U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

TESTING OF MEASURING EQUIPMENT

A MANUAL FOR WEIGHTS AND MEASURES OFFICIALS

NATIONAL BUREAU OF STANDARDS HANDBOOK 45

U. S. DEPARTMENT OF COMMERCE

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A Manual for Weights and Measures Officials

Ralph W. Smith

Issued May 15, 1951

UNITED STATES

GOVERNMENT PRINTING OFFICE

WASHINGTON: 1951

For sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C. $1.25

PREFACE

This volume completes the series of four Handbooks of the National Bureau of Standards designed to present in compact form comprehensive information relative to weights and measures regulatory activities. Current editions of the other three handbooks of this series are Handbook H26, Weights and Measures Administration, published in 1941 and superseding Handbook H11 of the same title; Handbook H37, Testing of Weighing Equipment, published in 1945; and Handbook H44, Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices, published in 1949, and superseding several earlier publications issued under similar titles. Handbook H26 treats of the general aspects of the subject of weights and measures administration. Handbook H37 describes various types of scales and weights, discusses the principles of their operation, and presents methods for their inspection and test. Handbook H44 presents the codes of specifications, tolerances, and regulations for commercial weights and measures and weighing and measuring devices, adopted by the National Conference on Weights and Measures and recommended by the National Bureau of Standards for State promulgation. Necessarily, the Handbook of specifications, tolerances, and regulations is issued periodically in order to present up-to-date information, incorporating the changes made from time to time by the National Conference.

The present volume deals with commercial measures and measuring devices, and includes descriptions of these instruments, recommendations for the testing apparatus needed for their official examination, and instructions for their inspection and testing by weights and measures officials. This Handbook is a companion volume to Handbook H37; taken together, these two Handbooks are intended to provide practical instructions to weights and measures officials for the inspection and testing of all of the types of commerical weighing and measuring devices which such officials are normally called upon to examine. As was done in Handbook H37, the present volume includes step-by-step testing outlines which supplement the several discussions on testing procedures. Also included, in the first three chapters, are some general comments relative to inspection and testing, which are applicable to all classes of commercial devices.

It is inevitable that the weights and measures official will encounter in the course of his official duties measures or measuring devices which differ from the general types treated herein. It is believed, however, that no difficulty should be experienced in adapting to practically any variation from the general type, the basic principles which are outlined, and in modifying appropriately the testing outlines which are presented.

It is desired to acknowledge the valuable assistance rendered by members of the staff of the National Bureau of Standards in reviewing portions of the text of this Handbook that relate to their special fields. Similar assistance has been rendered by numer-

ous representatives of equipment manufacturers and industry, and this assistance is gratefully acknowledged. The courtesy of those individuals and organizations who have supplied photographic material and who have permitted reproduction, in whole or in part, of equipment drawings, is greatly appreciated. The collaboration of W. S. Bussey and M. J. J. Harrison, each of whom has reviewed the entire manuscript and offered many valuable suggestions, is especially acknowledged.

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

E. U. CONDON, *Director*.

CONTENTS

Testing of Measuring Equipment

Ralph W. Smith

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

Chapter 1.—INTRODUCTION

Scope of Handbook.—This Handbook is directed primarily to procedures recommended for use by weights and measures officials when exercising their routine regulatory controls over commercial measuring equipment. Accordingly, recommendations are conditioned upon the special characteristics of regulatory control as distinguished from commercial or industrial maintenance service, and the limitations under which weights and measures organizations are normally required to operate, particularly budgetary limitations, have been kept in mind. Testing procedures recommended are, in general, the *minimum* requirements considered necessary to enable the official to determine whether or not equipment should be approved for commercial use. More exhaustive tests than those specified are frequently desirable; minimum procedures should be expanded to whatever extent is deemed by the official to be appropriate, whenever special conditions or circumstances indicate the advisability of this.

Uniformity of Requirements.—Recommendations herein are based upon the codes of specifications, tolerances, and regulations for commercial devices as adopted by the National Conference on Weights and Measures and recommended by the National Bureau of Standards for State promulgation.[1] Whenever reference is made to specifications, tolerances, or regulations, the National Conference material is meant unless the contrary is stated.

Weights and measures jurisdictions are urged to pro-

[1] These codes are currently published in National Bureau of Standards Handbook H44, Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices (1949).

mulgate 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 does 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 is, of course, passed on to the purchaser of equipment. On the other hand, if designs can be standardized by the manufacturer to conform to a single set of technical requirements, production costs can be kept down, to the ultimate advantage of the general public. Moreover, it seems entirely logical that equipment which is suitable for commercial use in the "specification" States should be equally suitable for such use in other States.

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, than under a system in which even minor deviations from standard practice are introduced by independent State action.

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 these codes by each State is strongly recommended.

Testing procedures presented in this Handbook are commended to the consideration of commercial and industrial testing organizations as minimal procedures. If these are observed by the inspectors and service and maintenance men of equipment manufacturers and users, there should always be satisfactory agreement between their test results and those of the regulatory officials.

Tolerances for Commercial Equipment.—The official tolerances prescribed by a weights and measures jurisdiction for commercial equipment are the limits of inaccuracy officially permissible within that jurisdiction. 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 increase 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 or adjusted 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 service 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 measure-containers, which are used only once.

When tables of tolerances for general weights and measures use are published, it is customary to use the maintenance tolerances for the tabular values, stating the values of the acceptance tolerances—if these are different—in terms of the maintenance tolerances; this is done for convenience of reference by the official, since it is to be expected that he will actually make many more maintenance tests than acceptance tests and so will have more frequent need to use maintenance tolerances than he will to use acceptance tolerances.

The theory of 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. It follows that manufacturing is simplified and that 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.

In the preceding discussion of tolerances for commercial equipment, there have been set forth reasons for the establishment of uniform tolerances, and for the uniform observance of such tolerances by weights and measures officials. But there is another aspect of tolerances which 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 repair or service man 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.[2]

Testing Apparatus.—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

[2] The National Conference on Weights and Measures has now adopted General Regulation G–R.4., to the effect that whenever equipment is adjusted, the adjustments shall be so made as to bring errors as close as practicable to zero value.

its intended use, when it is so constructed that it will retain its characteristics for a reasonable period under conditions of normal use, when it is available in denominations appropriate for a proper determination of the value or performance of the commercial equipment under test, and when it is accurately calibrated.

In subsequent chapters recommendations will be made relative to the design and construction characteristics and the amount of testing apparatus considered necessary for testing various classes of commercial measuring equipment. With respect to the factor of accuracy, however, the general comments which follow apply to testing equipment of whatsoever kind, and will not be repeated in the chapters devoted to particular classes of equipment.

A general principle which has long been recognized by the National Bureau of Standards is 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 which 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.

At the National Bureau of Standards various "classes" have been established for standards of mass, appropriate tolerances being specified for each class. This system of "classes" has not been extended to standards of measure, but tolerances have been fixed by the Bureau for standards of length and capacity considered suitable for use by weights nad measures officials. These tolerances, methods of calibration and computation, and the use of "corrections" will be fully treated in a forthcoming Circular of the National Bureau of Standards; when issued, this

Circular should be obtained by every weights and measures jurisdiction and kept available for reference.

The accuracy of testing apparatus should invariably be verified prior to the official use of the apparatus. Standards should be reverified as often as circumstances require. By their nature, metal volumetric standards are more susceptible to damage in handling than are standards of some other types. Whenever damage to a standard is known or suspected to have occurred, and whenever repairs which might affect the accuracy of a standard have been made, the standard should be recalibrated. Routine recalibration of standards, particularly volumetric 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 official may always be in an unassailable position with respect to the accuracy of his testing apparatus. If use is made of "secondary" standards, such as special fabric testing tapes or mechanisms such as fluid meters, these should be verified much more frequently than such basic standards as steel tapes or volumetric provers, to demonstrate their constancy of value or performance.

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

General.—In chapter 2 there are presented some general observations on the inspection of commercial equipment as distinguished from the testing of this equipment; in general, the recommendations made are applicable to the inspection of all classes of commercial devices. Similarly, in chapter 3 the general subjects of the adjustment, the rejection, and the sealing of commercial equipment are discussed, and there again the recommendations are generally applicable to all classes of commercial equipment.

Informative records should be maintained of all official inspections and tests. From time to time in later chapters comment will be made on data appropriate for entry on official reports and records. For a general discussion of a system of weights and measures records, the official is referred to NBS Handbook H26, chapters 30 and 31.

Beginning with chapter 4, there are presented discussions of testing procedures for the various classes of commercial measuring equipment for which final codes are published in NBS Handbook H44; a chapter is devoted to each such class, and the order of treatment is the same as that in H44. (The concluding chapter gives references to sources of information on meters for which there are no codes in H44). The treatment in each case includes as much description of the measuring equipment under consideration as is deemed necessary for an understanding of its use or operation, so that the reasons for the recommended testing procedure may be apparent. In certain cases there will be mentioned some of the important points to be checked when inspecting the equipment.

Whenever it is believed that the reading or study of supplementary material will be helpful to an understanding of a particular discussion herein, such material will be cited as "References" at the end of the chapter carrying that discussion.

References

National Bureau of Standards Handbook H26, Weights and Measures Administration (1941), chapters 9, 14, 16, 30, 31. Price $1.50.*

National Bureau of Standards Handbook H44, 1949, Specifications, Tolerances, and Regulations for Commercial Weighing and Measuring Devices (1949). Price $1.~~00~~.* 25

* Available from Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

Chapter 2.—INSPECTION OF MEASURING EQUIPMENT

Inspection and Testing.—A distinction may be made between the "inspection" and the "testing" of commercial equipment, which should be useful in differentiating between the two principal groups of official requirements—"specifications" and "performance requirements". Although frequently the term "inspection" is loosely used to include everything which the official has to do in connection with commercial equipment, it is useful to limit the scope of that term primarily to examinations made to determine compliance with the requirements of specifications. The term "testing" may then be limited to those operations carried out to determine the accuracy of value or performance of the equipment under examination, by comparison with the actual physical standards of the official. These two terms will be used herein in the limited senses defined.

Necessity for Inspection.—It is not enough merely to determine that the errors of equipment do not exceed the appropriate tolerances. Specification requirements may be equally as important as are tolerance requirements, and both should be enforced. Inspection is particularly important, and should be carried out with unusual thoroughness, whenever the official examines a type of equipment not previously encountered. This is the way the official learns whether or not the design and construction of the device conform to the specification requirements. 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 measuring equipment.

Specification Requirements.—A thorough knowledge by the official of the specification requirements is a prerequisite to competent inspection of equipment. The inexperienced official should have his specifications before him when making an inspection, and should check the requirements one by one against the equipment itself; otherwise some important requirement may be overlooked. As experience is gained, the official will become progressively less dependant on "the book", until finally observance of faulty conditions becomes almost automatic, and the time and effort required to do the inspecting are reduced to a minimum. The printed specifications, however, should always be available for reference, to refresh the official's memory or to be displayed to support his decisions, and they are an essential item of his kit.

It will not be inappropriate to remind officials and others who are using the National Conference codes that the specification requirements for a particular class of equipment are not all to be found in the separate code for that class. The requirements of the General Code apply, in general, to *all* classes of equipment, and these must always be considered in combination with the requirements of the appropriate separate code to arrive at the total of the requirements applicable to a piece of commercial equipment.

General Considerations.—The simpler the commercial device the fewer, generally speaking, are the specification requirements affecting it and the easier and quicker can an adequate inspection be made. As a device increases in complexity, inspection demands more and more time and effort; moreover, inspection becomes increasingly important as mechanical complexity increases, because the opportunities for the existence of faulty conditions are multiplied. It is on the relatively complex device, too, that the unscrupulous operator is most apt to attempt some modification to gain an advantage to which he is not lawfully entitled. Of course, not every modification made by an operator is made with dishonest intentions; but sometimes a change is made innocently enough but with most unfortunate results, because the operator does not thoroughly understand his equipment and so fails to appreciate the effects of what seems to him to be a simple and desirable modification. So it behooves the official to be alert to discover all of the "homemade" alterations which may be made to commercial equipment, in order that he

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may cause the elimination of all that are fraudulent, all that facilitate or are conducive to the perpetration of fraud, and all that are otherwise objectionable from a weights and measures viewpoint.

It is essential for the official to know how a particular commercial device is normally designed and constructed, in order to discover, upon inspection, deviations from standard practice. Such knowledge can be obtained from the catalogues and advertising literature of manufacturing plants, from observation of the operations performed by service men when reconditioning equipment in the field, and from study of the commercial devices themselves. Furthermore, to determine the effect of some deviation from accepted design, the official must know the operating principles of the device in question and be able to deduce or demonstrate how these are or may be violated by the alteration of the original mechanism. Much helpful information on the design and operating characteristics of commercial equipment can be obtained from the trained service mechanics and from the engineers of the equipment manufacturers; it is recommended that officials take advantage of every opportunity to "talk shop" with such men and so add to their knowledge of the construction and operation of measuring equipment of different kinds and makes.

Inspection should be extended beyond the measuring instrument itself to include any auxiliary equipment the performance of which has a bearing on the measuring characteristics of the instrument under examination or has any weights and measures significance in relation to the operation of the instrument under examination. General conditions external to the equipment should likewise be observed, to learn any adverse effects which they may have, from the weights and measures point of view, upon the installation as a whole.

It is important not only that required elements of a measuring instrument be provided, but that these be in proper condition to function as intended. Inspection will frequently disclose the need for maintenance work before deterioration has progressed to the point of failure or before official rejection of the equipment becomes necessary. Mechanical parts may be worn or weakened. Leaks may be developing in volumetric equipment. Certain elements may be in need of cleaning or refinishing. Evidence may be found of poor general maintenance which is shortening the useful life of the equipment.

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 which is obviously indicated by its construction or which is indicated by instructions on the equipment, and operation in any other manner should be prohibited.

Recommendations.—A comprehensive knowledge of each installation will enable the official to make constructive recommendations to the equipment owner regarding proper maintenance of his measuring devices and the suitability of his equipment 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 to an owner. The official will, of course, carefully avoid partiality toward or against equipment of specific makes, and will confine his recommendations to points upon which he is qualified, by knowledge and experience, to make suggestions of practical merit.

Inspection will often provide clues to the causes of faulty performance of equipment, thus enabling the official to make specific suggestions for the reconditioning of rejected devices. Such suggestions, based upon a careful diagnosis, can be of material assistance to an equipment owner, and may effect a saving of time and money. The official is cautioned, however, that suggestions of this kind are, in a strict sense, "extra-official"; legally he need go no further, in the case of equipment which he cannot approve for commercial use, than to reject it, leaving it to the owner to take whatever steps he sees fit to accomplish the reconditioning of his equipment. Although it is recommended that officials make helpful suggestions of the kind here under discussion when they are fully qualified to do so, in a spirit of rendering maximum service to the public, the inexperienced official will do well to refrain from this course lest he render a wrong diagnosis or suggest a wrong procedure.

Accurate and Correct Equipment. — Finally, the weights and measures official is reminded that commercial equipment may be "accurate" without being "correct". A device is "accurate", under the definition in the General Code of the National Conference (G-D.1.), "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 which fails so to conform is "inaccurate". A device is "correct" (G-D.2.) 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 which is "correct" should be sealed and approved for commercial use.

References

National Bureau of Standards Handbook H26, Weights and Measures Administration, chapter 15. Superintendent of Documents, Government Printing Office, Washington 25, D. C. Price $1.50.

Chapter 3.—ADJUSTMENT, REJECTION, AND SEALING OF MEASURING EQUIPMENT

Adjustment of Equipment.—Many types of measuring instruments are not susceptible of adjustment for accuracy by means of adjustable elements. Linear measures, liquid measures, graduates, measure-containers, milk and lubricating-oil bottles, and dry measures are in this category. Other types—for example, taximeters and odometers and some metering devices—may be adjusted in the field, but only by changing certain parts such as gears in gear trains. Some types, of which fabric-measuring devices are an example, are not intended to be adjusted in the field, and if inaccurate require reconditioning in shop or factory. Liquid-measuring devices and grease-measuring devices are usually equipped with adjustable elements, and some vehicle-tank compartments have adjustable indicators; field adjustments may readily be made on such equipment. The discussion which follows, insofar as this relates to adjustments made by the weights and measures official, is directed primarily to the use of those adjustable elements incorporated in liquid-measuring devices to facilitate altering the quantities discharged per indicated unit of delivery. The principles pointed out and the recommendations made are, however, applicable to adjustments on any commercial equipment, by whatever means accomplished.

The weights and measures official should remember that when he examines commercial equipment his *duty* is merely to determine that the equipment is or is not suitable for commercial use, and to approve or reject it accordingly. As the criteria for this determination he has his specifications and tolerances. If a device conforms to all of the official requirements, it is approved for use and is "sealed" to indicate this approval. If a device is incorrect, in that it fails to meet one or more of the applicable requirements, basically the official is *required* only to reject it and prohibit its use until it is brought into conformance with all applicable requirements. The point of importance to this discussion is that the official is *not required* to undertake adjustments or other corrections on equipment found to be faulty:

Whether or not the official *should* at times make adjustments or other corrections on equipment found to be incorrect is a moot question. Some officials contend that this should never be done, and that an official should confine himself strictly to those duties imposed upon him by his statute. Other officials—and these are believed to be a majority—take a more liberal view, and hold that under some circumstances a weights and measures officer is serving the best interests of all concerned by making such minor corrections and such adjustments (when adjustment is called for) as may be required to correct equipment found to be faulty and thus to keep it in commercial service. Within proper limitations this latter view seems to be the more sound, but the limitations are of importance.

It is recommended that the official never undertake repairs of a major character. Such repairs should always be left to commercial agencies.

It is recommended that the official refrain from making even minor corrections when the services of commercial agencies are readily available. The justification for the undertaking, by the official, of minor corrections lies in the delay and the expense which would be incurred if these corrections were required to be made by a service agency and the nearest service agency were located at a considerable distance. The saving to the equipment owner is a consideration, as is also the saving in time and expense on the part of the official, who may thus avoid a return visit for a retest. Another consideration is that the equipment may be kept in service without interruption; this is of particular importance if the owner happens to be dependent upon only a single item of equipment and would be "out of business" while this was tied up for repairs.

