954. The value expressed in feet became effective July 1, 1959.

AREA MEASURE [1]

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

CUBIC MEASURE [2]

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 [3]

4 gills	=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

---

[1] Squares of units are sometimes abbreviated by using the superior figure 2. For example, ft^2 means square foot or feet.

[2] Cubes of units are sometimes abbreviated by using the superior figure 3. For example, ft^3 means cubic foot or feet.

[3] 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 name of the *liquid* unit.

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) [=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 [4]

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

AVOIRDUPOIS WEIGHT [5]

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

$27^{11}/_{32}$ 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)[6]
20 hundredweights	=1	ton =2 000 pounds[6]

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

112 pounds	=1	gross or long hundredweight[6]
20 gross or long hundredweights	=1	gross or long ton=2 240 pounds[6]

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

---

[4] 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 name of the *dry* unit.

[5] 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.

[6] When the terms "hundredweight" and "ton" are used unmodified, they are commonly understood to mean the 100-pound hundredweight and the 2000-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.

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 lb)=96 drams apothecaries=288 scruples=5 760 grains

Part 2.—NOTES ON BRITISH WEIGHTS AND MEASURES TABLES

In Great Britain, the yard, the avoirdupois pound, the apothecaries pound, and the troy ounce are now identical for science and industry with the units of the same name in the United States, and are essentially identical for commercial purposes. The use of the troy pound is illegal in Great Britain. 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 3.—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 (dam.)
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 =1 000 milliliters
10 liters	=1 dekaliter (dal)
10 dekaliters	=1 hectoliter (hl)=100 liters
10 hectoliters	=1 kiloliter (kl)=1 000 liters

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 liter
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 (dag)
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, kilo, mega, giga,* and *tera* meaning respectvely, 10, 100, 1 000, 1 000 000, and 1 000 000 000, and *deci, centi, milli, micro, nano,* and *pico,* meaning, respectively, one-tenth, one-hundredth, one-thousandth, one-millionth, one-billionth, and one-trillionth. 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.

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.)

It is to be noted that in the case of the prefix *deka,* the symbol formerly recognized by the National Bureau of Standards was *dk,* as *dkm* for dekameter, *dkl* for dekaliter, and *dkg* for dekagram. The current international recommendation for the *deka* symbol is *da,* and this has been used in the preceding metric tables; thus *dam* stands for dekameter, *dal* for dekaliter, and *dag* for dekagram.

Part 4.—TABLES OF INTERRELATION OF UNITS OF MEASUREMENT

[Exact equivalents are indicated by bold face type]

UNITS OF LENGTH

Unit		Inches	Links [a]	Feet
1 inch	=	**1**	0.126 262 6	0.083 333 33
1 link	=	**7.92**	**1**	**0.66**
1 foot	=	**12**	1.515 152	**1**
1 yard	=	**36**	4.545 45	**3**
1 rod	=	**198**	**25**	**16.5**
1 chain	=	**792**	**100**	**66**
1 mile	=	**63 360**	**8 000**	**5 280**
1 centimeter	=	0.393 700 8	0.049 709 70	0.032 808 40
1 meter	=	39.370 08	4.970 970	3.280 840

Unit		Yards	Rods	Chains [a]
1 inch	=	0.027 777 78	0.005 050 505	0.001 262 626
1 link	=	**0.22**	**0.04**	**0.01**
1 foot	=	0.333 333 3	0.060 606 06	0.015 151 52
1 yard	=	**1**	0.181 818 2	0.045 454 55
1 rod	=	**5.5**	**1**	**0.25**
1 chain	=	**22**	**4**	**1**
1 mile	=	**1 760**	**320**	**80**
1 centimeter	=	0.010 936 13	0.001 988 388	0.000 497 097 0
1 meter	=	1.093 613	0.198 838 8	0.049 709 70

Unit		Miles	Centimeters	Meters
1 inch	=	0.000 015 782 83	**2.54**	**0.025 4**
1 link	=	**0.000 125**	**20.116 8**	**0.201 168**
1 foot	=	0.000 189 393 9	**30.48**	**0.304 8**
1 yard	=	0.000 568 181 8	**91.44**	**0.914 4**
1 rod	=	**0.003 125**	**502.92**	**5.029 2**
1 chain	=	**0.012 5**	**2 011.68**	**20.116 8**
1 mile	=	**1**	**160 934.4**	**1 609.344**
1 centimeter	=	0.000 006 213 712	**1**	**0.01**
1 meter	=	0.000 621 371 2	**100**	**1**

[a] Gunter's or Surveyors.