The official is cautioned about turning too quickly to the adjustable elements of a commercial device to correct for inaccuracies. Many times the cause of inaccurate performance of such an instrument as, for example, a liquid meter, lies not in a faulty positioning of the adjustable elements, but in some fault of installation or some defective part. Any faulty installation conditions should be corrected, and any defective parts should be renewed or suitably repaired, before adjustments are undertaken. In other words, adjustment should be made only when it is certain that by this means the real cause of the inaccuracy will be corrected.

Under no circumstances should the official undertake an adjustment or other correction on commercial equipment unless he thoroughly understands what he is doing and is competent to complete successfully what he undertakes. He should not experiment with equipment belonging to a commercial user, with the possibility of leaving it in worse shape than that in which he found it. Even when he is fully competent to make minor corrections and adjustments, the official should undertake them only with the express permission of the owner or his representative and with the definite understanding that there is no guarantee of a successful outcome; in this way the official will protect himself from adverse criticism and from possible claims for damage to equipment.

The practical and ethical objections to charges made by an official for services such as are here under discussion are so well understood that it should be unnecessary to elaborate upon them. In the absence of statutory authorization or direction, the official should never charge an equipment owner for these services, which he is justified in undertaking, if at all, only in the public interest. In those rare instances in which the law specifically authorizes or directs the assessment against an equipment owner of charges for repairs or corrections made by a weights and measures official, it is believed that the law should promptly be changed to delete such authorization or directive.

In the majority of cases, when the weights and measures official tests commercial equipment he is verifying the accuracy of a value or the accuracy of the performance as previously established, either by himself or by someone else. There are times, however, when the test of the official is the initial test on the basis of which the value of the device is first fixed or its performance first established. The most common example of this is the vehicle tank, the compartments of which are used as measures; not infrequently the official makes the first determination to be made on the capacities of the compartments of a vehicle tank, and his test results may be used to determine the proper settings of the compartment indicators for the exact compartment capacities desired. Adjustments of the position of an indicator under these circumstances are clearly not the kind of "adjustments" under discussion above.

Rejection of Equipment.—The weights and measures law usually contains a provision to the general effect that the official "shall condemn and seize and may destroy incorrect weights, measures, or weighing or measuring devices which, in his best judgment, are not susceptible of satisfactory repair; but such as are incorrect and yet, in his best judgment may be repaired, he shall mark or tag as 'Condemned for repairs' ".[3] This provision is customarily followed by others requiring that equipment which has been "condemned for repairs" be corrected within such reasonable period as may be specified by the official, that if not so repaired the equipment shall be confiscated, and that pending repairs the equipment shall be neither 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 which has been condemned. In cases of doubt, the official should initially "condemn for repairs" 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, condemnation for repair is clearly inappropriate for numerous items of measuring equipment. This is true in the case of most linear measures, of many liquid and dry measures, and graduates, measure-containers, milk bottles, and lubricating-oil bottles. When such equipment is incorrect it is either impractical or impossible to adjust or repair it, and the official has no alternative to outright condemnation. When only a few such items are involved, immediate destruction or confiscation is probably the best procedure. If a considerable number of items are involved—as, for example, a stock of measures in the hands of a dealer, or a large shipment of bottles—return of these to the manufacturer for credit or replacement should ordinarily be permitted so long as the official is assured that they will not get into com-

[3] Quoted from the Model State Law on Weights and Measures as adopted by the National Conference on Weights and Measures.

mercial use. Thus the official can protect the owner financially and can make possible the conservation of at least some of the material of which the equipment is constructed. In rare instances confiscation and destruction are justified as a method of control where less harsh methods have failed.

In the case of incorrect mechanisms such as fabric-measuring devices, taximeters, liquid-measuring devices, and the like, repair of the equipment is usually possible, so condemnation for repair is the customary procedure. Seizure may occasionally be justified, but in the large majority of instances this should be unnecessary. Even in the case of worn-out equipment some salvage is usually possible, and this should be permitted under proper controls.

It will ordinarily be practicable to mark or tag as "condemned for repairs" each item of measuring 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 sometimes happens that measuring equipment can not be tested by the official at the time of his regular visit to the premises where the equipment is located. This situation can arise, for example, when there is no gasoline in the supply tank of a gasoline-dispensing device, or when the supply of lubricant for a grease-measuring device is exhausted. In such circumstances condemnation for repair is not appropriate; some officials affix to such equipment a "non sealed" tag, stating that the device has not been tested and sealed and that it must not be used commercially until it has been officially tested and approved. This form of marking is recommended whenever, in a case of this kind, any considerable time will necessarily elapse before the device can be tested.

A somewhat similar situation is occasionally met in an establishment with commercial equipment in use but having also on hand some equipment which is not in service, which may never be put into service, but which is of a type suitable for commercial use and which might be so used at some future time. Such equipment (1) may be tested and otherwise treated by the official just as he treats equipment in commercial service, (2) if readily portable it may be removed from the premises to eliminate possibility of its inadvertent use for commercial purposes, or (3) it may be marked "non sealed".

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 tested, and is not to be used commercially.

The official will be well advised to keep careful records of equipment which is condemned for repairs so that he may follow-up on this to insure that the repairs have been made as prescribed. As soon as practicable following completion of the repairs the equipment should be retested. Complete records should also be kept of equipment which has been tagged as "nonsealed" or "noncommercial"; such records may be invaluable should it subsequently become necessary to take disciplinary steps because of the improper use of such equipment.

Sealing of Equipment.—All equipment which is officially approved for commercial use (with certain exceptions to be pointed out later) should be suitably marked, or "sealed", to show this fact. Because it is desirable that the public be advised that the equipment which is used to serve them has been officially examined and approved, the seal of approval 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, and this is an aid to the public in determining quickly that a piece of equipment has been tested 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 instruments such as fabric-measuring devices, liquid-measuring devices, taximeters, and the like, decalcomania seals are recommended; these are somewhat more expensive than other types but their qualities of permanence and good appearance recommend them highly. Steel stamps are most suitable for liquid and dry measures and for some types of linear measures. An etched seal, applied with suitable etching ink, is excellent for steel tapes and greatly preferable to a seal applied with a steel stamp. For a vehicle tank the official may wish to devise a relatively large seal, perhaps of metal, with provision for stamping data relative to compartment capacities, the whole to be welded or otherwise permanently attached to the shell of the tank.

An exception is made to the general rule that all equipment approved for commercial use should be individually sealed to show this approval, with respect to such equipment as is not individually tested but is approved upon the basis of tests of samples only. In this category are measure-containers, milk bottles, and lubricating-oil bottles. The official normally tests samples of these items preliminary to their sale within his jurisdiction, and subsequently makes "spot checks" by testing representative samples of the measure-containers or bottles selected at random from new stocks. The theory upon which this procedure is justified is that manufacturing processes for these items can be and are closely controlled and that an essentially uniform product is produced by each manufacturer. Thus, if a particular item is once found to be correct, the manufacturer can duplicate that in his regular production; to see that he does so, the official tests samples of the product from time to time.

It would be physically possible to test and seal individually all glass bottles in use. To do this, however, would be a tremendous task, requiring the expenditure of a large amount of time and effort. Considering the high degree of uniformity of the bottles manufactured by modern processes, the slight increase in accuracy to be gained by the individual testing of bottles by weights and measures officials, as compared with the method of testing by sample, is clearly out of all proportion to the difference between the costs of the two methods. In the case of single-service measure-containers, individual testing is not possible, and supervision can only be exercised by the method of testing by sample.

References

National Bureau of Standards Handbook H26, Weights and Measures Administration, chapters 17, 18, and 19. Superintendent of Documents, Government Printing Office, Washington 25, D. C. Price $1.50.

Chapter 4.—LINEAR MEASURES

Description.—Commercial linear measures are to be distinguished from linear-measuring devices. The basic difference between the "measure" and the "measuring device" is that the former is essentially a one-piece instrument, whereas the latter is a mechanism comprising diverse elements which operate together to measure and indicate, usually automatically, the length of material passed through the device. "Linear measure" means, for weights and measures purposes, a rigid measure such as a "yard stick", a folding measure comprising two or more rigid sections, or a metal tape; these are covered by the code for "linear measures". In the case of "linear-measuring devices", two varieties are now covered by specifications, "fabric-measuring devices" and "cordage-measuring devices", and each is covered by a separate code, but the code for cordage-measuring devices is tentative only, final action not having been taken as yet.

There are two basic varieties of linear measures, "line" measures and "end" measures. A line measure is characterized by a zero graduation and a "capacity" graduation that define the total interval; intermediate graduations are customarily provided. Familiar examples of line measures are some of the "rulers" intended for home, school, or office use, and a considerable proportion of the metal tapes in service.

In an end measure, the total interval represented by the measure is defined by the ends of the measure itself; one end corresponds to a zero graduation and the other to a capacity graduation. An example of an end standard is the "gage block", used extensively in precision industrial measurements.

A combination end-and-line measure is very commonly employed in commercial and industrial service; here the zero and capacity points are defined by the ends of the measure, and intermediate between the ends are graduations defining subdivisions of the total interval. Examples of these combination measures in common use are the familiar wooden "yard stick", the majority of "foot rules" or "rulers", mechanics' "scales", and carpenters' "rules".

Certain metal tapes, sometimes used by engineers and surveyors and in the building-construction industry, are "line" tapes as to their capacity graduations but are more nearly "end" tapes as to their zero points. On such a tape the zero or starting point for the series of graduations is defined by the end of a ring or loop affixed to the zero end of the tape. The precise zero point is customarily the extreme outside point of the ring or loop. The length of one of these terminal rings or loops is ordinarily about 1 inch. If such a tape is subdivided into small intervals, there will, of course, be an ungraduated interval adjacent to the zero point. On tapes of this design, in addition to the uncertainty regarding the correct zero point—that is, the inside or the outside of the terminal ring or loop—there is the uncertainty regarding possible deformation of the ring or loop with resulting change in the position of its end in relation to the graduations on the tape. Serious errors may be introduced as a result of the stretching or flattening of a ring or loop (it is usually the former) or by the replacement of a damaged or lost ring or loop by a part which is not of the correct dimensions.[4]

Linear measures are commonly constructed and graduated in units of the customary system only—yards, feet, and inches. Combination measures are made, however, carrying on one side or edge graduations in units of the customary system and on the opposite side or edge graduations in units of the metric system. Such combination measures are not to be recommended for commercial purposes unless both customary and metric values are actually needed in the particular service where the measure is used. Metal tapes for use by surveyors are customarily graduated in feet and tenths of feet; the use of such tapes in commercial service is not to be recommended, because of the possibility that the tenth-foot subdivisions will be mistaken for 1-inch subdivisions.

The linear measures commonly encountered by the weights and measures official are rigid, wooden, one-yard end measures (the familiar "yard stick"), and metal tapes in lengths ranging from 3 feet to 50 feet. Some metal 1-yard line measures, designed to be mounted upon counters and used for the measurement of cloth and other

[4] Tapes of the design discussed in this paragraph, although not recommended, are accepted by the National Bureau of Standards for test, and a report is issued showing their errors, but they are not marked with a National Bureau of Standards seal.

textile products, may be encountered from time to time. Under the regulations, measures constructed of tacks driven into a counter, or similar measures, are not allowed in commercial use, and if found in service these should be dismantled and be replaced by measures or measuring devices conforming to specification requirements. Other homemade measures and measuring sticks may occasionally be discovered in use, and these should be similarly treated.

Inspection.—Measures should be individually inspected for compliance with the applicable requirements of general specifications G–S.1., G–S.2., G–S.3., G–S.4.1., G–S.4.2., and G–S.6., and general regulation G–R.3., and with each applicable specification requirement of the code for linear measures. Inspection should precede testing.

For a metal tape for general service, the type having a zero graduation on the tape itself is to be preferred for commercial service, as compared with the type equipped with a terminal ring or loop to define the zero point. The latter type is not prohibited by the specifications, however, and therefore it can be approved for use when found correct. The ring or loop should receive particular attention by the official; if, because of its material or construction, it is considered probable that this ring or loop will become deformed as a result of normal use of the tape, the tape may properly be rejected under general specification G–S.3.

In his inspection of a linear measure the official should give attention to the graduations, not alone for their width, length, spacing, arrangement, and designation, but also for their legibility. If graduations and figures are indistinct, as from rusting of a metal tape or from wear or abrasion, the measure may properly be rejected under general specification G–S.4.1.

On an end measure, the ends should be examined critically; these should be square and sharp—that is, at right angles to the sides of the measure (and so parallel with the graduations) and with all edges well defined and not rounded off.

Testing Apparatus.—The character and amount of commercial equipment to be examined by the official will determine the character and diversity of the testing apparatus to be provided.

Unless metric equipment is to be tested, no metric standards need be provided. But it should be remembered that it is not practicable to test metric linear measures with standards having values only in the customary system, and therefore, if metric measures must be tested, suitable metric standards or combination standards should be obtained. The following discussion will be confined to apparatus of the customary system, upon the assumption that commercial metric linear measures will seldom, if ever, be encountered. It will be evident from the discussion what metric standards should be procured, should any be needed.

For general field use a metal tape will be much more satisfactory than one or more rigid measures. If only a single tape can be provided, a 50-foot tape, graduated throughout in $\frac{1}{16}$-inch subdivisions, is recommended; this will be useful to the official for many purposes in addition to its use for the testing of commercial linear measures. An advisable addition to the field kit will be a 6-foot metal tape graduated throughout in $\frac{1}{32}$-inch subdivisions; this is recommended because the 6-foot tape will be somewhat more convenient than a 25-foot or 50-foot tape for the testing of yard measures and for making short measurements for other purposes. Each such tape should have a zero graduation on the tape, a blank space of not less than 6 inches at either end beyond the graduations, and should be protected by a case. A flexible, steel, 6-inch scale, about one-half inch wide, will be useful for checking short intervals both in the field and in the office; it is suggested that this scale be graduated on one side or edge in $\frac{1}{32}$-inch subdivisions and on the opposite side or edge in $\frac{1}{50}$-inch (0.02-inch) subdivisions. This scale should have a case for protection.

If a very considerable number of yard measures are to be tested, either in the field or in the office, time can be saved by using for this purpose a rigid standard rather than a tape. For testing end measures such as ordinary yard sticks, still greater convenience of operation can be attained if this rigid standard is provided with a fixed stop at one end against which one end of the measure under test can be placed, with the measure then in such a position that its graduations can be directly compared throughout its length with corresponding graduations on the standard; a few extra graduations on the standard at the end opposite to the stop will facilitate determination of errors in excess.

The standard tape for office use should be of 100-foot length. This may be supplemented, if desired, by tapes of shorter lengths. Each such tape should have a zero graduation on the tape.

The statement of tolerances for metal tapes specifies the tensions at which tapes should be tested. Except where precise results are demanded, it will be satisfactory in field testing to estimate the prescribed tension, and so ordinarily the use in the field of spring scales to measure tension will not be necessary. For office testing of tapes, however, two accurate spring scales should be provided; these should have capacities of not less than 10 pounds and preferably not more than 20 pounds, and should preferably be of straight-face tubular design.

As a part of the office tape-testing apparatus, four clamps will be needed. These clamps should be designed to grip a metal tape firmly but without bending or otherwise damaging the tape; this can be accomplished by means of a block fastened to a base member with screws. Two of the clamps are for anchoring the zero ends of the standard tape and the tape under test, and means must be provided for engaging the clamps with some element sufficiently rigid to withstand the pull when the tapes are drawn taut from their opposite ends. The third clamp is mounted at the capacity end of the tape under test and the fourth is mounted on the standard tape approximately opposite the third one; a spring scale is attached to each of these clamps (No. 3 and No. 4) and the scales are engaged with some rigid member. The position of at least one of the clamps at the zero end should be adjustable, so that the zero graduations on the two tapes can be accurately alined. The positions of the mounts for the two spring scales should be adjustable so that the prescribed tension can be applied to each tape. The entire arrangement should be such that the tapes, when mounted for test, are supported throughout on a horizontal flat surface (a floor is satisfactory) with their edges parallel and close together.

A hand lens of medium power is required for use in both field testing and office testing of linear measures, in order that readings and settings may be made with precision.

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Use of a flash lamp will be required for proper illumination under many field conditions.

Testing Procedure.—For simplicity of language in the discussion which follows, the measure under test will be referred to as "the measure", and the standard tape, scale, or bar will be referred to as "the standard".

Measures must be individually tested to determine their accuracy. If a measure has once been examined and found to be correct, repeated retesting may be unnecessary as long as careful inspection shows that the physical condition of the measure remains unchanged. The measure should be retested, however, if there is any doubt regarding its continued accuracy.

The testing of a linear measure is essentially simple, consisting of a direct comparison of the intervals of the measure with those of the standard. The total interval represented by the measure should always be verified. Clearly, it will not be practicable to compare each subdivision of the measure, or the interval from zero to each successive graduation on the measure, with the corresponding interval on the standard. Nor is this necessary or even desirable in a measure graduated throughout its length into many—perhaps hundreds—of subdivisions; the spacing of the graduations is usually accomplished by a machine operation of some sort, and accidental errors, such as might result from graduation by hand, are not to be anticipated. On a measure graduated throughout into relatively small subdivisions, observations should normally be made at not less than six intermediate points. If the total number of intermediate graduations does not exceed 10 or 12, it will be advisable to make an observation at each such graduation.

When testing at intermediate graduations, the procedure should be to consider in each case the entire interval from zero to the graduation under observation, rather than the interval defined by any two intermediate graduations or the interval from a particular graduation to the capacity graduation. This conforms to the normal method of using a measure.

The basic procedure in testing any measure is first to place the standard and the measure with their corresponding series of graduations in such proximity that any failure of agreement in the positions of the graduations can be determined accurately. This is accomplished when testing a bar (such as a yard stick) with another bar, by placing measure and standard side by side, if possible with the edges carrying the graduations immediately adjacent and in the same plane. (To do this it may be necessary to reverse the standard end for end, bringing its capacity graduation or end into alinement with the zero graduation or end of the measure. There is no objection to this procedure.) Or, in this same case, the standard may be set on one edge directly on the bar being tested and overlapping the graduations on the measure; obviously, the standard should be parallel with the measure. If the measure is a bar and the standard is a tape, the tape is laid directly on the bar. If both measure and standard are tapes, they are stretched out side by side.

The second step is to aline accurately the zero graduations of the two series of graduations (or the zero ends of measure and standard, or the zero graduation of one and the zero end of the other). If a tape is involved (as measure or standard or both) the tape or tapes should then be brought approximately to the proper tension as specified in the statement of tolerances for metal tapes—5 pounds for tapes of less than 25 feet, and 10 pounds for tapes of 25 feet and over. Finally, the amounts by which the intervals on the measure fail to agree with the intervals on the standard are determined by observing the relative positions of corresponding graduations. The alinement at zero should be checked at the conclusion of these observations to insure that the relative position of measure and standard has not shifted while the observations were in progress.

The official will require assistance in maintaining the position and tension of any tape involved in a test if the intervals being compared exceed a few feet, and always if he finds it necessary to use a lens in making a close observation.

Care must be exercised to establish the same relative line of sight when viewing all pairs of graduations for agreement; the possibility of parallax effects is increased when a hand lens is used. Uniformity of lighting is also important, particularly if a beam of artificial light is utilized; the beam should be essentially parallel with the graduations being observed, and if it is not there may appear to be errors which, in fact, do not exist, this appearance resulting from the lighting conditions alone.

If, when determining agreement or errors, it is necessary to project the line of a graduation of one series to reach the other series, as when the two series of graduations, on measure and standard, are not immediately adjacent, this must be accurately done; a straight-edge should be used (such as the edge of the 6-inch scale), or use may be made of a small, accurate T-square. Readings and settings should be made at the center line of a graduation rather than on either edge when comparing two series of graduations, to avoid errors which would otherwise be introduced if the graduations of the two series differ in width. The 6-inch scale is recommended for auxiliary use in making precise determinations of errors whenever this becomes necessary, and in making close determinations as to whether or not an error exceeds the applicable tolerance.

The length of a steel tape is considered to be standard at 68° F. An increase in temperature causes the tape to expand and become longer, and a decrease in temperature has the opposite effect. Thus at 78° F. an interval on a steel tape which is 100 feet at 68° F. will be approximately 100.00645 feet, or 100 feet plus 0.08 inch; at 58° F. that interval will be approximately 99.99355 feet, or 100 feet minus 0.08 inch. A 10° F. change in the temperature of a 25-foot steel tape causes a change in its length of approximately 0.02 inch; on a 6-foot tape the corresponding change in length is only about 0.005 inch. As can be seen from these figures, moderate changes in temperature seldom bring about changes in the lengths of steel tapes which are of such magnitude as to be significant in weights and measures regulatory work. The official can safely disregard temperature changes in his linear-measure testing in the field if he will simply avoid using his standards when these are at abnormally high or low temperatures. In office testing, temperature corrections can safely be disregarded in testing all short measures. When testing steel tapes in the office, the only precaution necessary with respect to temperature is to have the measure and the standard at approximately the same temperature; the value of the standard being known at 68° F., the value of the measure will then be determined as for 68° F., since both measure and standard will be equally affected by the prevailing temperature.

Testing Outlines

(For tests of linear measures by weights and measures officials)

Case I. Rigid measures, when a metal tape is used as the standard:

1. Position the standard on the measure, so that the series of graduations on the standard will partially overlap the series of graduations on the measure.[5]
2. Shift the position of the standard as required to bring the zero graduation of the standard into precise alinement with the zero of the measure.
3. Apply the prescribed tension to the standard.
4. Compare the total interval of the measure with its nominal equivalent on the standard. Note the amount of the error, using the 6-inch scale, if necessary, for this purpose.
5. Proceed as in step 4 to compare at least six intervals, from zero to each of six intermediate graduations.
6. Check the alinement of the zero graduation of the standard with the zero of the measure. (If the position of the standard is found to have shifted from that established in step 2, the test should be repeated after reestablishing proper alinement.)

Case II. Rigid measures, when a rigid measure is used as a standard: [6]

1. Position the standard on edge on the measure (or vice versa) so that the two series of graduations are brought together, or position the standard beside the measure so that the two series of graduations are in the same plane.
2. Proceed as in steps 2, 4, 5, and 6 of case I.

[5] If the measure is not fastened in position (as to a counter) and has graduations extending to the edge of the measure, the positions of measure and standard may be reversed if desired. In this case the standard is laid out on a flat surface and the measure is placed upon it, resting on one edge so that the two series of graduations are brought together.

[6] If a standard with a fixed stop at one end is being used, the exact procedure for steps 1 and 2 will be determined by the particular design of the standard.

Case III. Field test of metal tapes, a metal tape being used as the standard:

1. Position the standard on the measure (or vice versa) so that one series of graduations will partially overlap the other, the tapes being supported on a horizontal flat surface.
2. Shift the position of the upper tape as required to bring the zero graduations of the standard and the measure into precise alinement.[7]
3. Apply the prescribed tension, as accurately as feasible, to both tapes.
4. Proceed as in steps 4, 5, and 6 of case I.

Case IV. Office test of metal tapes:

1. Position the measure and the standard side by side, and as close together as practicable, both tapes being supported on a horizontal flat surface.
2. Establish precise alinement between the zero graduations of the standard and the measure and secure the zero ends of both tapes.
3. By means of spring scales apply the prescribed tension separately to each tape and secure the scales so that this tension will be maintained throughout the test.
4. Compare the total interval on the measure with its nominal equivalent on the standard. Note the amount of the error, using the 6-inch scale and a straight-edge or T-square for this purpose.
5. Proceed as in steps 5 and 6 of case I.

[7] If the zero of the measure is defined by the end of a loop or ring, establish the zero alinement here specified by alining the first main graduation (1-inch or 2-inch, for example) on the measure with the corresponding graduation on the tape. Subsequently determine the accuracy of the interval on the measure from the end of the loop to the first main graduation; any error found on this interval is to be combined with the errors on tested intervals beginning with the first main graduation on the measure, to arrive at the errors for the intervals from zero to the terminal points of such tested intervals.

[8] See footnote 7.

References

National Bureau of Standards Circular C328, Testing of Measuring Tapes at the Bureau of Standards. Price 10 cents.*

National Bureau of Standards Circular 329, Calibration of a Divided Scale. Out of print; available for consultation in Government Depository libraries.

National Bureau of Standards Circular C332, Testing of Line Standards of Length. Price 10 cents.*

National Bureau of Standards Reprint RP743, Calibration of the Line Standards of the National Bureau of Standards. Price 5 cents.*

National Bureau of Standards Scientific Paper S535 (Scientific Papers of the Bureau of Standards, vol. 21, page 395), A Fundamental Basis for Measurements of Length. Out of print; available for consultation in Government Depository libraries.

National Bureau of Standards Letter Circular LC930, Standards of Length, Mass, and Time. Free upon application to the National Bureau of Standards.

* Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D.C.

Chapter 5.—FABRIC-MEASURING DEVICES

Description.—As ordinarily encountered by the weights and measures official, a fabric-measuring device is a machine used in a retail establishment for the automatic measurement of fabric passed through the machine and for the automatic computation of the total money value of the material measured for each of a series of unit prices. Such a device serves for dry goods sold by linear measure the same general function as is performed by a computing scale for commodities sold by weight. Under the definition given in the National Conference code, a fabric-measuring device may or may not be equipped with means for price computation, but it is believed that none without this feature will now be found in retail use, and the code is limited in its application to devices "which, by reason of the character of their primary indicating elements, are obviously designed for use in connection with retail sales." Noncomputing types may be found in some wholesale establishments; although wholesale machines are not covered by the code cited, their measuring characteristics are similar to those of the retail machines, and the official should have no difficulty in adapting to the test of the wholesale type the principles which are outlined for the retail type in what follows.

The measuring element of a fabric-measuring device is a measuring roller several inches long which is connected through a gear train with the length-indicating elements. The conventional yardage-indicating elements comprise a "clock-face" dial and two indicators, the longer indicator making one complete revolution for 1 yard and showing inches and eighth-yards, and the shorter indicator showing whole yards up to a total of 12 yards for a complete revolution. An additional "customers' " indicator is normally provided. There is an idler roller opposite to the measuring roller, and the fabric to be measured is drawn between the two rollers, which are held together under spring pressure; passage of the fabric between the rollers actuates the measuring roller, and its motion is communicated to the indicating elements. By means of a lever, one of the rollers may be locked in a raised position to permit insertion of the fabric between the rollers, with the end of the piece of fabric at the correct starting position. Operation of a conveniently positioned trigger releases the raised roller. As the fabric is drawn through the machine, the indicating elements are driven forward or backward, depending upon the direction of movement of the fabric, and the registration is maintained, through a clutch mechanism, until it is desired to "clear" the indication back to a zero reading. Clearing is accomplished by depressing a "zeroizing" button, which releases the clutch, when the indicating elements automatically return to zero positions; in earlier models the button must be held in the depressed position until the clearing operation is completed, whereas in later models it is merely necessary to push the button to start the zeroizing operation which, once started, is automatically carried through to completion.

In the fabric-measuring devices currently on the market, a knife is mounted on the roller-operating lever previously mentioned, the purpose of which is to make a short cut in the edge of a piece of fabric to mark the point to which the desired measurement has been made and at which the cut is to be carried by hand across the strip of fabric. When, for example, a 5-yard piece has been measured from a bolt of cloth, the single operation of depressing the lever results first in making the cut in the selvage of the fabric and, second, in opening the rollers and locking them in the open position so that the cloth can be slipped out. On late models there is an interlock which normally prevents the operation of the lever except when the machine indicates an exact measurement of some eighth-yard multiple; when the desired measured interval falls between eighth-yard points, it is necessary to clear the machine before the lever can be operated to notch the fabric and separate the rollers.

The point on the fabric-measuring device at which the knife descends corresponds, of course, to the point to which the end of the cloth is set at the start of a measurement. As the machines have been built for the past 20 years or more, they are equipped with an interlock actuated by a fork which is positioned between the jaws of the machine in line with the correct zero position of the end of the piece of fabric to be measured. If the operator carelessly positions the end of the fabric so that this extends through the jaws beyond the correct zero position, the fabric changes the position of the fork and locks the trigger which releases the raised roller. The fabric must be *behind* the fork before the roller can be released and the machine put into condition for a measuring operation. This interlock is designed to prevent overmeasure that might result from an incorrect starting position of the fabric.

For the computation of money values, current models of fabric-measuring devices are equipped with charts carried on two rolls; these rolls are geared to the measuring roller of the device and are automatically actuated by rotation of the measuring roller. Computations are made for certain fractions of yards only—customarily for each eighth yard—the devices being of the "limited-computing type" covered by specification S.4.2. of the National Conference code. When the device is cleared, the price-computing chart is automatically returned to its zero position along with the yardage indicators. There may, however, be a supplementary chart carrying computations for odd lengths (that is, not even eighth yards), mounted on a small roll and designed to be pulled out manually for observation when needed.

The fabric being measured is drawn through the device by the operator from left to right. The left hand of the operator guides the fabric into the jaws in a straight course, and the necessary tension to draw the fabric through the rollers—which is very small—is applied with the right hand. It is obvious that if a piece of fabric is at all elastic and if this is stretched tight as it passes through the machine, short measure will result. For this reason the operator should not grasp the fabric being measured with the left hand as it is being drawn through the machine; the fabric should be free to pass into the machine with no drag or back-pull. Fabric-measuring devices are not intended for use in measuring exceptionally elastic fabrics. (See specification S.6.)

A fabric-measuring device may be mounted on a counter in a fixed position, or on a track so that its position may be shifted for the convenience of the operators. Pedestals of different heights are available to adapt an installation to the merchandise to be measured.

Inspection.—Fabric-measuring devices should be individually inspected, and inspection should precede testing. Inspection should be made for compliance with the applicable requirements of general specifications G–S.1., G–S.2., G–S.4., and G–S.6., with general regulations G–R.2., and G–R.5., and with each applicable specification requirement of the code for fabric-measuring devices.

When the rollers are in the closed position they should be parallel and in contact throughout their length. A simple way of checking this is to direct a flash-lamp beam between the jaws from one side when the rollers are presumably in contact, and observe from the other side the streak of light passing between the rollers. If this streak of light is wedge-shaped, the rollers are either worn or out of adjustment.

The device should be checked for the correct functioning of all buttons, levers, triggers, or other similar elements, for the correct alinement of value figures with unit-price figures, and for the correct alinement of the value figures in the aperture of the housing. The device should be operated for a short interval and then cleared, several times, to check the return of all indicating elements to proper zero positions; both the customers' indicating face and the elements designed to be read by the operator should be checked and agreement between them required.

The general accuracy of the value chart or charts should be established by checking a reasonable number of the computations. This need be done only once for each variety of chart. It will ordinarily be possible to see the designating number of the chart without disassembly of the device, and charts bearing the same number may be assumed to be of identical design.

Testing Apparatus.—The recommended testing apparatus for a fabric-measuring device is a "secondary length standard" consisting of a graduated strip of special fabric. It is practicable for an official to prepare one of these "testing tapes" himself, and instructions for doing this will be found in the paper beginning on page 93 of the Report of the Fifteenth National Conference on Weights and Measures, NBS Miscellaneous Publication M51. These instructions are not repeated here because fabric testing tapes for fabric-measuring devices are now procurable from commercial sources, and practically all officials appear to prefer purchasing the prepared tapes to constructing tapes themselves.

The testing tape commercially available conforms to the essential recommendations given in the paper cited above. It is 2½ inches wide and has a graduated length of 12 yards.

Because of the probability that there would be some slippage between the rollers, a steel tape should not be used as the testing standard for a fabric-measuring device.

Testing Procedure.—The yardage test of a fabric-measuring device consists essentially of passing the testing tape through the device in a manner corresponding to the commercial use of the device, and comparing from time to time the indications of the device with the corresponding lengths of the standard tape which have been passed through the device. Because in its basic mechanical design the device is nothing more than a gear train, it may be argued that it is sufficient to test the device up to only 1 or 2 yards, upon the assumption that subsequent operating cycles will merely repeat the operations involved in such a short test. While this argument has some validity, it is nevertheless the fact that faulty conditions involving elements other than the gear train might exist, which would be disclosed only when the test is carried to points approaching the capacity of the device. Accordingly it is recommended that a fabric-measuring device always be tested to the 12-yard indication, or to its maximum indication should this be less than 12 yards. (If the official tests a wholesale-type device, having a capacity considerably in excess of 12 yards, the test should be extended to 30 or 40 yards or even more, depending upon the capacity of the device, its performance in the lower portion of its operating range, and similar factors.)

Certain general considerations should be observed in testing: The testing tape should be passed through the device at a right angle with the axis of the measuring roller; if a straight course is not maintained, and the tape passes between the rollers with a weaving motion, erroneous results will be obtained. The testing tape should be drawn through the device at moderate speed, approximating that of commercial operation. The tape should not be positioned so far back in the jaws that its edge will rub against the housing; in fact, it is advisable that the tape be far enough forward in the jaws to clear the knife on the roller-separating lever. The indications of the customers' and operator's yardage indicators should be compared frequently for agreement. Alinement of value figures should be checked from time to time, including an observation at the maximum point to which the device is tested. Should the device be equipped with a totalizing counter, an "inventory indicator", or similar element, the increase in the indications of this element should be checked for agreement with the primary yardage indications of the device.

When making observations, errors of indications should be read on the tape and not by means of the indicating elements of the device. That is to say, the tape should be drawn through the device until coincidence is obtained between the indicator and the graduation representing the interval being tested, and the error, if any, should be read from the tape. If the actual length of tape passed through the device exceeds the indication of the device, the error of the device is the difference between the two and the error is in the direction of under-registration; if the length of tape passed through the device is less than the length indicated by the device, the error is one of over-registration. In order to read the tape with precision, a definite line of sight must be established for the zero tape reading, and this line of sight must be duplicated in all subsequent tape readings. The official may find it useful to improvise a sighting gage which can be held against the side of the housing each time a reading is made or fastened to the housing with rubber bands for the duration of a test, to assist him in maintaining a uniform sighting line when reading the tape.

In the commercial use of a fabric-measuring device, the operator may overrun the desired measurement and then "back up" to the indication wanted. For an indicated length of a given amount, the actual length of the measured fabric when the fabric is advanced through the rollers may differ from the length when the direction of movement of the fabric is reversed just prior to the completion of the operation, as in the case mentioned above; this difference results from backlash or lost motion in the gear train. The official should compare the tape reading for some device indication following forward travel of the tape, with the reading for the same indication following tape travel in the reverse direction, to learn whether or not any appreciable backlash exists.

If it does, then observations should be made following both forward and backward travel of the tape at each point where the error on the normal forward test is in the direction of over-registration and approaches in amount the value of the applicable tolerance. It is proper to reject the device if its error on either backward or forward test exceeds the applicable tolerance.

The testing tape is properly positioned at zero at the beginning of a test, as follows: With the rollers separated, the end of the tape is inserted squarely in the jaws, the trigger is operated to bring the rollers together, and the tape is advanced until, according to the established line of sight, a "zero" tape reading is obtained. In this operation the tape should be *advanced* to position—the mechanism should not be run backward immediately prior to being stopped for the zero setting of the tape. Next the device is cleared by operating the zeroizing button. Everything is then in readiness to start the test.

Whenever the tape is to be removed from the device, care must be exercised to avoid cutting the edge of the tape. The tape may be run completely through the device, first clearing the device if necessary, before operating the roller-separating lever. If the tape is far enough out in the jaws to clear the knife, the lever may, of course, be operated safely whenever desired.

In the actual test, observations should be made at the first graduation (which will probably be 1 inch), and successively at the graduations representing 1/8 yard, 1/4 yard, 12 inches, 1/2 yard, 24 inches, 3/4 yard, and 1 yard, and at each subsequent even-yard graduation to the capacity of the device. In the upper portion of the indicating range, at least one observation involving some fractional part of a yard should also be made. For each of these "normal" observations the tape should be advanced carefully as the indicator of the device approaches the graduation at which the observation is to be made, and should be stopped as coincidence between indicator and graduation is obtained; that is, the tape should be moved in a forward direction to its stopping point. If inadvertently the tape is moved too far, thus causing the indicator to overrun the desired graduation, the tape should be run backward several inches and should then again be run forward to the proper stopping point, thus avoiding the introduction of any backlash error.

The backlash error is determined as follows: Following the normal observation at the ¼-yard graduation, advance the tape a few inches and then reverse its direction, "backing up" the indicator to the ¼-yard graduation but avoiding overrunning it. If the second tape reading is less than the first, the difference between the tape readings on these two observations represents the error caused by backlash or lost motion in the gear train. It is recommended that as a check, this backlash test be repeated at least once at some higher graduation. Note that if an appreciable backlash error is found to exist, the backlash test should also be repeated at any graduation where the error on a normal observation is in the direction of over-registration and approaches in amount the value of the applicable tolerance.