UNITS OF AREA

Unit		Square inches	Square links [a]	Square feet
1 square inch	=	**1**	0.015 942 25	0.006 944 444
1 square link	=	**62.726 4**	**1**	**0.435 6**
1 square foot	=	**144**	2.295 684	**1**
1 square yard	=	**1 296**	20.661 16	**9**
1 square rod	=	**39 204**	**625**	**272.25**
1 square chain	=	**627 264**	**10 000**	**4 356**
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	=	0.155 000 3	0.002 471 054	0.001 076 391
1 square meter	=	1 550.003	24.710 54	10.763 91
1 hectare	=	15 500 031	247 105.4	107 639.1

See footnote at end of table.

Unit		Square yards	Square rods	Square chains[a]
1 square inch	=	0.000 771 604 9	0.000 025 507 60	0.000 001 594 225
1 square link	=	0.048 4	0.000 6	0.000 1
1 square foot	=	0.111 111 1	0.003 673 095	0.000 229 568 4
1 square yard	=	1	0.033 057 85	0.002 066 116
1 square rod	=	30.25	1	0.062 5
1 square chain	=	484	16	1
1 acre	=	4 840	160	10
1 square mile	=	3 097 600	102 400	6 400
1 square centimeter	=	0.000 119 599 0	0.000 003 953 686	0.000 000 247 105 4
1 square meter	=	1.195 990	0.039 536 86	0.002 471 054
1 hectare	=	11 959.90	395.368 6	24.710 54

Unit		Acres	Square miles	Square centimeters
1 square inch	=	0.000 000 159 422 5	0.000 000 000 249 097 7	6.451 6
1 square link	=	0.000 01	0.000 000 015 625	404.685 642 24
1 square foot	=	0.000 022 956 84	0.000 000 035 870 06	929.030 4
1 square yard	=	0.000 206 611 6	0.000 000 322 830 6	8 361.273 6
1 square rod	=	0.006 25	0.000 009 765 625	252 928.526 4
1 square chain	=	0.1	0.000 156 25	4 046 856.422 4
1 acre	=	1	0.001 562 5	40 468 564.224
1 square mile	=	640	1	25 899 881 103.36
1 square centimeter	=	0.000 000 024 710 54	0.000 000 000 038 610 22	1
1 square meter	=	0.000 247 105 4	0.000 000 386 102 2	10 000
1 hectare	=	2.471 054	0.003 861 022	100 000 000

Unit		Square meters	Hectares
1 square inch	=	0.000 645 16	0.000 000 064 516
1 square link	=	0.040 468 564 224	0.000 004 046 856 422 4
1 square foot	=	0.092 903 04	0.000 009 290 304
1 square yard	=	0.836 127 36	0.000 083 612 736
1 square rod	=	25.292 852 64	0.002 529 285 264
1 square chain	=	404.685 642 24	0.040 468 564 224
1 acre	=	4 046.856 422 4	0.404 685 642 24
1 square mile	=	2 589 988.110 336	258.998 811 033 6
1 square centimeter	=	0.000 1	0.000 000 01
1 square meter	=	1	0.000 1
1 hectare	=	10 000	1

[a] Gunter's or Surveyors.

UNITS OF VOLUME

Unit		Cubic inches	Cubic feet	Cubic yards
1 cubic inch	=	1	0.000 578 703 7	0.000 021 433 47
1 cubic foot	=	1 728	1	0.037 037 04
1 cubic yard	=	46 656	27	1
1 cubic centimeter	=	0.061 023 74	0.000 035 314 67	0.000 001 307 951
1 cubic decimeter	=	61.023 74	0.035 314 67	0.001 307 951
1 cubic meter	=	61 023.74	35.314 67	1.307 951

Unit		Cubic centimeters	Cubic decimeters	Cubic meters
1 cubic inch	=	16.387 064	0.016 387 064	0.000 016 387 064
1 cubic foot	=	28 316.846 592	28.316 846 592	0.028 316 846 592
1 cubic yard	=	764 554.857 984	764.554 857 984	0.764 554 857 984
1 cubic centimeter	=	1	0.001	0.000 001
1 cubic decimeter	=	1 000	1	0.001
1 cubic meter	=	1 000 000	1 000	1

UNITS OF CAPACITY—LIQUID MEASURE [8]

Unit		Minims	Fluid drams	Fluid ounces	Gills
1 minim	=	1	0.016 666 67	0.002 083 333	0.000 520 833 3
1 fluid dram	=	60	1	0.125	0.031 25
1 fluid ounce	=	480	8	1	0.25
1 gill	=	1 920	32	4	1
1 liquid pint	=	7 680	128	16	4
1 liquid quart	=	15 360	256	32	8
1 gallon	=	61 440	1 024	128	32
1 cubic inch	=	265.974 0	4.432 900	0.554 112 6	0.138 528 1
1 cubic foot	=	459 603.1	7 660.052	957.506 5	239.376 6
1 milliliter	=	16.231 19	0.270 519 8	0.033 814 97	0.008 453 742
1 liter	=	16 231.19	270.519 8	33.814 97	8.453 742

Unit		Liquid pints	Liquid quarts	Gallons	Milliliters
1 minim	=	0.000 130 208 3	0.000 065 104 17	0.000 016 276 04	0.061 609 79
1 fluid dram	=	0.007 812 5	0.003 906 25	0.000 976 562 5	3.696 588
1 fluid ounce	=	0.062 5	0.031 25	0.007 812 5	29.572 70
1 gill	=	0.25	0.125	0.031 25	118.290 8
1 liquid pint	=	1	0.5	0.125	473.163 2
1 liquid quart	=	2	1	0.25	946.326 4
1 gallon	=	8	4	1	3 785.306
1 cubic inch	=	0.034 632 03	0.017 316 02	0.004 329 004	16.386 61
1 cubic foot	=	59.844 16	29.922 08	7.480 519	28 316.05
1 milliliter	=	0.002 113 436	0.001 056 718	0.000 264 179 4	1
1 liter	=	2.113 436	1.056 718	0.264 179 4	1 000

[8] See footnote at end of table.

UNITS OF CAPACITY—LIQUID MEASURE [8]—Continued

Unit		Liters	Cubic inches	Cubic feet
1 minim	=	0.000 061 609 79	0.003 759 766	0.000 002 175 790
1 fluid dram	=	0.003 696 588	0.225 585 9	0.000 130 547 4
1 fluid ounce	=	0.029 572 70	1.804 687 5	0.001 044 379
1 gill	=	0.118 290 8	7.218 75	0.004 177 517
1 liquid pint	=	0.473 163 2	28.875	0.016 710 07
1 liquid quart	=	0.946 326 4	57.75	0.033 420 14
1 gallon	=	3.785 306	231	0.133 680 6
1 cubic inch	=	0.016 386 61	1	0.000 578 703 7
1 cubic foot	=	28.316 05	1 728	1
1 milliliter	=	0.001	0.061 025 45	0.000 035 315 66
1 liter	=	1	61.025 45	0.035 315 66

[8] See also table of equivalents between U.S. and British liquid measure units, p. 250.

UNITS OF CAPACITY—DRY MEASURE

Unit		Dry pints	Dry quarts	Pecks	Bushels
1 dry pint	=	1	0.5	0.062 5	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 cubic inch	=	0.029 761 6	0.014 880 8	0.001 860 10	0.000 465 025
1 cubic foot	=	51.428 09	25.714 05	3.214 256	0.803 563 95
1 liter	=	1.816 217	0.908 108 4	0.113 513 36	0.028 378 39
1 dekaliter	=	18.162 17	9.081 084	1.135 136	0.283 783 9