Testing Outline

(For test of fabric-measuring devices by weights and measures officials.)

1. Insert the testing tape and *advance* this to the point where a precise tape reading of zero is obtained.
2. Clear the device to produce zero indication.
3. *Advance* the tape until the indicator of the device is in coincidence with the first graduation (probably the 1-inch graduation). Read the error from the tape, or determine that the error is within the applicable tolerance.
4. *Advance* the tape until the indicator is in coincidence with the ⅛-yard graduation. Read the error from the tape, or determine that the error is within the applicable tolerance.
5. Repeat step 4 at the ¼-yard indication.
6. Advance the tape several inches and then reestablish coincidence of the indicator and the ¼-yard graduation, moving the tape in a *backward* direction. The difference between the tape readings on steps 5 and 6 is in the backlash error. Rejection of the device is proper if the actual error developed on the backward observation exceeds the applicable tolerance.
7. Repeat step 4 at the 12-inch, ½-yard, 24-inch, ¾-yard, and 1-yard graduations, at each subsequent even yard, and at some graduation representing a total

length of several yards and a fraction of a yard. (If at any point the device develops an error of over-registration which approaches the applicable tolerance, repeat step 6.)

References

The following references are to papers and discussions on the general subject of fabric-measuring devices, appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M14, Eleventh Conference Report, 1916, pages 117–120.
M43, Thirteenth Conference Report, 1920, pages 169–170.
M51, Fifteenth Conference Report, 1922, pages 93–101.
M80, Twentieth Conference Report, 1927, pages 8–11.

Chapter 6.—TAXIMETERS

Description.—A taximeter is an instrument for attachment to a taxicab to compute passenger fares, and consists essentially of a system of mileage gears, and usually a clock movement, in combination with a fare-indicating mechanism. The gear train utilized for mileage registration was formerly actuated by one of the front wheels of the cab, with which it was connected by a flexible shaft; this gear train is now almost universally actuated by the rear wheels of the cab through the drive shaft or "transmission", with which connection is made by means of a flexible shaft. The clock movement is of the ordinary type. The indicating elements, marked in terms of money values, may be in the form of drums or discs. A manually-operated "flag" serves as the control by means of which the mileage gears and the clock movement are connected with and disengaged from the indicating mechanism and the meter face is cleared of the accumulated fare for a given trip.

On a taximeter equipped with a clock movement, the amount of the fare for a particular trip may be determined by two factors, the mileage traveled and the amount of "waiting time". Charges for waiting time are registered as a result of clock operation. When the meter flag is in the position for normal operation of the meter (usually designated as the "Hired" position), the clock automatically causes charges to accrue at the waiting-time rate of so much per hour while the cab is not in motion and whenever the speed of the moving cab drops below the point at which the rate of mileage revenue per unit of time equals the waiting-time rate. At another position of the flag (usually designated as the "time not recording" position), the clock is stopped or is disconnected from the fare-indicating elements; with the flag in this position, fare will be registered only by the operation of the mileage mechanism.

Taximeters may be equipped with separate, manually operated, "extras" indicators for recording fixed charges for extra baggage, extra passengers, and the like. There may also be totalizing counters or their equivalent for

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summarizing the indications of the taximeter; such elements may show total mileage, mileage for which fares have been collected, number of trips or "flag pulls", number of unit charges in addition to the initial charges which have been registered by the taximeter, the amount of "extras" registered, and the like.

Taximeters are so designed that they may be modified to operate at different rates of fare for mileage and waiting time. Changes may be introduced with respect to (1) the value of the "initial money drop", registered when the flag is thrown to the hired position, (2) the value of subsequent money drops, (3) the mileage interval corresponding to the initial money drop, (4) subsequent mileage intervals, (5) the waiting-time rate, (6) the initial and subsequent waiting-time intervals, and (7) the "extras" units. Modifications may also be made to adapt the registration to tires of different sizes, by means of various combinations of "change gears". All these modifications are shop operations, requiring a greater or lesser degree of disassembly of an installation or a taximeter.

Inspection.—Taximeters, and taximeter installations on cabs, should be individually inspected for compliance with the applicable requirements of general specifications G–S.1., G–S.2., G–S.3., G–S.4.1., G–S.5., and G–S.6., and general regulations G–R.2., G–R.3., and G–R.5., and with each applicable specification requirement of the code for taximeters. In general, inspection should precede testing.

Inspection should include a number of operations designed to determine whether or not certain parts are functioning properly. The flag should be placed in each of its several positions to determine that its position is correctly indicated on the taximeter face in each instance and that shutters or shields operate as they should; in these operations the flag should be operated both rapidly and slowly, and in a backward as well as in a forward direction whenever the backward motion is proper. The centering of figures and legends in their apertures should be checked. The correct "clearing" of the taximeter when the flag is returned to its "vacant" or highest position, should be checked. With the flag in the "Time Not Recording" position it should be noted that the operation of the clock is actually stopped or that its operation does not, in fact, cause any fare registration. The extras mechanism should be checked for proper sequence of money indications for its full range or up to an indication of about $2, and for proper clearing of the indications when the flag is returned to the "vacant" position.

Each of the specifications of the taximeter code with the exception of S.6. and S.9., and in addition, taximeter note N.1. and regulation R.1. and all of the general requirements cited above except G–S.3., contain requirements which can readily be checked by inspection, and this should be done. If the inspection is of an installation previously approved, it is still recommended that the inspection be complete, and in addition the protective seals previously affixed should be examined for security and evidence of tampering.

Testing Apparatus.—There are three types of mileage test which are employed for taximeters, (1) the "bench" test, in which the test is confined to the taximeter head with or without a gear box attached, (2) the "road" test, in which the taximeter is mounted on the cab and is actuated by travel of the vehicle, and (3) the "wheel" test, in which the taximeter is mounted on the cab and cab travel is simulated by rotation of the wheel or wheels of the cab while the vehicle remains at rest. The advantages and disadvantages of these three types of test will be discussed later under "Testing".

The apparatus required for a bench test may be very simple or rather elaborate. The essentials are some means for rotating the driving spindle of the taximeter, and some mechanical means for counting the revolutions. Rotation can be accomplished by a simple hand crank, a method which is acceptable if only a small number of tests are to be made. If a considerable number of tests are to be made, it is recommended that a machine be designed employing an electric motor to turn the taximeter spindle, power being transmitted through a clutch which can be engaged or disengaged readily, means being provided for varying the speed of spindle rotation as desired, and a bracket being provided for convenient mounting of the taximeter during the test. If the number of anticipated tests is large, such a machine as has been described can well be modified to provide several brackets, so that tests of several taximeters can be carried on simultaneously; individual clutches, one for each taximeter, will be required, but only one motor will be needed. In all cases the mechanical counter should be so mounted that complete spindle revolutions will automatically be registered; one counter will be required for each bracket provided. A dial and index combination for each bracket should be provided so that partial revolutions of the spindle can be accurately determined.

A measured course laid out on some street or road is required for a road test of a taximeter installation. The course should be accurately measured and should be as nearly straight and level as practicable. The length of the course should be one or, preferably, two miles. Permanent markers should be provided to establish accurately the one-mile points and such subdivisions as are utilized in the prevailing taxicab rates—half-miles, third-miles, quarter-miles, fifth-miles, etc. If a choice exists, the course should be located where traffic is relatively light.

For a wheel test of a transmission-driven taximeter it is necessary to provide means for rotation of one or both of the rear wheels of the vehicle, and a mechanical counter to register the number of wheel revolutions. The cab can be jacked up on one side and the raised wheel rotated by means of a hand crank, but this method is so laborious that it is not recommended. With one side of the vehicle jacked up the cab motor can be utilized to rotate the raised wheel for all but the last few revolutions preceding a money drop, the final revolutions being made by hand power. With the same set-up, the mechanical counter can be so mounted that it can be disengaged at the instant a particular money drop occurs, thus registering only the number of wheel revolutions required for the interval under observation. (In all these cases where only one of the two rear vehicle wheels is rotated, the other being held fast, it must be remembered that one revolution of the single wheel has the same effect on the drive shaft as one-half revolution of both rear wheels simultaneously rotating at the same speed.) A fourth method of causing wheel rotation is by means of two rollers or drums, mounted parallel, and forming a cradle to receive the rear wheels of the cab. One of these rollers or drums is driven by an electric motor and the other is an idler; rotation of the driven roller or drum causes simultaneous rotation of both of the wheels with which it is in contact. Means should be provided for varying the speed of operation and for stopping wheel rotation quickly when desired. This form of apparatus is recommended if any appreciable number of wheel tests are to be made.

With the old type of mounting in which the taximeter is driven from one of the front wheels of the cab, the apparatus needed for a wheel test is similar to that described in the preceding paragraph. Power-operated means for causing wheel rotation is recommended.

The "time" test of a taximeter requires that observations be made to the nearest second. An ordinary watch with a small second hand is not satisfactory, and a watch or clock having a sweep second hand should be provided; a stop watch or a desk type of interval timer, which can be started from and reset to zero time as desired, will be found most convenient.

Testing Procedure: General Considerations.—The purpose of testing a taximeter installation is to determine whether or not the various indications on the face of the taximeter occur following the proper number of revolutions of the cab wheel or the proper intervals of waiting time. As a general principle the test should, as nearly as may be, approximate service conditions. However, considerations of testing expediency make it advisable to recommend some deviations from this principle; whenever this is done the deviation is believed to be amply justified.

Reference has been made under "Testing Apparatus" to the three types of mileage tests employed for taximeters, (1) the bench test, (2) the road test, and (3) the wheel test. The bench test is a shop test of the taximeter itself, disconnected from other elements of a complete installation, except that the gear box may be attached. This test makes possible a very complete and satisfactory examination of the taximeter head, and it is recommended in all cases. The time test of the taximeter is most satisfactorily made in conjunction with the bench test. Obviously, the bench test should be supplemented by some form of test of the complete installation, after the taximeter is mounted on the cab on which it is to be used.

The road test is recommended as the supplement to the bench test. The wheel test merely simulates, without duplicating, the road test, and is the recommended alternative to the road test if the latter can not be made.

Either of these tests enables the official to check the accuracy or correct functioning of all gears, cables, and connections between the taximeter head and the driving wheels. In addition to this, the road test has the advantage of subjecting the parts of the assembly to road shocks such as are encountered in normal taxicab operation; simulation of these by artificial means is not recommended. In a wheel test, computations must be made in relation to tire sizes; these are eliminated in the road test, where the tires are operated under actual service conditions. Objections which may be advanced against the road test are the time consumed, the difficulty of driving a perfectly straight course throughout the test with the possibility of introducing some slight inaccuracy in the distance assumed to have been traveled by the cab, and the limited distances for which it is practicable to operate a cab on this test; opposed to these are the advantages of testing under actual service conditions.

While it is possible to conduct as a part of a wheel or road test all of the operations which will be specified later in the detailed consideration of the bench test, this is not considered practicable and is not recommended. These operations may be performed much more satisfactorily and conveniently in the shop, and the cab is kept out of service for a shorter period.

The recommended system of bench tests supplemented by road tests (or wheel tests) operates in this manner: From the stocks of taximeters in the possession of taxicab or taximeter companies, the official "bench-tests" a supply of taximeter heads; those found correct are suitably tagged, and these comprise the stock from which installations will be made. Then whenever one of these correct heads is installed on a cab, the official conducts the final examination as a road test, approving and sealing the complete installation if it is found that the installation meets specification requirements and that all of the auxiliary elements and the effective size of tires on the driving wheels properly combine with the taximeter head to produce accurate performance. The separate test of the taximeter heads is practicable, because each make or model of taximeter is designed to have its own standard number of spindle revolutions per indicated mile. The official approves taximeter heads which are "standard" within prescribed tolerances. The mechanic installing a taximeter then selects the auxiliary gears required for the installation with the knowledge that the taximeter head is "standard", choosing these gears according to the number of revolutions per mile of the tires with which the cab is equipped. The official's road test of the finished installation then checks the accuracy of what the mechanic has done.

Testing Procedure: Time Test.—The time test of a taximeter consists of timing the intervals between money drops, and is conveniently divided into a "separate-interval" test and an "average-interval" test. In the separate-interval test, the times elapsing between successive money drops are separately determined. Considering only the accuracy and completeness of the results, this test should be continued for an hour or more; however, if a minimum of the first five intervals are found to be individually accurate, it is suggested, as a matter of testing expediency, that the separate-interval test be discontinued at that point.

The separate-interval test is initiated by throwing the taximeter flag to the "Hired" position and simultaneously starting the stop watch or timer. At the instant the next money drop occurs the elapsed time to the nearest second is noted from watch or timer and this is recorded. (The watch or timer is not stopped, but will be allowed to continue running throughout the entire period of the time test.) Similar observations are made and recorded as subsequent money drops occur.

To illustrate a convenient method of recording these observations and computing the results, assume that the taximeter under test has (1) an initial money drop of 20 cents, (2) subsequent money drops of 10 cents, (3) a nominal initial time interval of 8 minutes, and (4) a time rate of $1.50 an hour or 10 cents for each 4 minutes. The recorded results might then be:

Meter No.------

Drop	Elapsed time	Interval	Error in seconds
Start	0:0		
30	8:10		
40	12:14		
50	16:14		
60	20:12		
70	24:14		

The first interval has been designated as the 30-cent drop, the second as the 40-cent drop, and so on. Actually these money values are those corresponding to the second interval, the third interval, and so on, but these are the values recorded by the taximeter at the conclusion of the first interval, the second interval, and so on. It is simpler to record these values as they are observed, and this introduces no complications in subsequent computations. Note that in the Elapsed Time column the entries are the actual readings of the timer as the indicated money drops occur.

The computations to be entered in the third and fourth columns of the data sheets should be made immediately following entry of the observed values; after five observations have been recorded as above, the sheet would appear as follows:

Meter No.______

Drop	Elapsed time	Interval	Error in seconds
Start	0:0		
30	8:10	8:10	10
40	12:14	4:04	4
50	16:14	4:00	0
60	20:12	3:58	2
70	24:14	4:02	2

These errors being small as compared with the prescribed tolerances, the official may discontinue the separate-interval test and proceed at once with the average-interval test. If, on the contrary, the results were to indicate erratic performance or errors nearly equaling the tolerances, the separate-interval test should be carried on for a total of ten or more observations. (It may be noted here that if a taximeter is to be rejected because of errors developed on the separate-interval test, little purpose will be served by proceeding with an average-interval test.)

Proceeding to the average-interval test, the taximeter is not cleared at the conclusion of the separate-interval observations, nor is the timer stopped. Operation is continued for at least one hour, without intervening observations. When the test is to be concluded, the time at which a money drop occurs is observed and recorded, after which the taximeter may be cleared. Thus in the example, the data sheet might read as follows at the conclusion of the time test:

Meter No.______

Drop	Elapsed time	Interval	Error in seconds
30	8:10	8:10	10
40	12:14	4:04	4
50	16:14	4:00	0
60	20:12	3:58	2
70	24:14	4:02	2
2.20	84:51		

The tolerance on the average time interval specifies that the initial interval shall be excluded. The computation in the example would be: The difference between \$2.20 and 30 cents is \$1.90, representing the charge for nineteen 10-cent intervals, each having a nominal time value of 4 minutes. The nominal elapsed time for these 19 intervals is 76 minutes (19×4 minutes). The actual elapsed time for these 19 intervals is the difference between 84 minutes 51 seconds and 8 minutes 10 seconds, or 76 minutes 41 seconds. The total error on the 19 intervals is, therefore, 41 seconds in the direction of underregistration, and the average error is 41 seconds divided by 19, or slightly more than 2 seconds per interval.

The official can readily conduct time tests on several taximeters simultaneously by staggering the starting times—for example, starting the tests at 30-second or 1-minute intervals. Unless the clock mechanisms are very irregular, there should be ample time between money drops for recording and computing. The time test can be made either before the bench mileage test is begun or after it has been concluded.

Testing Procedure: Bench Mileage Test.—The primary objective of the bench test is to determine that the mileage-drop mechanism of the taximeter is functioning properly. Many taxicab trips are for relatively short distances, involving only the first few money drops. It is in the first few drops that the largest percentage errors of registration are apt to occur. It is proper, therefore, to give special attention to the performance of the taximeter throughout this portion of its range. But a test dealing only with the first few drops does not bring all of the taximeter parts into operation in a way to demonstrate that they are functioning correctly, and so there must be included a test corresponding to a greater traveled distance. For convenience of reference these two divisions of the bench test may be referred to as the "short-haul" and the "long-haul" tests.

In the short-haul test the flag should be in the "Time Not Recording" position so that only the mileage portion of the mechanism will affect the registration, and the mechanism should be operated at a slow speed so that observations may be made with precision. (The official is cautioned that taximeters may be so constructed that the registering mechanism is advanced whether the spindle is rotated in a forward or in a backward direction.) Each interval of the first mile—and preferably of the second mile also—as represented by separate money drops, should be tested, and the initial interval should be tested several additional times. It may be noted that errors on successive intervals may be in opposite directions, and that errors on the several tests of the initial interval may be found to be inconsistent among themselves and with errors on subsequent intervals. Errors in terms of spindle revolutions are computed by comparing the actual number of revolutions for a given mileage interval with the nominal number of revolutions for that interval. The nominal equivalent of one revolution in terms of feet of vehicle travel is arrived at by dividing 5280 by the nominal number of revolutions per mile.

In the long-haul test the flag may be in either the "Hired" or the "Time Not Recording" position, and the speed of operation should be increased at least to one corresponding to the maximum anticipated operating speed of the taxicab—not less than 40 miles per hour. It will be desirable that the operating speed of the taximeter in this test be several times the value just stated; such a speed will not be harmful to the taximeter mechanism, and has the advantage that it may disclose some conditions such as loose or worn parts which would not be disclosed by a test at slow speed and which will eventually manifest themselves in the course of service operation. In the long-haul test the taximeter should be operated continuously for an interval of not less than 5 miles and preferably for a 10-mile interval. Throughout the test the taximeter should be kept under observation so that any sticking of the money drops, any failure of money drops to occur in the proper sequence, any incorrect alinement of figures, or any other abnormal condition may be discovered; conditions such as these are, of course, proper cause for rejection.