Unit		Liters	Dekaliters	Cubic inches	Cubic feet
1 dry pint	=	0.550 595 1	0.055 059 51	33.600 312 5	0.019 444 63
1 dry quart	=	1.101 190	0.110 119 0	67.200 625	0.038 889 25
1 peck	=	8.809 521	0.880 952 1	537.605	0.311 114
1 bushel	=	35.238 08	3.523 808	2 150.42	1.244 456
1 cubic inch	=	0.016 386 61	0.001 638 61	1	0.000 578 703 7
1 cubic foot	=	28.316 05	2.831 605	1 728	1
1 liter	=	1	0.1	61.025 45	0.035 315 66
1 dekaliter	=	10	1	610.254 5	0.353 156 6

UNITS OF MASS NOT GREATER THAN POUNDS AND KILOGRAMS

Unit		Grains	Apothecaries scruples	Pennyweights
1 grain	=	1	0.05	0.041 666 67
1 apoth scruple	=	20	1	0.833 333 3
1 pennyweight	=	24	1.2	1
1 avdp dram	=	27.343 75	1.367 187 5	1.139 323
1 apoth dram	=	60	3	2.5
1 avdp ounce	=	437.5	21.875	18.229 17
1 apoth or troy ounce	=	480	24	20
1 apoth or troy pound	=	5 760	288	240
1 avdp pound	=	7 000	350	291.666 7
1 milligram	=	0.015 432 36	0.000 771 617 9	0.000 643 014 9
1 gram	=	15.432 36	0.771 617 9	0.643 014 9
1 kilogram	=	15 432.36	771.617 9	643.014 9

UNITS OF MASS NOT GREATER THAN POUNDS AND KILOGRAMS—Continued

Unit		Avoirdupois drams	Apothecaries drams	Avoirdupois ounces
1 grain	=	0.036 571 43	0.016 666 67	0.002 285 714
1 apoth scruple	=	0.731 428 6	0.333 333 3	0.045 714 29
1 pennyweight	=	0.877 714 3	0.4	0.054 857 14
1 avdp dram	=	1	0.455 729 2	0.062 5
1 apoth dram	=	2.194 286	1	0.137 142 9
1 avdp ounce	=	16	7.291 667	1
1 apoth or troy ounce	=	17.554 29	8	1.097 143
1 apoth or troy pound	=	210.651 4	96	13.165 71
1 avdp pound	=	256	116.666 7	16
1 milligram	=	0.000 564 383 4	0.000 257 206 0	0.000 035 273 96
1 gram	=	0.564 383 4	0.257 206 0	0.035 273 96
1 kilogram	=	564.383 4	257.206 0	35.273 96

Unit		Apothecaries or troy ounces	Apothecaries or troy pounds	Avoirdupois pounds
1 grain	=	0.002 083 333	0.000 173 611 1	0.000 142 857 1
1 apoth scruple	=	0.041 666 67	0.003 472 222	0.002 857 143
1 pennyweight	=	0.05	0.004 166 667	0.003 428 571
1 avdp dram	=	0.056 966 15	0.004 747 179	0.003 906 25
1 apoth dram	=	0.125	0.010 416 67	0.008 571 429
1 avdp ounce	=	0.911 458 3	0.075 954 86	0.062 5
1 apoth or troy ounce	=	1	0.083 333 333	0.068 571 43
1 apoth or troy pound	=	12	1	0.822 857 1
1 avdp pound	=	14.583 33	1.215 278	1
1 milligram	=	0.000 032 150 75	0.000 002 679 229	0.000 002 204 623
1 gram	=	0.032 150 75	0.002 679 229	0.002 204 623
1 kilogram	=	32.150 75	2.679 229	2.204 623

Unit		Milligrams	Grams	Kilograms
1 grain	=	64.798 91	0.064 798 91	0.000 064 798 91
1 apoth scruple	=	1 295.978 2	1.295 978 2	0.001 295 978 2
1 pennyweight	=	1 555.173 84	1.555 173 84	0.001 555 173 84
1 avdp dram	=	1 771.845 195 312 5	1.771 845 195 312 5	0.001 771 845 195 312 5
1 apoth dram	=	3 887.934 6	3.887 934 6	0.003 887 934 6
1 avdp ounce	=	28 349.523 125	28.349 523 125	0.028 349 523 125
1 apoth or troy ounce	=	31 103.476 8	31.103 476 8	0.031 103 476 8
1 apoth or troy pound	=	373 241.721 6	373.241 721 6	0.373 241 721 6
1 avdp pound	=	453 592.37	453.592 37	0.453 592 37
1 milligram	=	1	0.001	0.000 001
1 gram	=	1 000	1	0.001
1 kilogram	=	1 000 000	1 000	1