Under certain conditions there may be some interference between the time mechanism and the mileage mechanism, resulting in over-registration of the taximeter when operated with the flag in the "Hired" position. A final "interference" test should therefore be made to determine if this interference exists; this test consists of determining the taximeter performance when the taximeter is in the "Hired" condition and then comparing this with the performance, as previously determined, when the taximeter was in the "Time Not Recording" condition.

When the interference just mentioned does occur, it is most pronounced at cab speeds just slightly in excess of the "speed of rate agreement", which may be defined as the speed at which basic mileage and waiting-time rates correspond—that is, the speed at which the basic rate of mileage revenue per unit of time equals the basic waiting-time rate. By "basic" rate is meant the rate for other than the initial interval. To arrive at the "speed of rate agreement" for a particular taximeter, first determine the money value of 1 minute of waiting time, second determine the mileage corresponding to this 1-minute waiting-time value, and finally multiply this mileage by 60 to get the required speed in miles per hour. For example: Assume a taximeter having a basic waiting-time rate of 10 cents per 2 minutes and a basic mileage rate of 10 cents per $\frac{1}{3}$ mile. The money value per minute of waiting time is 10 cents divided by 2, or 5 cents. The mileage corresponding to 5 cents is $\frac{1}{3}$ mile divided by 2, or $\frac{1}{6}$ mile. Multiplying $\frac{1}{6}$ by 60 the result is $\frac{60}{6}$, which equals 10; ten miles per hour is therefore the "speed of rate agreement" on this particular taximeter. In any particular community only a limited number of rates—perhaps only one—will be in effect, so the computation outlined need be made only a few times at most.

The interference test is made by throwing the taximeter flag from the "vacant" to the "hired" position, and immediately thereafter operating the taximeter for a 1-mile interval at a speed corresponding to a cab speed of 2 or 3 miles per hour greater than the "speed of rate agreement". The performance of the taximeter on this test should be in substantial agreement with that previously observed for the same mileage interval when the flag was in the "Time Not Recording" position.

The accuracy criterion for the bench test is the nominal number of spindle revolutions per indicated mile. It should be remembered that one revolution of the spindle corresponds to many revolutions of the driving wheels of a taxicab. Thus an error of even a fractional part of a spindle revolution may represent a cab travel of a very considerable distance. Gear boxes may or may not be attached during the bench test; the reduction which they introduce may safely be computed.

If a taximeter is designed to issue a statement or receipt on which the passenger charges are automatically printed, the accuracy and legibility of the printed statement are equally as important as the accuracy and legibility of the indications on the taximeter face. The official should critically examine all of the slips issued by the taximeter in the course of the test, requiring legibility and agreement between printed statements and taximeter indications in all cases. (In a taximeter of this design, the totalizing counters ordinarily provided may be replaced by means for automatically printing a summary record of taximeter operations on a tape retained within the housing. The attitude of the official toward this record should be the same as toward the totalizing counters, as discussed below.)

The totalizing counters of a taximeter are essential parts of the registering elements, and are utilized by cab companies in auditing the accounts of the drivers and compiling records of cab operation. These counters do not, however, have any direct relation to the fares paid by passengers, and so are of secondary weights and measures importance. The operation of the totalizing counters should be checked against the performance of the taximeter during test, by comparing their indications at the beginning and at the end of the test for proper registration of all operations which have been performed; also, intermediate checks should be made from time to time. Rejection of a taximeter solely because the totalizing counters are inaccurate or inoperative is of doubtful legality under the National Conference code, but any inaccuracies found in these elements should certainly be reported to the proper parties—taximeter company or taxicab company, as the case may be.

Taximeters can be constructed to register mileage fares at either one of two rates, to meet the situation where a higher rate may be authorized for carrying more than a specified number of passengers. Legal provision for two-tariff taximeters is not recommended, because of the probability that overcharges will be made, inadvertently or otherwise, by exacting fares at the higher rate from passengers who should rightfully be carried at the lower rate. A two-tariff taximeter must be given a complete mileage test for each tariff, because different sets of gears are used for the two rates and each set must be checked.

Testing Procedure: Road Mileage Test.—When a taximeter head which has already been approved after a bench test is installed on a taxicab, the purpose of the road test is to check the accuracy of the taximeter in combination with all of the other elements of the complete installation under conditions of actual road travel. Normally this test will not involve stopping of the vehicle at each money drop, but will comprise two 1-mile or 2-mile runs, observations being made for the total interval in each case. However, during each run the taximeter should be kept under close observation to detect any effects of road shocks on the mechanism or any abnormality of operation of the indicating elements.

With the cab accurately positioned at one end of the course, the flag should be thrown to the "Time Not Recording" position; this is to insure that the clock mechanism will not affect the registration should it become necessary to stop the cab during the run. The cab should then be driven over the course, being operated at maximum legal speed and traveling as nearly as may be in a straight line. The cab should be stopped at the instant when the money drop corresponding to the 1-mile (or 2-mile) interval occurs. The distance by which the cab is short of or beyond the corresponding course marker is the error, which can be determined, if necessary, by measuring with a steel tape. If the drop occurs before the marker is reached, the error is in the direction of over-registration, and vice versa.

If the road test is the only test made, this should be expanded to include as much as possible of the bench test as previously described, including the time test and, of course, complete inspection. For this combined test, at least the following procedure should be followed: (1) With the taximeter in the "Time Not Recording" condition, test each individual interval for the first two miles, the cab being driven at slow speed so that it can be stopped, if required, at the instant at which a drop occurs, for accurate determination of the error. Repeat the test on the initial interval at least twice. (2) With the taximeter in the "Hired" condition, retest the first 1-mile interval, the cab being driven at a speed of 2 or 3 miles per hour greater than the "speed of rate agreement" [9]; the error should be in substantial agreement with the error for this same interval when the flag was in the "Time Not Recording" position. During this test the cab should not be stopped and its speed should not at any time drop below that specified for this test; should a stop or "slow down" be unavoidable, the test should be rerun. (3) With the taximeter in the "Time Not Recording" condition, test the first 2-mile interval—or, as an alternative, make two tests of the first 1-mile interval—, the cab being driven at the maximum legal speed. Record observations for the total interval only, but keep the taximeter under close observation to check for sticking of money drops, improper sequence of money drops, poor alinement of figures, and any other abnormal condition, and particularly for premature money drops which might occur as a result of road shocks.

If there is any question about compliance with tolerances, the official should not estimate distances from the moving cab. No rougher approximation than the pacing of the distance between the points in question should be resorted to. As each money drop defining an interval under test occurs, the cab should be stopped, the cab driver being on the alert to make a quick stop upon signal by the official. The official should be sufficiently familiar with the location of the markers on the testing course so that when intervals are merely being checked, as distinguished from being tested, he can mentally mark the spot where a drop occurs and determine at once if it is advisable to stop the cab and determine the actual error by measuring the distance from that spot to the proper marker.

Testing Procedure: Wheel Mileage Test.—It has already been pointed out that a wheel test is an expedient for testing a complete taximeter installation when the preferred road test can not be made. This test involves computations of cab travel based upon number of wheel revolutions and mean effective circumference of the tires with which the cab is equipped. In any given area the

[9] See p. 51.

number of varieties of tires used on taxicabs will probably not be very large, and it will be convenient for the official to compile a table of the makes, kinds, and sizes of tires commonly used, showing for each its revolutions per mile and fraction of a mile.

Except for the added step of converting data observed in terms of wheel revolutions into terms of cab travel, the procedure for the wheel test is essentially the same as for the road test. In the wheel test the count of wheel revolutions is compared with the appropriate value from the table discussed in the preceding paragraph, just as in the road test the position of the cab is compared with the markers of the testing course.

Testing Procedure: Sealing.—The term "sealing" is here used in two senses—sealing to provide security, and sealing to indicate official approval. In the first sense, a taximeter head found correct on a bench test should at once be so sealed with lead-and-wire seals that adjustments or changes which would affect its performance can not be made without mutilation of the seals. When a complete installation on a taxicab is approved, each of the several connections from taximeter head to transmission (or wheel) should be similarly sealed.

To indicate to the riding public the official approval of a taximeter installation, a conspicuous seal of approval should be applied to the face of the taximeter head. The shape, size, and location of this seal should be such that no required legend or indication of the taximeter is obscured. These seals should be dated and should be marked to show the size of tires for which the installation has been approved.

When a taximeter head is approved on a bench test it is advisable that it be tagged to show this fact, the tag being attached by a lead-and-wire seal. This tag will remain on the taximeter until it is replaced by a seal of approval as the final act of approving a complete installation.

Testing Outlines

(For tests of taximeters by weights and measures officials.)

Case I. Time test:

1. Throw flag from "Vacant" to "Hired" position and simultaneously start watch or timer.

2. Note time, to nearest second, at which second money drop occurs. Record time and compute error for first time interval.
3. Note time, to nearest second, at which third money drop occurs. Record time and compute interval and error for second time interval.
4. Proceed as in step 3 for the third, fourth, and fifth time intervals. If errors are seriously inconsistent or are close to the tolerance, continue as in step 3 for each time interval through the tenth; otherwise go at once to step 5.
5. At conclusion of the separate-interval portion of the test—steps 1 through 4—allow taximeter operation to continue for approximately 1 hour. Note time at which next money drop occurs. Compute total elapsed time and total error for all time intervals from the second to the final one, inclusive (the initial time interval is excluded), and divide this total error by the number of intervals involved to arrive at the average error.

Case II. Bench test, short-haul portion:

1. Throw flag from "Vacant" to "Time Not Recording" position.
2. Rotate taximeter spindle slowly until second money drop occurs. Stop rotation of spindle at the instant the drop occurs, note and record exact number of revolutions, to the nearest eighth-revolution at least, required to cause drop, and compute the error. This is a test of the initial mileage interval.
3. Resume rotation of the spindle at a slow speed and continue until the instant of the third money drop. Note and record as before the exact number of revolutions from the start of the test; this will be the number of revolutions corresponding to the first two mileage intervals, and by comparison with the number for the initial interval, the number corresponding to the second interval may be derived and the error for the second interval can then be computed.
4. Continue as in step 3 to determine the error for each separate mileage interval for at least the first mile and preferably for the first 2 miles.

5. Repeat steps 1 and 2 at least twice.
6. From time to time observe indications of totalizing counters to see that these register accurately.

Case III. Bench test, long-haul portion:

1. Throw flag from the "Vacant" position to either the "Hired" or the "Time Not Recording" position.
2. Rotate taximeter spindle at relatively fast speed for at least a 5-mile interval and preferably for a 10-mile interval. Slow down the rotation just before the occurrence of the drop which defines the interval under test, stopping the rotation at the instant this drop occurs. Keep taximeter face under observation throughout this step to check on correct functioning of indicating parts. Record the number of revolutions and compute the error for the total interval as in step 2 of case II.
3. Throw flag from "Vacant" to "Hired" position.
4. Without delay, rotate taximeter spindle for a 1-mile interval at a speed corresponding to a cab speed of 2 or 3 miles per hour greater than the "speed of rate agreement". Proceed as in step 2 to determine the error on this total interval. Compare this error with the error for the first 1-mile interval as determined under case II; they should be in substantial agreement.
5. Check totalizing counters.
6. If taximeter head is approved, affix appropriate security seals to taximeter housing and attach approval tag.

Case IV. Road mileage test, the taximeter head having previously been approved on a bench mileage test:

1. Position taxicab accurately at one end of testing course and throw flag from "Vacant" to "Time Not Recording" position.
2. Drive cab over testing course at maximum legal speed for 2-mile run. (If the course is shorter than 2 miles, the run should be for the full length of the course.) Slow down just before the occurrence of the drop which defines the

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interval under test, stopping at the instant this drop occurs. Keep taximeter face under observation throughout the run to check on correct functioning of indicating parts. From the position of the cab on the course, determine the error on the total interval under test.

3. Repeat step 2.
4. If installation is approved, affix appropriate security seals to connections and affix approval seal to taximeter face.

Case V. Road mileage test, when the taximeter head has not previously been given a bench mileage test:

1. Position taxicab accurately at one end of the testing course and throw flag from "Vacant" to "Time Not Recording" position.
2. Drive cab at slow speed, stopping at the instant the second money drop occurs. From the position of the cab on the course, determine the error on the initial mileage interval.
3. Resume cab travel at slow speed, stopping at the instant of the third money drop. From the position of the cab on the course, determine the error for the first two mileage intervals and, by computation, determine the error for the second mileage interval.
4. Continue as in step 3 to determine the error for each separate mileage interval for at least the first mile and, preferably, for the first two miles if the course is that long.
5. Repeat at least twice steps 1 and 2, except that the cab may be positioned accurately at any convenient intermediate marker of the course at the beginning of the second or subsequent repeat tests.
6. Position the cab accurately at one end of the course, throw the flag from the "Vacant" to the "Hired" position, and drive the cab at a speed of 2 or 3 miles per hour greater than the "speed of rate agreement", stopping at the instant of the money drop defining the first 1-mile interval. This test must be run without intermediate stops and the speed should not drop below that specified. Determine the

error as before and compare this with the error for the initial 1-mile interval as determined in step 4; they should be in substantial agreement.

7. Position the cab accurately at the end of the course and throw the flag from the "Vacant" to the "Time Not Recording" position.
8. Drive the cab at maximum legal speed, slowing down just before the occurrence of the drop which defines the first 2-mile interval and stopping the cab at the instant this drop occurs. (As an alternative to this 2-mile run, two 1-mile runs may, if necessary, be made.) Keep the taximeter face under observation throughout this step to check on correct functioning of indicating parts. From the position of the cab on the course, determine the error on the total interval. (Intermediate intervals can be roughly checked during this step by noting the positions on the course where intermediate drops occur; if erratic performance is indicated, further tests should be made, as dictated by the circumstances.)
9. From time to time observe indications of totalizing counters to see that these register correctly.
10. If installation is approved, affix appropriate security seals to taximeter housing and to all connections and affix approval seal to taximeter face.

Case VI. Wheel mileage test:

1. The steps to be followed parallel those outlined for case IV and case V. Rotation of the wheel or wheels should be at speeds corresponding to the cab speds specified for road tests, except that in the operations corresponding to step 2 of case IV and step 8 of case V, the speed of wheel rotation may be greatly increased without danger to the taximeter mechanism.

Supervision Over Use.—If full protection to the riding public is to be provided, a system of strict inspection of taximeter installations should be maintained. The date on the seal of approval should be checked, so that taximeters found overdue for retest may be called in or other appropriate action taken. The size of tires in use should be checked against the size shown on the seal, so that any substitution of smaller tires may be discovered and appropriate action taken. Security seals should be checked to disclose whether or not these have been tampered with.

References

The following references are to papers and discussions on the general subject of taximeters, appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M41, Twelfth Conference Report, 1919, pages 85–87.
M59, Seventeenth Conference Report, 1924, pages 117–125.
M70, Eighteenth Conference Report, 1925, pages 78–97.
M74, Nineteenth Conference Report, 1926, pages 31–37.
M80, Twentieth Conference Report, 1927, pages 80–84.
M87, Twenty-first Conference Report, 1928, pages 21–40.

Chapter 7.—ODOMETERS

Description.—An odometer is an instrument designed to be mounted on a vehicle to register automatically the distance traversed by the vehicle. It is a simple gear device, with indicating means reading in terms of miles and tenth-miles, and is actuated by direct or cable connection to an appropriate moving part of the vehicle. Thus, an odometer may be mounted at the hub of one of the front wheels of the vehicle; this variety is known as a "hub odometer". Again, the indicating elements may be mounted inside the vehicle, being connected by means of a driving cable with the drive shaft or "transmission" of the vehicle. The mileage-recording portion of an automobile "speedometer", cable-driven from the drive shaft, is a form of odometer. In all of these cases, the indicating elements are customarily in the form of a straight-reading counter, having a series of indicating wheels or drums carrying figures on their peripheries.

An odometer is essentially a revolution counter. The accuracy of its mileage registration depends upon the suitability of the gears between the indicating elements and the point of connection to the moving element of the vehicle, in relation to the effective circumference of the vehicle tires. In the case of a hub odometer, only one tire is involved—the one on the wheel on which the odometer is installed. In the case of a transmission-driven odometer, the tires on the driving wheels of the vehicle are the ones involved.

Inspection.—When an official is called upon to examine an odometer, he is usually confronted with a completed installation. In any event, the bench testing of an odometer head is not recommended, and the test should be made on the complete installation. Inspection of the installation should precede testing, and the inspection should be made for compliance with the applicable requirements of general specifications G–S.1., G–S.2., G–S.3., and G–S.4.1., and general regulations G–R.2. and G–R.3., and with the applicable requirements of each specification of the code for odometers.

Testing Apparatus.—Since a separate bench test of an odometer serves no particularly useful purpose and is not recommended, no shop testing apparatus need be provided. The preferred test of an odometer installation is a road test, for which a measured testing course is required. Such a course should be laid out as previously described in Chapter 6 under testing apparatus for taximeters,[10] except that the only subdivisions of the mile which will be needed are perhaps two tenth-mile points—for example, 0.2 mile and 0.5 mile. Of course, there is no objection to tenth-mile markers throughout the entire length of the course. The course should be 2 miles in length if at all possible, and in no case less than 1 mile.

If a measured course can not be provided, the alternative is apparatus for a wheel test, which can be identical with that described for taximeter testing in Chapter 6.[11]

Testing Procedure.—The road or wheel test of an odometer installation should follow the general principles of the corresponding test of a taximeter installation, but the odometer test is simpler because of the greater simplicity of the instrument. The test should be made when the vehicle is carrying an average load and with its tires inflated to normal pressure.

For a road test, the vehicle should be positioned accurately at one end of the course. It is then necessary to establish a precise odometer reading as the "zero" or starting reading for the test. This does not mean that each indicating wheel must stand at zero, although if the odometer is of the design that permits a ready resetting to zero, and if the odometer is frequently reset to zero in the course of normal service operation, this should be done. Ordinarily, however, an odometer is not designed to be reset by the user to zero indication, and so the procedure outlined in the next paragraph will normally be followed by the official.

An experienced observer can do reasonably well in estimating a reading to hundredths on a straight-reading counter which reads to tenth-miles, but it is not recommended that this be done when testing an odometer; 0.01 mile is almost 53 feet and is 1 percent of a mile, and this value is relatively large as compared with the tolerances to be applied. It is recommended, therefore, that when the vehicle is spotted for the start of the test, a wheel

[10] See p. 44.