UNITS OF MASS NOT LESS THAN AVOIRDUPOIS OUNCES

Unit		Avoirdupois ounces	Avoirdupois pounds	Short hundred weights	Short tons
1 avoirdupois ounce	=	1	0.062 5	0.000 625	0.000 031 25
1 avoirdupois pound	=	16	1	0.01	0.000 5
1 short hundredweight	=	1 600	100	1	0.05
1 short ton	=	32 000	2 000	20	1
1 long ton	=	35 840	2 240	22.4	1.12
1 kilogram	=	35.273 96	2.204 623	0.022 046 23	0.001 102 311
1 metric ton	=	35 273.96	2 204.623	22.046 23	1.102 311

Unit		Long tons	Kilograms	Metric tons
1 avoirdupois ounce	=	0.000 027 901 79	0.028 349 523 125	0.000 028 349 523 125
1 avoirdupois pound	=	0.000 446 428 6	0.453 592 37	0.000 453 592 37
1 short hundredweight	=	0.044 642 86	45.359 237	0.045 359 237
1 short ton	=	0.892 857 1	907.184 74	0.907 184 74
1 long ton	=	1	1 016.046 908 8	1.016 046 908 8
1 kilogram	=	0.000 984 206 5	1	0.001
1 metric ton	=	0.984 206 5	1 000	1

Part 5.—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 (Å) [9]	0.1 millimicron (exactly). 0.000 1 micron (exactly). 0.000 000 1 millimeter (exactly). 0.000 000 003 937 inch.
1 cable's length	120 fathoms. 720 feet. 219.456 meters (exactly).
1 centimeter (cm)	0.393 7 inch.
1 chain (ch) (Gunter's or surveyors)	66 feet. 20.116 8 meters (exactly).
[1 chain] (engineers)	100 feet. 30.48 meters (exactly).
1 decimeter (dm)	3.937 inches.
1 dekameter (dam.)	32.808 feet.

[9] The angstrom is basically defined as 10^{-10} meter.

1 fathom	6 feet. 1.828 8 meters (exactly).
1 foot (ft)	0.304 8 meter (exactly).
1 furlong (fur.)	10 chains (surveyors). 660 feet. 220 yards. 1/8 statute mile. 201.168 meters (exactly).
[1 hand]	4 inches.
1 inch (in.)	2.54 centimeters (exactly).
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). 0.201 168 meter (exactly).
[1 link (li) (engineers)]	1 foot. 0.304 8 meter (exactly).
1 meter (m)	39.37 inches. 1.094 yards
1 micron (μ [the Greek letter mu])	0.001 millimeter (exactly). 0.000 039 37 inch.
1 mil	0.001 inch (exactly). 0.025 4 millimeter (exactly).
1 mile (mi) (statute or land)	5 280 feet. 1.609 kilometers.
1 mile (mi) (nautical, international)[10]	1.852 kilometers (exactly). 1.151 statute miles.
1 millimeter (mm)	0.039 37 inch.
1 millimicron (mμ [the English letter m in combination with the Greek letter mu])	0.001 micron (exactly). 0.000 000 039 37 inch.
1 point (typography)	0.013 837 inch (exactly).[11] 0.351 millimeter.
1 rod (rd), pole, or perch	16½ feet. 5½ yards. 5.029 2 meters (exactly).
1 yard (yd)	0.914 4 meter (exactly).

AREAS OR SURFACES

1 acre[12]	43 560 square feet. 4 840 square yards. 0.405 hectare.
1 are	119.599 square yards. 0.025 acre.
1 hectare	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)	929.030 square centimeters.
1 square inch (sq in.)	6.451 6 square centimeters (exactly).

---

[10] See Table of Linear Measure, p. 248.
[11] This value is nearly 1/72 inch.
[12] A square 208.710+ ft on a side has an area of 1 acre.

1 square kilometer (km^2)	247.105 acres. 0.386 square mile.
1 square meter (m^2)	1.196 square yards. 10.764 square feet.
1 square mile (sq mi)	258.999 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.[13]
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$\frac{45}{64}$ 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 9.309 gallons.[14]
[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. 2 219.36 cubic inches.
1 cord (cd) (firewood)	128 cubic feet.
1 cubic centimeter (cm^3)	0.061 cubic inch.
1 cubic decimeter (dm^3)	61.024 cubic inches.
1 cubic foot (cu ft)	7.481 gallons. 28.316 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 dekaliter (dal)	2.642 gallons. 1.135 pecks.
1 dram, fluid (or liquid) (fl dr or *f*ʒ) (U.S.)	⅛ fluid ounce. 0.226 cubic inch. 3.697 milliliters. 1.041 British fluid drachm.
[1 dram, fluid (fl dr) (British)]	0.961 U.S. fluid dram. 0.217 cubic inch. 3.552 milliliters.

---

13 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.

14 This is a mathematical equivalent, useful only in correlating units of liquid and dry measure.

15 Frequently recognized as 1¼ bushels, struck measure.

1 gallon (gal) (U.S.)	231 cubic inches. 0.134 cubic foot. 3.785 liters. 0.833 British gallon. 128 U.S. fluid ounces. 0.107 U.S. struck bushel.[16]
[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). 238.474 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. 1.164 U.S. liquid quarts.[16]
1 quart (qt), liquid (U.S.)	57.75 cubic inches (exactly). 0.946 liter. 0.833 British quart. 0.859 U.S. dry quart.[16]
[1 quart (qt) (British)]	69.354 cubic inches. 1.032 U.S. dry quarts. 1.201 U.S. liquid quarts.
1 tablespoon	3 teaspoons.[17] 4 fluid drams. ½ fluid ounce.
1 teaspoon	⅓ tablespoon.[17] 1⅓ fluid drams.[17]

[16] This is a mathematical equivalent, useful only in correlating units of liquid and dry measure.

[17] 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.

WEIGHTS OR MASSES

1 assay ton [18] (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	64.798 91 milligrams (exactly).
1 gram (g)	15.432 grains. 0.035 avoirdupois ounce.
1 hundredweight, gross or long [19] (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 (μg [the Greek letter mu plus the letter g]) [20]	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.
1 point	0.01 carat (exactly). 2 milligrams.
1 pound, avoirdupois (lb avdp)	7 000 grains. 1.215 troy or apothecaries pounds. 453.592 37 grams (exactly).
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)	2 204.623 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.

[18] 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.

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

[20] The Greek letter gamma (γ) is also used as a symbol for "microgram."

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

Appendix III.—PUBLICATIONS FOR STUDY AND REFERENCE

Of the publications listed below, some are no longer available for purchase; it should be possible, however, to consult most of these in the larger libraries, public or institutional.

Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices adopted by the National Conference on Weights and Measures. Published by the National Bureau of Standards as NBS Handbook 44. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C., 20402. (When ordering, the "latest issue" should be specified.) Prepared in loose-leaf form with sheets punched for a standard, 3-ring, 5 by 8 inch binder, and carries a post-card request form whereby replacement sheets to be substituted for sheets on which changes have been made may be obtained, automatically and without cost, as these are issued from time to time. Handbook 44 is the basic United States publication in its field.

Weights and Measures Administration. Prepared by the Office of Weights and Measures of the National Bureau of Standards and published in 1962 as NBS Handbook 82. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. This is the third in a series of handbooks of the same title, and supersedes NBS Handbooks 11 and 26. It presents a comprehensive picture of what an effective weights and measures regulatory program should embrace. The principles set forth are specifically recommended by the National Conference on Weights and Measures to all weights and measures officials and to the legislative bodies of States, counties, and cities. The recommendations are intended to serve as a guide to agencies and individuals interested in setting up a system of weights and measures supervision in a State or subdivision thereof or concerned with strengthening such supervision where it now exists. In its entirety the Handbook is intended to be useful as a training manual for new weights and measures officials and as a manual for review training for experienced officials, in the area of fundamental principles and general procedures.