[11] See pp. 44–45.

be jacked up and rotated in a forward direction until a precise indication of the next tenth-mile is established on the odometer; the reading of the odometer is then the "zero" reading for the first test run. This precise indication can be obtained by accurately centering a tenth-mile figure in its aperture or by bringing the extreme top of a figure into coincidence with the upper edge of the aperture or by similarly alining the extreme bottom of a figure with the lower edge of the aperture. An alternative procedure, if no jack is available, is to advance the vehicle on the course until the desired precise indication of the odometer is obtained, measure the distance between the vehicle and the end course marker, and correct for this offset at the time each observation is made during the test run.

A known zero condition having been established by one of the methods described, the vehicle is then driven over the course until the odometer gives a precise indication of a certain number of tenth-miles more than the "zero" indication. If the course has been subdivided throughout by tenth-miles, it is optional with the official at what point he will make his first fractional-mile observation. If only the first 0.2-mile and 0.5-mile points have been marked, as has been suggested as minimal course subdivision, then observations will be made at these values. Upon the assumption that tests are to be made on the 0.2-mile and 0.5-mile intervals, the vehicle will first be stopped when the odometer indication has been increased by precisely 0.2 mile from its "zero" indication. By comparing the positions of the vehicle and the 0.2-mile marker, making due allowance for any offset which may have existed at the starting end, the error of the odometer for the 0.2-mile interval is arrived at. If the added 0.2-mile indication is given by the odometer before the corresponding actual distance has been traversed by the vehicle, the error is in the direction of over-registration, and vice versa. It is stated above that the vehicle "will first be stopped" when a certain odometer indication is given. Obviously, in the case of a hub odometer, which can only be read by an observer from a position on the ground while the vehicle is not in motion, several actual "stops" of the vehicle may be required before the specified odometer indication is accomplished, these stops being made to enable the official to read the odometer as the desired indication is approached and to direct the vehicle driver how much farther to advance the vehicle along the course. Care should be exercised to avoid overrunning the desired indication; should this occur, the test should be repeated.

On the assumption that the next interval to be tested is to be the 0.5-mile interval, the vehicle will next be advanced along the course until the odometer indicates precisely 0.5 mile more than its "zero" indication, and the error will be determined as before. The next determination will be made when the odometer indication is precisely 2 miles more than its "zero" indication, if the testing course is 2 miles long, or 1 mile more than its "zero" indication if the course is only 1 mile in length. The error will be determined as before. In all three determinations involved in this first test run, the intervals under test are the total intervals from the start of the run, that is, in the example given, 0.2 mile, 0.5 mile, and 2 miles (or 1 mile).

Finally, another 2-mile test run will be made (or a 1-mile run if the course is only 1 mile long), omitting fractional-mile observations; the same precautions are to be observed as at the start of the first test run, with respect to a precise "zero" indication.

For a wheel test of an odometer assembly, the official will need to know the number of revolutions per mile of the actuating vehicle wheel or wheels, based upon the effective tire circumference. This can be determined in each individual instance at the time of test. However, if any considerable amount of odometer testing is to be done, a table should be prepared in advance for the varieties and sizes of tires commonly employed. Observations should be made, as in the road test, on at least two fractional-mile intervals and on at least one longer interval, with a repeat observation on the long interval. It should be practicable in a wheel test to increase this long interval to several miles, and a 5-mile interval is recommended. With respect to the starting or "zero" indication of the odometer, the same precautions should be observed as in the road test. Errors will be computed upon the basis of the difference between the actual number and the standard number of wheel revolutions required for the intervals under test; if the actual number of revolutions is less than the standard number, the error of the odometer for the interval in question is in the direction of over-registration, and vice versa.

If the odometer installation is found to be correct, security seals should be applied to the odometer housing and at all connections between the odometer and the driving wheel or drive shaft, so that changes which might affect the performance can not be made without mutilation of the seals. If the odometer head is cable-driven and is mounted inside the vehicle, the customary seal of approval should be affixed thereto. In the case of a hub odometer it will be impracticable to affix a special seal of approval, and the lead-and-wire security seal should be construed as the seal of approval.

Testing Outlines

(For tests of odometer installations by weights and measures officials.)

Case I. Road test:

1. Position vehicle accurately at one end of testing course.
2. Jack up actuating wheel and rotate it in a forward direction until odometer gives a precise indication of any tenth-mile value. Record odometer reading as the "zero" reading for the test run. (An alternative procedure which avoids jacking up a wheel, is to advance the vehicle along the course until a precise odometer indication is obtained, measure the offset of the vehicle from the end of the course, and use this zero-position correction in subsequent determinations.) If the odometer has a zero set-back mechanism, use this to "clear" the indication to zero reading, instead of following the procedure first specified; in this event, subsequent "precise" indications must duplicate the zero position of the tenth-mile figure in its aperture.
3. Drive vehicle over course until odometer indicates precisely two or three tenth-miles more than the "zero" reading, and determine error for this interval from the position of the vehicle on the course.
4. Advance vehicle along course until odometer indicates precisely several tenth-miles more than

in step 3, and determine error for the total interval.

5. Advance vehicle along course until odometer indicates precisely 2 miles (on a 2-mile course) or 1 mile (on a 1-mile course) more than the "zero" reading, and determine the error on the total interval.
6. Repeat steps 1, 2, and 5.
7. If installation is approved, affix appropriate seals.

Case II. Wheel test:

1. Rotate actuating wheel or wheels in a forward direction until odometer gives a precise indication of any tenth-mile value. Record odometer reading as the "zero" reading for the test run. If the odometer has a zero set-back mechanism, use this to "clear" the indication to zero reading, instead of setting up a "zero" reading as prescribed; in this event, subsequent "precise" indications must duplicate the zero position of the tenth-mile figure in its aperture.
2. Rotate actuating wheel or wheels until odometer indicates precisely two or three tenth-miles more than the "zero" reading, and compute error for this interval from the counted number of revolutions compared with the standard number of revolutions for this interval.
3. Continue rotation of actuating wheel or wheels until odometer indicates precisely several tenth-miles more than in step 2, and compute error for the total interval.
4. Continue rotation of actuating wheel or wheels until odometer indicates precisely 5 miles more than the "zero" reading, and compute error for the total interval.
5. Test, as in step 4, another 5-mile interval.
6. If installation is approved, affix appropriate seals.

Chapter 8.—LIQUID MEASURES

Description.—The code for liquid measures defines a liquid measure as "a rigid measure of capacity, designed for general and repeated use in the measurement of liquids", but limits the application of the code to those liquid measures for which separate codes have not been set up. Thus, graduates, milk bottles, and lubricating-oil bottles, although they are "liquid measures" under the basic definition quoted above, are excluded from the purview of the code for liquid measures because for each of these special classes there is a separate code. Measure-containers, which are frequently used for the measurement of liquids, are not "liquid measures" by definition, because they are not designed "for repeated use" but are intended to be used once only; measure-containers, too, are covered by a separate code. These distinctions will be observed in the discussions which follow.

The use of liquid measures in retail trade has suffered a sharp decline in recent years as a result of the tremendous increase in the packaging of commodities. Whereas every store retailing vinegar, molasses, syrups, turpentine, linseed oil, bulk oysters, bulk milk, and similar commodities could once be expected to have in use a series of liquid measures, such measures have now largely been eliminated from use. Prepackaged commodities have displaced commodities dispensed from bulk supply, and the measures which once were so necessary are no longer needed. Liquid measures are still widely used, however, in the sale of petroleum products, particularly lubricating oil for use in the crankcases of automotive vehicles.

The simple type of commercial liquid measure is one having a pouring lip extending all or part way around the top edge. For use at filling stations a popular modification of the simple design is one having a discharge spout, hinged or flexible, leading from the bottom of the measure with some form of valve at its inlet end, designed to facilitate discharge into a crank-case fill-pipe. Measures are required to be of a single capacity only—that is, subdivided measures are not allowed—and the capacity is defined by the top edge of the measure or by some fixed element near the top edge. Practically all measures now encountered are made of metal. The ice cream brick molds, such as are referred to in note N.1 of the liquid-measure code, are special rectangular measures used in the ice cream industry to determine amounts of the frozen product which are later subdivided mechanically into smaller units. Ice cream "cans" are cylinders used in wholesale sales.

Inspection.—Liquid measures should be individually inspected, and inspection should, in general precede testing. The requirements of general specifications G–S.1., G–S.2., and G–S.6., and of general regulations G–R.2. and G–R.3., are applicable to liquid measures. Under G–R.2., measures should be required to be kept suitably clean, and measures which are dented or otherwise damaged in a way to affect their accuracy or which have defective valves or valve parts should be rejected. Measures should also be inspected for compliance with the applicable specification requirements of the code for liquid measures; compliance with specification S.3.3. can be determined as a part of the testing procedure.

Testing Apparatus.—For general field use the official should have, as a minimum, a set of metal liquid-measure standards from 4 fluid ounces to 1 quart, a 1-gallon and a 5-gallon "field standard", and a cylindrical glass graduate having a capacity of 1 fluid ounce and subdivided to ¼ fluid dram. It is desirable that the set first mentioned be increased by the addition of measures having capacities of 2 fluid ounces, ½ gallon, and one gallon, that a 3-gallon, and preferably a 2-gallon and a 4-gallon field standard be added, and that either a 120-minim cylindrical glass graduate subdivided to 5 minims or a similar 10-milliliter graduate subdivided to 0.2 milliter be added. All of this apparatus should be calibrated "to deliver" at 68° F. Not all of this apparatus will be needed for the testing of commercial liquid measures, but the items listed will be required if all types of volumetric testing are to be carried on in the field; specifically, the 2-fluid-ounce measure and the second glass graduate may be omitted if graduates in pharmacies are not to be tested in the field.

The measures of the liquid-measure set should be conical in shape, having small-diameter tops, and the tops should be ground so that a "slicker plate" may be used when it is necessary to make precise determinations. (The slicker plate is a circular piece of plate glass with one side ground, having a diameter slightly larger than the top diameter of the largest standard with which it is to be used. The slicker plate is slid across the top of the filled measure to cut off the water precisely even with the top edge of the measure. With the slicker plate held firmly in position, the standard can then be inverted and delivery of the water can be started by carefully sliding the plate a short distance to one side.) Cylindrical liquid-measure standards from 1 quart down to 2 fluid ounces are available in nested sets; they have relatively small diameters and are designed for use with a slicker plate, and they may be substituted for conical standards of equivalent capacities.

By "field standards" is meant a measure of particularly rigid construction having a tall, small-diameter, cylindrical neck equipped with a gage glass or a window and a graduated scale. The height of the liquid surface is read directly from the scale. The proper fill point for the nominal capacity of the standard is defined by the "zero" graduation on the scale; the amount by which the liquid in the standard is less than or more than the nominal capacity of the standard can be read directly from the scale, within the limits of the graduated portion of the neck. The graduated scale usually reads by 1-cubic-inch subdivisions to 20 or 30 cubic inches above and below the "zero" graduation.

Testing Procedure.—There is a measurable difference between the amount of liquid which a measure will contain and the amount which it will deliver. When the liquid is water, which is ordinarily the testing medium used in the testing of commercial liquid measures, this difference is not large in relation to the tolerance and so may be disregarded.

To avoid any contamination of the standard and for maximum convenience in the testing procedure, the standard is normally used "to deliver", the measured amount of water being poured from the standard into the measure under test. The inside of the measure should be reasonably clean in any event before its test is undertaken. The standard, the measure, and the water used in the test should be at approximately the same temperature, although this factor is not critical in the testing of commercial measures; the change in volume of the water as a result of any temperature changes which will occur in the course of ordinary testing operations, will not be significant. Sometimes a considerable amount of air is entrapped in tap water, and this may separate rapidly and collect as bubbles of air on the sides of a standard or measure; this condition might be serious enough to be significant in testing even commercial measures, and so should be guarded against. If necessary, the standard should be filled from a supply of water from which the entrapped air has had ample opportunity to escape.

Liquid measures should be individually tested. The testing procedure is a simple one, and consists of establishing a known volume of water by use of the standard and transferring this to the measure under test, finding the error on the measure by determining how much more water is required to fill it (when the measure is too large) or how much of the measured amount remains after the measure has been filled (when the measure is too small). The standard should be of the same nominal capacity as the measure being tested, although it is acceptable practice to use twice a standard having a nominal capacity of one-half that of the measure under test, or to use in combination two or more standards of different capacities to build up to the capacity of the measure.

It will be well always to use the slicker plate with a standard constructed for such use. The standard is filled with water to the point where the water is rounded up over the top. The slicker plate, with the ground side downward, is then pushed from one side across the top edge of the standard until the plate entirely covers the top of the standard. During this operation the slicker plate is held gently but firmly in contact with the top edge of the standard. The excess of water is thus cut off and the standard should then have been accurately filled with water. There should be no air bubble beneath the slicker plate; if one is present the standard is not correctly filled. In this case the plate should be slid back far enough to expose the bubble, a small additional amount of water should be added to the standard, and the plate should again be advanced across the top of the standard until this is covered.

Any water clinging to an exposed surface of the slicker plate or to the outside of the standard should then be brushed or wiped away. With the fingers of one hand, firm pressure is then exerted on the top surface of the slicker plate to keep it in position, and the standard is lifted with the other hand and partially inverted preparatory to pouring its contents into the measure under test; the slicker plate prevents any loss of water. Next, with the standard tipped approximately 90° from a standing position and with its mouth over the mouth of the measure being tested, the slicker plate is carefully slid back a short distance to expose a small opening at the mouth of the standard through which some of the water is allowed to flow into the measure; after the flow has started the slicker plate is gradually withdrawn to enlarge the opening and increase the rate of flow, being kept, however, continuously in contact with as much of the top edge as it covers. When it is finally completely removed, the slicker plate should be slid off—not lifted off—in order to scrape from it and retain in the standard any water that may have been clinging to the under side of the plate. The entire discharge can be made from the standard as one operation, as described, or when about half of the water has been discharged the standard may be righted, the slicker plate slid off, and the discharge completed as an ordinary pouring operation.

During this procedure the measure under test should be kept under observation. If it appears that the measured volume of water is going to be more than enough to fill the measure to the proper point, it will be advisable to transfer the water remaining in the standard to the graduate or to a smaller standard so that the measure may be carefully and slowly filled to just the proper point; the water remaining then represents the error of the measure—the amount by which it is too small. If the measure accepts all of the water from the standard and still is not filled to the proper point, the graduate is filled to its capacity graduation and from it water is added to the measure until it is properly filled; the difference between the amount of water remaining in the graduate and the amount it originally contained represents the error of the measure—the amount by which it is too large. When the measure under test is being filled, the effort should be to fill it as precisely as practicable to the exact point called for by the design of the measure. If any of the measured volume of water is accidentally spilled during a test, the test should be repeated.

When the standard is being emptied it should be completely drained. A uniform 10-second drainage period is recommended, to be consistently observed in all testing operations. When timing the drainage period, the timing should begin when the main flow has ceased. A convenient way of timing the 10-second drainage interval is by counting. The expressions "thousand and one", "thousand and two", etc., when pronounced, aloud or mentally, at a normal conversational speed, require very close to one second; by repeating these expressions consecutively through "thousand and ten", the desired time interval is measured. This method, or the use of a watch, is recommended; if one attempts merely to "guess" a 10-second interval, the probability is that the interval will be underestimated and that successive "guesses" will be anything but uniform.

The curved upper surface of the liquid in a tube or graduate is known as the "meniscus". When making a reading or setting on a graduate, the lowest portion of the meniscus, which appears as a dark line as viewed through the wall of the graduate, is the proper index, and this should be viewed at eye level, with the graduate held in a vertical position.

A pipette is a convenient accessory for use when more than the desired amount of water has inadvertently been placed in a measure and some must be withdrawn. A small pipette equipped with a rubber bulb to create the necessary suction (like an enlarged medicine dropper) is recommended.

When the standard used is a "field standard", the testing procedure is similar to that outlined above except as to the filling of the standard. For an amount corresponding to the nominal capacity of the standard, the water is brought to the level of the "zero" graduation on the graduated scale, the lowest portion of the meniscus being in coincidence with the graduation. When a setting is being made it is essential that the standard be supported on a level surface or be suspended in a plumb position from its bail.

It is not practicable to test ice cream molds volumetrically. The bottoms may be removable, to facilitate removal of the brick from the mold, and this type is not water tight. Moreover, since a mold ordinarily is shaped like a rectangular tray, the area of the top surface is so great that a precise volumetric determination could not be made in any event. Accordingly, these molds are best tested by computing their capacities from their linear dimensions. The mean inside length, breadth, and depth, in inches, are multiplied together to arrive at the capacity in cubic inches. This product can then be compared with the nominal capacity in cubic inches, derived by using the equivalent, 1 liquid quart equals 57.75 cubic inches.

The foregoing discussion is confined to the field testing of commercial liquid measures. For instructions on the calibration of large-capacity "provers", to be used as standards, reference should be made to the text on page 123, to the forthcoming National Bureau of Standards Circular referred to on page 5, and to the ASME-API Petroleum P. D. Meter Code (API Code No. 1101) cited in the list of references at the end of chapter 13.

Testing Outlines

(For tests of liquid measures by weights and measures officials.)

Case I. When the nominal capacities of standard and measure are the same:

1. Fill standard with water to proper point.
2. Remove any water adhering to outside of standard.
3. Pour measured water into measure being tested, until measure is filled to proper point or all measured water is transferred. In latter case drain standard for 10 seconds.
4. If measure is too small and will not accept all of the measured water, transfer remaining water to the graduate, draining the standard for 10 seconds. The water in the graduate represents the error "in deficiency", of the measure.
5. If the measure is not properly filled after all of the measured water has been transferred to it, fill the graduate to its capacity graduation and pour water from it into the measure until the measure is properly filled. Read the amount of water remaining in the graduate; the differ-

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ence between this amount and the capacity of the graduate represents the error "in excess", of the measure.

Case II. When the capacity of the standard is a submultiple if the capacity of the measure:

1. Fill standard with water to proper point.
2. Remove any water adhering to outside of standard.
3. Pour measured water into measure, draining standard for 10 seconds.
4. If the nominal capacity of the measure is twice that of the standard, follow steps 1 through 5 of case 1.
5. If the nominal capacity of the measure is more than twice that of the standard repeat steps 1, 2, and 3 as often as required, then follow steps 1 through 5 of case 1.