Characteristics and Applications of Resistance Strain Gages. Published in 1954 by the National Bureau of Standards as Circular 528. Proceedings of the NBS Semicentennial Symposium on Resistance Strain Gages, held at the National Bureau of Standards on November 8 and 9, 1951.

Precision Laboratory Standards of Mass and Laboratory Weights, by T. W. Lashof and L. B. Macurdy. Published by the National Bureau of Standards in 1954 as NBS Circular 547, Section 1. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington D.C., 20402. This is the first part of the revision of NBS Circular 3, Design and Test of Standards of Mass, last revised in 1918. Standards of mass of the following classes are treated: Class J (for the calibration of equipment for microanalysis), class M (reference standards for high-precision work and work demanding high constancy), class S (laboratory working standards), class S–1 (for routine analytical work with quick-weighing balances), class P (laboratory weights for routine analytical work), class Q (for technical and student use), and class T (for rough weighing operations). Tolerances are given, and the denominations, composition, construction, marking, packing, and performance of weights of each class are fully described. Also described are the nature and precision of the tests available and other features of the Bureau's weight-calibration service.

The Federal Basis for Weights and Measures, by Ralph W. Smith. Published by the National Bureau of Standards in 1958 as NBS Circular 593. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. This is a historical review of Federal legislative effort, statutes, and administrative action in the field of weights and measures in the United States. The review is presented, for the period 1776-1956, very largely in chronological form, and deals with congressional efforts and accomplishments in the general weights and measures area, with particular emphasis on units and standards. In its entirety the Circular presents a connected and comprehensive story of the Federal contribution to the legislative basis for weights and measures administration in the United States.

Units of Weight and Measure (United States Customary and Metric) Definitions and Tables of Equivalents, by L. V. Judson. Published by the National Bureau of Standards in 1960 as NBS Miscellaneous Publication 233, superseding NBS Miscellaneous Publication 214 (of the same title)issued in 1955. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. The units of length, area, volume, capacity, and mass in the United States are defined, and tables of interrelation and tables of equivalents for these units in the metric system and in the U.S. customary system are given. This is the current basic publication of the Bureau in the field of conversion factors and tables for weights and measures, and reflects the "Refinement of Values for the Yard and Pound" announced in the Federal Register of July 1, 1959.

Weights and Measures Standards of the United States—A Brief History, by Lewis V. Judson. This was published by the National Bureau of Standards in 1963 as NBS Miscellaneous Publication 247, superseding NBS Miscellaneous Publication 64, History of the Standard Weights and Measures of the United States issued in 1925. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. A historical account is given of the standards of weight and measure of the United States from the time of the American Revolution through the year 1962. Current and historical standards of length and mass now in the possession of the Bureau are listed, described, and illustrated.

Reports of the National Conferences on Weights and Measures. As of June 1963, forty-eight meetings of the National Conference have been held and a separate report on each meeting has been published by the National Bureau of Standards in its Miscellaneous

Series of publications. Only the later reports are available for purchase; when so available, copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Program papers and committee reports are presented in full, discussions are presented in condensed form, and formal actions are recorded. The range of topics considered is wide, with emphasis on current developments and problems.

Index to the Reports of the National Conference on Weights and Measures from the First to the Forty-fifth, 1905 to 1960. Published by the National Bureau of Standards in 1962 as NBS Miscellaneous Publication 243, superseding NBS Miscellaneous Publication 203 issued in 1952. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. This is a cumulative index of the National Conference meetings from 1905 to 1960, inclusive. It is in two parts, (1) a thoroughly cross-indexed listing by subjects, and (2) a listing by names of speakers.

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 letailed 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.

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.

Industrial Weighing, by Douglas M. Considine. Published in 1948 by Reinhold Publishing Corporation, New York, N.Y. The volume comprises more than 550 pages and is rather profusely illustrated. The text is devoted solely to scales and weighing and purports to treat the subject in a broad manner; it is divided into two principal parts. Part I, "Scale Design, Construction, and Operation", deals with basic scale mechanics, design and construction of scales, and scale installation and maintenance. Part II, "Scales in the Industries", deals with the industrial applications of scales. Also included is a 50-page Glossary of Scale Terms (as compiled by the National Scale Men's Association). The author states that the book is intended for persons interested in scales—students, engineers, designers—but is intended especially for *users* of scales.