References

The following references are to papers and discussions on the general subject of liquid measures, appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M11, Eighth Conference Report, 1913, pages 181–200.
M129, Twenty-fourth Conference Report, 1931, pages 137–138.
M159, Twenty-seventh Conference Report, 1937, pages 103–107.

Chapter 9.—GRADUATES

Description.—The graduates which the weights and measures official tests are usually confined to those used in pharmacies in connection with the compounding of prescriptions and to those used in establishments selling perfumes from bulk supply. They are graduated liquid measures, made of glass, and are usually conical in shape, although cylindrical graduates will occasionally be encountered. The customary capacities of commercial graduates range from 1 fluid dram to 1 liquid quart in the customary system and from 5 milliliters (cubic centimeters) to 1 liter in the metric system. The range of capacities of the graduates found in the ordinary pharmacy will probably extend only from ½ or 1 fluid ounce to 16 fluid ounces or 1 liquid pint, in the customary system, and from 50 milliliters to 500 milliliters in the metric system. Some pharmacies may have only one or two metric graduates or even none at all.

The accepted rule for reading the level of the liquid in a graduate is to read to the bottom of the meniscus, that is, to the bottom of the curved upper surface of the liquid, which appears as a dark line as viewed through the wall of the graduate. When a reading is being made, the graduate should rest on a level surface or be held in a vertical position, and the meniscus should be at eye level. If the graduate is held in the hand when a reading is made, the observer should always check against possible tilting of the graduate by sighting through the graduate at eye level and verifying that the near and far portions of a particular graduation line are in coincidence, and that the graduation is horizontal from left to right. This sight may be taken across the ends of a graduation which extends only half way around a graduate; or if the graduation encircles the graduate, the entire graduation will have the appearance of a single straight line when the graduate is vertical and is viewed as described. This procedure should be followed by the official when reading both his own standard graduates and the graduates being tested.

Inspection.—Graduates should be individually inspected, and inspection should precede testing. Inspection should be made for compliance with the applicable requirements of general specifications G–S.1., G–S.4., and G–S.6., and general regulations G–R.2. and G–R.3., and with each applicable specification requirement of the code for graduates. The purpose of graduate specification S.3.1. is to insure proper sensitiveness, and a graduate failing to meet these requirements should be rejected. Under graduate specification S.3.2. a graduate with a badly broken base would be rejected. The requirements of graduate specifications S.4.1. and S.4.2. are particularly important; it should be noted that "pressed" or molded graduations are not acceptable under S.4.1.

Testing Apparatus.—It is believed that the use of metric units for medicinal prescriptions is increasing, and that in consequence of this the number of metric graduates or duplex-scale graduates in use in pharmacies is also increasing. Accordingly, volumetric standards should be provided in units of both the customary and metric systems.

For field use, sets of metal liquid standards, designed for use with slicker plates, and calibrated "to deliver", should be provided. These standards should have capacities of 1 pint, ½ pint, 1 gill (or 4 fluid ounces), and ½ gill (or 2 fluid ounces) in the customary system, and 500 milliliters (or cubic centimeters), 200 milliliters, 100 milliliters, and 50 milliliters in the metric system. In addition, two standard cylindrical graduates, graduated "to deliver", should be provided, one with a capacity of 2 fluid drams (or 120 minims) and subdivided to 5 minims, and the other with a capacity of 10 milliliters and subdivided to 0.2 milliliter. Supplementary equipment needed will be a pair of small inside calipers; a 6-inch steel scale subdivided to at least 1/16 inch, a 15-centimeter steel scale subdivided to at least 1 millimeter, or a single steel scale carrying both of the specified series of graduations; and a small "medicine dropper". The zero on each of the steel scales or on the combination scale should coincide with the end surface of the scale, and the scale should be not more than ½ inch in width.

For office testing, the use of burettes rather than standard graduates is recommended. A 125-minim burette subdivided to 1 minim and a 10-milliliter burette subdivided to 0.05 milliliter, will replace the two graduates specified for field use. Desirable additions are a 2-fluid-ounce burette subdivided to 5 minims and a 100-milliliter burette subdivided to 0.2 milliliter, these to be used in place of the ½-gill and 100-milliliter metal standards, respectively. A burette may be used satisfactorily several times in "building up" to the capacity of a graduate being tested, and so with the four burettes mentioned, practically all use of metal standards can be eliminated except for the testing of graduates of large capacity. (For maximum convenience, burettes of intermediate capacities may be added; for example, 4 fluid drams subdivided to 2 minims and 50 milliliters subdivided to 0.1 milliliter.)

Testing Procedure.—A commercial graduate is required to be marked to show whether it is graduated "to contain" or "to deliver" the indicated amounts when the temperature of the graduate is 20° C. (68° F.). The graduate "to deliver" is slightly larger than a corresponding graduate "to contain", the difference being caused by the amount of liquid which clings to the walls of the graduate as its contents is poured out.

Graduates are always tested with water. The graduate being tested, the testing apparatus, the water, and the atmosphere should be at approximately the same temperature while the test is being conducted. By specification, a commercial graduate is required to be so graduated as to be accurate when the temperature of the graduate is 20° C., or 68° F.; this temperature should be approximated for testing purposes.

The basic principle employed in the test of a graduate is the transfer to the graduate of known volumes of water, determined by use of standard measures or graduates (or burettes), to establish whether or not the graduate under test gives a reading agreeing (within tolerance) with each volume of water so transferred.

A graduate "to contain" must have its inside walls dry before a test is begun, and as successive measured amounts of water are added, care should be exercised to avoid wetting the inside surface of the graduate for more than a very small distance above the surface of the liquid.

Before the test is begun on a graduate "to deliver", the graduate should be filled to its capacity graduation and then emptied and allowed to drain for 10 seconds; the graduate, being returned to its normal upright position, then contains an amount of water representing the "clingage" to its walls, and is in proper condition to receive the measured increments from the standards. (The same objective could be attained by measuring the deliveries *from* the graduate under test, but this would make it necessary to give attention to the clingage factor for the standards used, and would materially complicate certain procedures.)

It may be repeated, for emphasis, that graduates being tested must always be in a vertical position when readings are made, the liquid surface must be at eye level, and the reading is to be made to the bottom of the meniscus; the same rules apply when reading standard graduates and burettes. Detailed instructions on the use of a slicker plate with metal measures will be found in chapter 8. Whenever a standard graduate or metal measure is emptied for the purpose of delivering a measured quantity of water, the customary 10-second drainage period should be observed.

In field testing, errors should be determined and tolerances applied in the same general way as has been described in chapter 8 in relation to liquid measures. Starting with a measured amount of water, this is transferred to the graduate under test. Coincidence should be established between the liquid surface and a graduation, and the error should be determined by measuring the amount of the measured water remaining or the amount required in excess of the original measured quantity. The smallest of the standard graduates will ordinarily be used to evaluate errors, the remaining water being measured if the graduate under test has an error in deficiency or additional water being added if the error is in excess. If the error to be evaluated is very small (2 or 3 minims, for example) it may be determined with the small dropper, upon the reasonable assumption that one drop of water approximates 1 minim or 0.06 milliliter; otherwise, however, actual measurements should be made in a standard graduate.

When burettes are used as standards, as can conveniently be done in office testing, the testing procedure is somewhat simplified. The burette to be used for a particular observation should be so chosen that errors can be read accurately directly on the burette; that is, the value of the subdivisions on the burette should not be several times the value of the tolerance to be applied. The burette may, if necessary, be filled and emptied more than once in bringing the liquid to the desired point in the graduate under test. The general procedure is to transfer water from the burette to the graduate under test until the water meniscus coincides with the graduation at which the observation is being made, the amount of water so transferred being read directly from the burette; the difference between the amount transferred and the nominal value of the graduation is the error of the graduate at that graduation. The meniscus of the liquid in the burette will be more sharply defined, and a more precise setting can be obtained, if a black shade or collar, consisting of a short split section cut from black rubber tubing and of such diameter as almost to encircle the tube of the burette, is positioned slightly below the meniscus.

It is not sufficient to test a commercial graduate merely at its capacity graduation. Each graduate should be tested at not less than three graduations. The first observation should be made at a main graduation corresponding roughly to 10 percent of the nominal capacity of the graduate, the second observation should be at a main graduation representing approximately 50 percent of the capacity, and the third observation should be at the capacity graduation. Should there be any indication of incorrect placement of graduations at any other points on the graduated scale, observations should be made at such points to determine the facts.

It is not necessary that graduates be tested repeatedly. Once having been found accurate, retests need not be made, for the accuracy characteristics of a graduate will not change as a result of use. Periodic inspections, however, are entirely in order, but these are merely for the purpose of determining whether or not the graduates have been damaged since the previous inspection.

It should be noted that acceptance and maintenance tolerances for graduates are identical, that the tolerances on graduates "to contain" are given in the tables of tolerances, and that the tolerances on graduates "to deliver" are 25 percent greater than the tabular values. Tolerances for a particular graduate are fixed by the inside diameters of the graduate at the points where observations are made. Before any transfer of measured water is made to a graduate under test, the inside diameter of the graduate should be measured, by using calipers and steel scale, at each graduation at which a test observation is to be made; from these diameters the tolerance at each test point is determined by reference to the appropriate tolerance table.

Testing Outlines

(For tests of graduates by weights and measures officials.)

Note.—Whenever a complete delivery is being made from a standard measure or graduate, drain this for 10 seconds.

Case I. For field test of graduates which are graduated "to contain":

1. Measure inside diameter of graduate at each graduation at which a test observation is to be made, and determine applicable tolerance. (Observations should normally be made at main graduations representing about $1/10$-capacity, $1/2$-capacity, and full-capacity.)
2. Using a standard graduate or a metal measure or both, as required, establish a measured amount of water corresponding to the value of the graduation at which the first observation is to be made. Carefully pour from this measured amount of water into the graduate under test until the water meniscus coincides with the graduation to be tested or until the entire amount has been transferred.
3. If some of the measured water remains in the standard, determine its amount; this amount is the error "in deficiency" at the graduation under test. *Then pour this water into the graduate under test.*
4. If, following step 2, more water is required to bring the water level to the graduation under test, fill the smallest standard graduate with water to its capacity graduation, transfer to the graduate under test the amount of water required to establish coincidence between the water meniscus and the graduation under test, read accurately the amount of water remaining in the standard graduate, and subtract this amount from the capacity of the standard grad-

uate; this difference is the error "in excess" at the graduation under test.

5. As in step 2, establish a measured amount of water corresponding to the difference between the value of the graduation just tested and the value of the next graduation to be tested; if the error at the graduation previously tested was "in excess", withdraw from this measured amount of water, and discard, an amount equal to that error. Then, as before, pour from this measured amount into the graduate under test until the water meniscus coincides with the graduation to be tested or until the entire amount has been transferred.
6. Proceed as in step 3 or step 4, depending upon whether there is more than enough or not enough of the measured water to bring the liquid to the graduation under test.
7. Proceed as in steps 5 and 6 to test at the next graduation, and at each additional graduation, at which an observation is to be made.

Case II. For field test of graduates which are graduated "to deliver".

1. Same as step 1 of case I. Note that tolerances on graduates graduated "to deliver" are 25 percent greater than tabular values.
2. Fill the graduate under test with water up to the graduation at which the first observation is to be made, empty the graduate in normal manner, and drain for 10 seconds.
3. Proceed as in steps 2, 3, and 4 of case I to determine the error at the graduation under test.
4. Fill the graduate under test with water up to the graduation at which the second observation is to be made, empty the graduate in normal manner, and drain for 10 seconds.
5. Proceed as in steps 2, 3, and 4 of case I to determine the error at the second graduation to be tested, using the full amount of water corresponding to the value of this graduation just as though this were the first observation being made.
6. Proceed as in steps 4 and 5 to test at the next

graduation, and at each additional graduation, at which an observation is to be made.

Case III. For office test of graduates which are graduated "to contain".

1. Same as step 1 of case I.
2. Deliver water from a burette to the graduate under test until the water meniscus coincides with the first graduation to be tested, reading the amount delivered directly from the burette. The error is the difference between the amount delivered and the nominal value of the graduation under test.
3. Deliver water from a burette to the graduate until the water meniscus coincides with the second graduation to be tested. Determine the *total* amount delivered in steps 2 and 3, compare this with the nominal value of the graduation, and compute the error of the graduation under test.
4. Proceed as in step 3 to test at the next graduation, and at each additional graduation, at which an observation is to be made.

Case IV. For office test of graduates which are graduated "to deliver":

1. Same as step 1 of case II.
2. Fill the graduate under test with water up to the capacity graduation, empty the graduate in normal manner, and drain for 10 seconds.
3. Proceed promptly as in step 2 of case III to determine the error at the first graduation to be tested.
4. Proceed promptly as in steps 3 and 4 of case III to determine the errors at each of the other graduations at which observations are to be made.

References

The following references are to papers on the general subject of graduates, appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M12, Ninth Conference Report, 1914, pages 48–51 and 126–136.
M116, Twenty-third Conference Report, 1930, pages 74–78.

Chapter 10.—MEASURE-CONTAINERS

Description.—In a broad sense a measure-container is something which performs the dual function of serving as the measure which determines the amount of a commodity which is to be delivered to a customer and of serving as the primary container in which the commodity is delivered to the customer. In the weights and measures specification sense the term "measure-container" is restricted to mean only those items which are "intended to be used once only"—that is, single-service containers—and which are used as measures "at the time of retail sale * * * from bulk supply". Moreover, the measurement is required to be "on the basis of liquid measure". All of these qualifications must be met for the item to be, for weights and measures regulatory purposes, a "measure-container". The code of specifications and tolerances for measure-containers defines a measure-container in the following words:

> A container intended to be used once only, to determine at the time of retail sale the quantity of commodity comprising a retail sale made from bulk supply on the basis of liquid measure and to serve as the container for the delivery of the commodity to the customer.

Also, it is stated in the paragraph dealing with the application of the code,

> This code does not apply to measure-containers used for milk, cream, and buttermilk, these being covered by the code for Milk Bottles, or to measure-containers used for the prepacking of "packages" of commodities.

In the foregoing statement, "packages" means packages put up in advance of retail sale, and includes all of the so-called "factory-packed" packages.

Accordingly, "measure-containers", for purposes of the code, are those paper-board containers designed to be used as measures, which a retailer keeps on hand, in empty condition, and which he uses from time to time as measures and containers when selling such commodities as ice cream, oysters, salads, cooked foods, pickles, olives, and the like, from bulk supply on the basis of liquid measure.

The nominal capacities of the measure-containers in most common use are ½ pint liquid, 1 pint liquid, and 1 quart liquid. The capacity of a measure-container may be defined by its top edge or by a graduation, shoulder, or indentation below the top edge. In shape, a measure-container may be in the form of a cylinder (having circular cross section of uniform diameter), an inverted truncated cone (having circular cross section but with the top diameter greater than the bottom diameter), or an inverted truncated pyramid (having rectangular cross section but with the dimensions at the top greater than those at the bottom). Means are always provided for closing the container, either by a separate lid or cover or by flaps which are extensions of the sides. When sitting upright a measure-container may rest upon its bottom, or the bottom may be raised above the lower edge of the side wall.

Inspection. — Measure-containers are mass-produced under conditions which should insure a satisfactory degree of uniformity in the finished product, and are inspected (and tested) "by sample"; that is, the inspection (or test) is made on a sample of (perhaps six) measure-containers of each make, design, and capacity, taken at random from regular production, and it is assumed that such sample is representative of the entire production of that particular variety. (For sanitary reasons, samples of measure-containers which are inspected and tested should not subsequently be used for dispensing food products.)

Inspection will ordinarily precede testing. Measure-containers should comply with the applicable provisions of general specifications G–S.1., G–S.2., G–S.3., G–S.4.1., G–S.4.2.1., and G–S.6., and general regulations G–R.3. and G–R.5. Under G–S.3., measure-containers of inadequate strength to maintain their shape, and thus their accuracy, within reasonable limits under normal service conditions should be rejected. Under G–S.4.1., measure-containers of the type in which the capacity point is defined by a graduation near the top edge of the measure-container, should be rejected if the graduations are not clear and definite and readily susceptible of giving accurate indications. Measure-containers should also be inspected for compliance with the applicable specification requirements of the code for measure-containers.

Testing Apparatus.—No volumetric standards will be required in addition to those specified in chapter 8 as necessary for the testing of liquid measures. Minimum requirements will be 1-quart, 1-pint, and ½-pint (and possibly ¼-pint) metal, slicker-slate, liquid-measure standards (see chapter 8) and a 1-fluid-ounce cylindrical graduate subdivided to ¼ fluid dram. If special bulb burettes, as suggested in chapter 11 for use in the office testing of milk bottles, are available, these can be used to advantage in the testing of measure containers. An inside caliper and a linear scale will be needed when inspecting for compliance with measure-container specification S.2.2. The 6-inch steel scale specified in chapter 4 will be adequate, although a longer scale, 9 or 12 inches, will be more convenient for use with measures of the larger capacities.

Testing Procedure.—It is practicable to test measure-containers in the field, although it is to be anticipated that, ordinarily, testing will be carried out in the office and that field work in connection with measure-containers will consist of inspections, as recommended later in this chapter under the heading "Supervision Over Use".

Water is recommended as the testing medium. It should always be practicable to test a measure-container by means of a standard of the same nominal capacity as the measure-container, and this is recommended. Measure-containers of circular cross section are ordinarily of sturdy construction and will not be deformed when filled with water. If the cross section is rectangular, some deformation from normal shape will take place unless the measure-container is made of unusually heavy material. Such deformation, consisting of a bulging of the sides, will increase the capacity as compared with the capacity when the measure-container is not deformed. *A measure-container should not be tested in a deformed condition.* Accordingly the measure-container of rectangular cross section should, if necessary, be so restrained before the actual test is begun that its sides will not bulge when it is filled with water. This can be accomplished by applying a metal plate or a piece of heavy cardboard to each side of the measure-container; these pieces should be only slightly smaller than the sides to which they are applied, and they can be held securely in place during the testing operation by means of rubber bands or cord applied near top and bottom. During test the measure-container should rest on a rigid, level surface.

The measure-container having been stiffened, if necessary, as described in the preceding paragraph, it is then tested with water in exactly the same way as has been prescribed in chapter 8 for the testing of a liquid measure.

Testing Outline

(For tests of measure-containers by weights and measures officials.)