Outlines of the Evolution of Weights and Measures and the Metric System, by William Hallock and Herbert T. Wade. Published in 1906 by The Macmillan Co., New York, N.Y. The text comprises some 260 pages, and treats a variety of topics. Of special interest and value are the first three chapters, dealing, respectively, with the beginnings and development of the science of metrology, the origin and development of the metric system, and the extension of the metric system throughout Europe and elsewhere. A useful index is provided. (Because of recent changes in certain fundamental conversion factors, use of the weights and measures conversion tables and tables of interrelation given in the Appendix of this publication is not recommended.)

The Strain Gage Primer, by C. C. Perry and H. R. Lissner. Published by McGraw-Hill Book Co., Inc., New York, N.Y. 332 p. "There are three basic steps in the ritual of experimental stress analysis with strain gages. The first involves selecting an appropriate strain gage and cementing it in the proper location. The second step is that of employing suitable instruments to obtain electrical signals proportional to the strains being measured. The final step includes translation of the strains to stresses. * * * The material in the first half of the book treats the above three steps in the order listed. The remainder of the book is devoted to extensions of the basic principles to various classes of 'special' applications. * * *"

Conversion Factors and Tables, by O. T. Zimmerman and Irvin Lavine. The third edition of this book was published in 1961 by Industrial Research Service, Inc., Dover, N.H. The volume comprises almost 700 pages; 12 pages are devoted to definitions, fundamental values, and physical constants, 278 pages are devoted to United States, British, and metric conversion factors, over 200 pages are devoted to foreign conversion factors grouped alphabetically by countries, a dozen pages are devoted to foreign monetary equivalents, over 100 pages are devoted to 31 conversion tables, and the book concludes with a 12-page index. The material is well presented, and as of the date of publication appears to be fully up-to-date.

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.

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.

Terms and Definitions for the Weighing Industry, prepared under the direction of the Terminology Committee of the Scale Manufacturers Association, Inc., and published in 1958 by the SMA. (A 1963 revision of this publication is anticipated.) The volume comprises over 100 pages, divided into a short section on "Load Cell and Electronic Weighing Terms and Definitions" and 97 pages of "Mechanical Weighing Terms and Definitions," and is based on United States usage. Copies of this glossary are available either from the association itself or from individual manufacturer-members of the association.

Glossary of Terms Used in the Scale Trade. Published in 1962 by W. & T. Avery, Limited, Birmingham, England. This volume comprises some 60 pages, and its terms and definitions reflect British usage. The preface states, "This glossary aims at being a complete record of the special language of the scale industry, past and present, and therefore many obselete and local terms have been defined. Terms in current use are printed in capital letters; others, obsolete or not recommended for use, are printed in lower case letters."

Catalogs and other literature of scale manufacturers. A continuing and valuable source of information on developments in the field of scale design and adaptations to special uses of new or conventional models is provided by the catalogs, bulletins, announcements, and other literature issued by scale manufacturers. Normally such material is readily available upon request, and consistent use of it to keep abreast of mechanical innovations should prove rewarding.

INDEX

A

B

C

D

E

F – G

H

I – J – K

L

M

N – O

P

R

S

T

U – V

W – Z

☆ U. S. GOVERNMENT PRINTING OFFICE: 1965—738074

DETACH THIS CARD FROM THE BOOK

If you wish to receive a set of loose-leaf Equipment Procedure Outlines, or revised EPO sheets as issued, or both, cut out the post card below, fill it in, stamp, and mail. (This card is mentioned on bottom of page 40.)

Cut along this line

Place
4-cent
stamp
here

Cut along this line

National Bureau of Standards
Office of Weights and Measures 202–213
Washington, D. C. 20234

Type or Print

Name ______________________________

Street Address ______________________________

City ______________ State ______________ Zip Code ______________

Affiliation ______________________________

Office of Weights and Measures: Date ______________________________

Check one or both

☐ Please send me a loose-leaf set of Equipment Procedure Outlines for Weighing Equipment.

☐ Please send me revised sheets as issued.