1. If the measure-container needs to be restrained to prevent distortion during test, apply flat pieces of metal or heavy cardboard to sides and secure these in position by rubber bands or cord.
2. Fill standard with water to proper point.
3. Remove any water adhering to outside of standard.
4. Pour measured water into measure-container being tested, until measure-container is filled to proper point or all measured water is transferred. In latter case drain standard for 10 seconds.
5. If measure-container is too small and will not accept all of the measured water, transfer remaining water to the graduate, draining the standard for 10 seconds. The water in the graduate represents the error "in deficiency" of the measure-container.
6. If the measure-container is not properly filled after all of the measured water has been transferred to it, fill the graduate to its capacity graduation and pour water from it into the measure-container until the measure-container is properly filled. Read the amount of water remaining in the graduate; the difference between this amount and the capacity of the graduate represents the error "in excess" of the measure-container,

Supervision Over Use.—The official need not test samples of measure-containers from every retail store in his jurisdiction. As has previously been mentioned, measure-containers of a particular make, design, and nominal capacity *should* be uniform—within small limits—in all respects. Having once critically inspected and tested, let us say, samples of the 1-pint container of manufacturer "A" known as style or model or type "x-y-z" and having found these acceptable, it is to be presumed that A's 1-pint x-y-z measure-containers as furnished to retailers for their use will be uniform with the samples examined and so will be suitable for commercial use. It will ordinarily be sufficient, then, if the official, encountering measure-containers of this particular description ready for use in retail stores, merely inspects a few of them from time to time for such obvious characteristics as the legibility of the required marking (which might have deteriorated through carelessness at the factory), and the definiteness and conspicuousness of the graduation if one is utilized. However, at irregular intervals a few of these measure-containers should be picked up, taken to the office, and tested, as a check on their continuing accuracy.

There is also another phase of the field supervision associated with measure-containers which should not be overlooked. A particular measure-container made from lightweight stock might have been approved by the official upon representation that it was always to be used with a restraining form which would prevent bulging of its sides during the filling and measuring operation. If field inspection discloses that the stipulation for use of the form is not being observed by a particular retailer or retailers the official would be justified in taking such remedial steps with respect to these particular users as circumstances indicate—insistence on use of the prescribed forms with the lightweight measure-containers, or procurement of measure-containers made from heavier stock.

Chapter 11.—MILK BOTTLES

Description.—The code for milk bottles defines a milk bottle as:

> Any glass bottle of the general form which has customarily been used for the measurement and delivery of milk, cream, and buttermilk at retail and any other container employed for this purpose.

It is important to note that by the terms of this definition, a container must, among other things, be used *as a measure* in order for it to qualify as a "milk bottle" under the code.

There are in common and widespread use two principal types of containers for the dispensing of market milk, cream, and buttermilk at retail, (1) a single-service, paper-board container which is not used as a measure, and (2) a multiple-use, glass bottle which is used as a measure. A third type, a single-service paper-board container which is used as a measure, appears to be in somewhat limited use.

The paper-board container which is not used as a measure results from the operation of an automatic, combination container-forming and liquid-measuring machine. The container is square in cross section, the top may be flat or may be shaped like a gable roof, and the level of the liquid when the container is filled in normal manner may be well below the extreme top of the container. The container itself does not in any way determine the amount of its contents; the measuring operation is performed by mechanical elements within the machine. Container and contents constitute a "package" in the weights and measures sense, which package is subject to the requirement for declaration of contents and to other labeling requirements just as in the case of any other food package. This type of container does not come within the purview of the code for milk bottles.

The multiple-use glass milk and cream bottle and the single-service paper-board container which is used as a measure (in the same way as is the glass bottle) do come within the purview of the code for milk bottles. Each type is pre-formed before use and each is provided with means for establishing definitely the "plane of the sealing surface" with respect to which the capacity point of the "regular" bottle is defined; in the bottle using the conventional paper-board "cap", this plane is defined by the cap seat, and in the bottle using the metal "crown cap" and not provided with a cap seat, this plane is defined by the top edge of the bottle. The filling machines with which these containers are used are not measuring machines, but merely fill each container to a certain level in the container. The capacity of the container thus determines the amount of milk or other liquid placed in the container, and the container is actually "used for the measurement" of its contents. These containers may be circular or essentially square in cross section, and when normally filled the level of the liquid is close to the top of the container. Container and contents constitute a "package" in the weights and measures sense. But this type of container is separately treated by the official as a measure in itself, and it is this treatment to which this chapter is primarily devoted.

There is in very limited use a "special" bottle, this being a variation of the "regular" glass bottle, in which the capacity point is defined by a graduation at some distance below the bottle top. (See specification S.2.2. of the code for milk bottles.) Specific reference to the testing of this bottle need not be made in this discussion; it can be tested under the procedure outlined in chapter 12 for lubricating-oil bottles.

The code for milk bottles specifies that the capacity of a milk bottle shall be 1/4 liquid pint or 1 gill, 1/2 liquid pint, 1 liquid pint, 1 liquid quart, 1/2 gallon, 1 gallon, or 2 gallons. The most common capacities for milk bottles are 1/2 pint liquid, 1 pint liquid, and 1 quart liquid. In more limited use are bottles having capacities of 1/4 pint liquid and 1/2 gallon, and occasionally 1-gallon and 2-gallon bottles may be encountered.

Inspection.—Milk bottles are mass-produced under conditions which normally result in a relatively high degree of uniformity in the finished product, and are inspected (and tested) "by sample". (Even though glass bottles are "measures" and are repeatedly used, it would be impracticable, under prevailing conditions, for an official to test each bottle individually for accuracy, nor is individual testing of such bottles considered at all necessary in view of the controls normally exercised in the

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manufacturing process.) Each make, pattern, and capacity of bottles is separately considered, and for purposes of inspection, as distinguished from test, a small sample, perhaps six bottles, should be adequate for each variety. Sample bottles should, of course, be chosen at random from regular production.

Inspection will normally precede testing. Milk bottles should comply with all applicable specification requirements of the code for milk bottles, and with the applicable provisions of certain general specifications, as follows: G–S.1. and G–S.6. apply to all bottles; G–S.3. applies to paper-board bottles; and G–S.4.1. and G–S.4.2.1. apply to "special" bottles.

Milk bottles are ordinarily purchased by prospective users in considerable quantity at one time; for example, a single order of a railway carload of glass bottles is not at all unusual. Since molds for glass bottles must be repaired and renewed from time to time and machines for forming paper-board bottles must be adjusted from time to time, it is possible that bottles of a given variety produced at a particular time may differ slightly from bottles of that variety produced at another time, such differences being unintentional on the part of the manufacturer. It is considered advisable, therefore, that the official check the continued acceptability of bottles of which samples have once been examined and found satisfactory. An effective method of maintaining such a check is to inspect (and test) a sample from each large shipment of bottles into the official's territory, before the bottles comprising such shipment are put into use. Thus, in the event that the bottles of a particular shipment are found to be inaccurate or otherwise not in compliance with the requirements, the entire shipment can be kept out of service. Under such a plan examinations of bottles in actual use by bottlers need not be made, effective controls being maintained by a system of supervision over incoming shipments of new bottles which will insure that only acceptable bottles get into service.

As in the case of measure-containers, for sanitary reasons single-service bottles which have been inspected or tested should not subsequently be used for dispensing food products.

Testing Apparatus.—For the field testing of milk bottles, no volumetric standards will be required in addition to those specified in chapter 8 as necessary for the testing of liquid measures. (However, see the recommendation for the use of special burettes for office testing of milk bottles, made later in this discussion.) Minimum requirements will be ¼-pint (1-gill), ½-pint, 1-pint, and 1-quart metal, slicker-plate, liquid measure standards (see chapter 8) and a 1-fluid-ounce cylindrical graduate subdivided to ¼ fluid dram; if ½-gallon, 1-gallon, or 2-gallon bottles are to be tested, metal standards of ½-gallon and 1-gallon capacities should be added to the series to avoid as nearly as practicable repeated use of a standard to build up to the capacity of these large sizes.

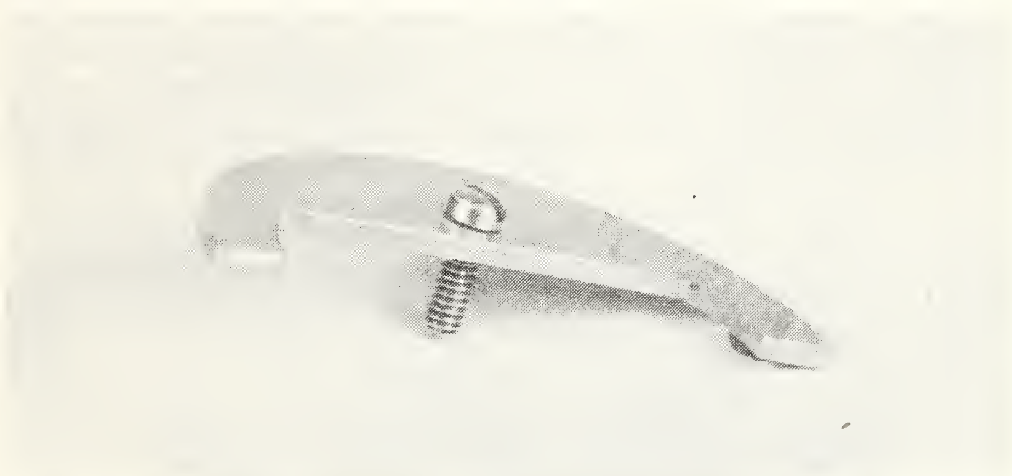


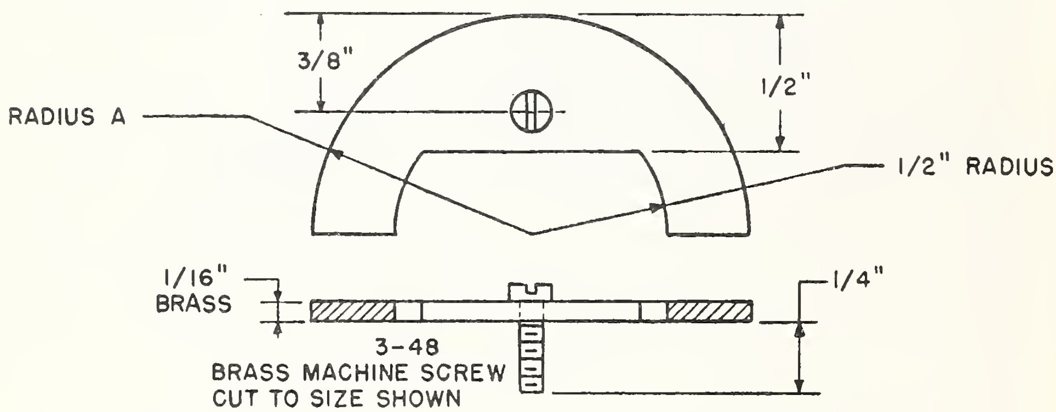
FIGURE 1. *Milk-bottle testing gage.*

The capacity point of a regular milk bottle is defined by the milk-bottle code as a certain distance below the plane of the bottle's sealing surface; for all types of bottles which will ordinarily be encountered, this distance is ¼ inch. A suitable depth gage is the most convenient and accurate means for determining when the liquid surface reaches the specified point in the course of the testing operation. Such a gage is illustrated in figure 1 and a working drawing for its construction is given in figure 2. This gage is designed to rest squarely on the cap seat of the bottle and a separate gage will be required for each different cap-seat size. Appropriate values for the "A" dimension of the gage for the three cap-seat sizes commonly employed are shown in figure 2.

The gage is provided with a pin which projects downward, the end of the pin being ¼ inch below the under side of the gage. When the gage is in position on the cap seat of a bottle, the tip of the pin is thus ¼ inch below the level of the cap seat.

The gage is used as follows: Measured water is transferred to the bottle under test until the level is close to the capacity point. The gage is then set in position on the cap seat and water is carefully added until the liquid surface just touches the tip of the gage; this is a very precise way of bringing the liquid surface to a point exactly ¼ inch below the plane of the cap seat.

For use with bottles without cap seats a single gage only will be required. This will differ only slightly from the gage which has just been described; the "A" dimension of figure 2 will be increased sufficiently for the gage to rest securely on the top surface of the largest ordinary bottle top, which has an outside diameter of approximately 2 inches. When the gage is in position, the tip of the pin is thus in a plane ¼ inch below the extreme



CAP-SEAT DESIGNATION	RADIUS A
No. 2	13/16"
No. 6	45/64"
No. 9	41/64"

FIGURE 2. *Working drawing of milk-bottle testing gage.*

top of the bottle. The gage should be so positioned on the bottle top that the pin will clear the wall of the bottle neck by not less than ⅛ inch.

It is practicable to test milk bottles in the field, although it is recommended that whenever practicable such testing be carried out in the office, where it can be done more conveniently and probably more accurately. For office use it is suggested that special bulb burettes in capacities of ½ liquid pint and one liquid pint, and if practicable of 1 liquid quart, be obtained, to be used in lieu of metal standards in the testing of milk bottles. A 2-fluid-ounce or a 4-fluid-ounce burette of standard pattern may be used for testing ¼-pint bottles.

The special bulb burette is illustrated in figure 3; in figure 4 is a working drawing for such a burette in the 1-pint capacity. Referring to figure 3, the container at the upper left is a reservoir for water, from which the burette at the right may be filled by gravity through the upper stop cock shown at the left of the tube of the burette. At the top of the burette, above the bulb, is a curved overflow tip enclosed in a vented chamber equipped with a drain; when the burette is filled to the point where water flows from this overflow tip and the supply is then cut off by the stop cock, any excess of water flows away through the drain tube to a suitable receptacle and a correct "zero" condition for the burette is automatically established. The cylindrical tube of the burette, below the bulb, is graduated; the graduation representing a delivery of an amount equal to the nominal capacity of the burette is at the midpoint of the graduated scale, the graduations above and below this "zero error" or "capacity" graduation enabling an observer to read directly the amount (within the limits of the graduated scale) by which an actual delivery exceeds or is less than the nominal burette capacity. The burette is calibrated "to deliver", and delivery is made through the lower stop cock directly into the milk bottle under test. Rubber tubing is used to connect reservoir and burette and to lead the overflow from the drain of the burette to a receptacle. The complete apparatus is mounted on a laboratory stand.

It should be particularly noted that the delivery tube below the delivery cock of the bulb burette does not drain under normal operating conditions but remains filled with water. Therefore, when the burette is about to be used following a period of nonuse during which the delivery tube has been emptied, it is important to refill the delivery tube before establishing the "zero condition" of the burette. Starting with a dry burette, the steps to be followed are: (1) With the lower or "delivery" stop cock closed, open the upper cock and partially fill the burette. (2) Close the upper cock. (3) Partially open the lower cock until the delivery tube is completely filled and some

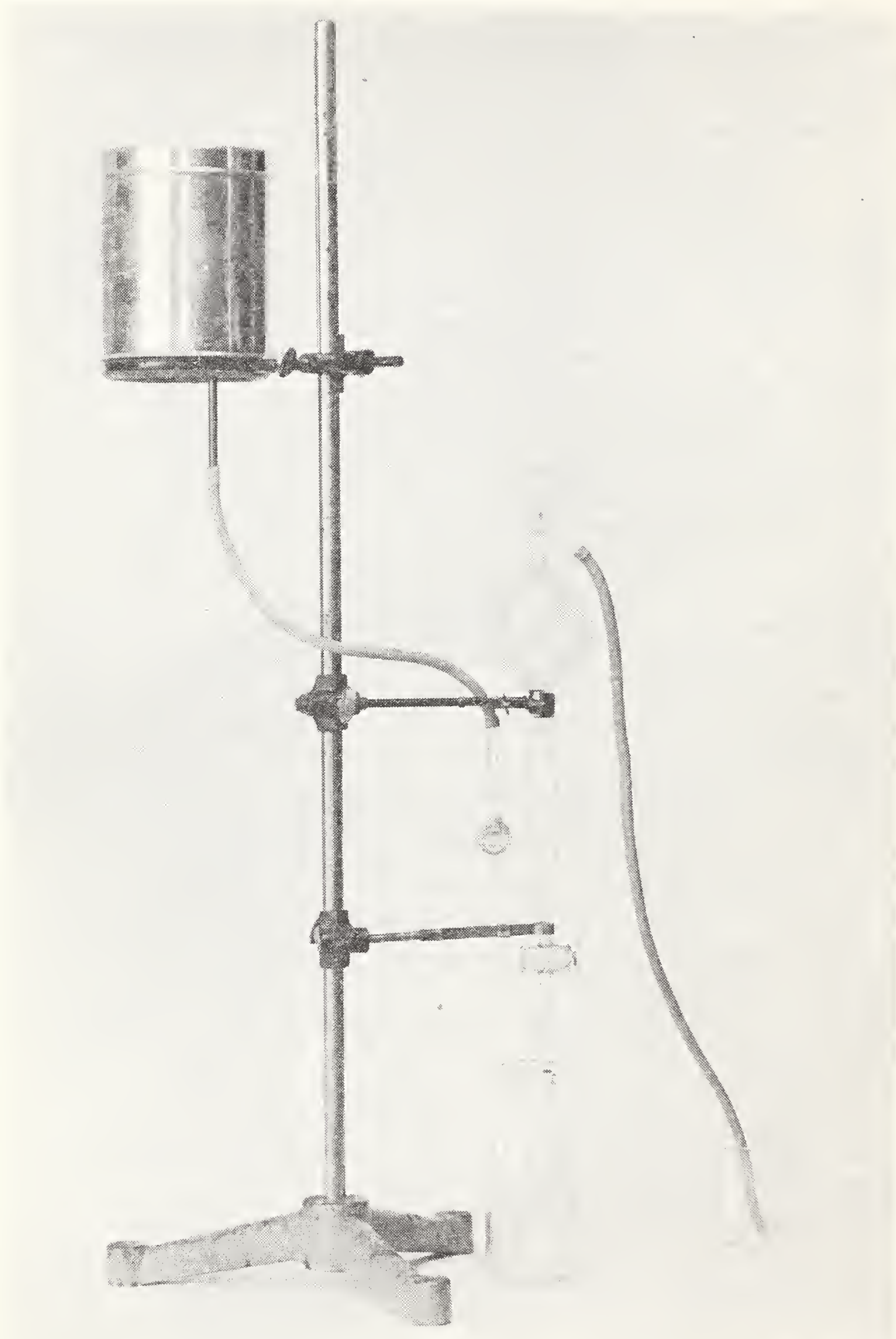


FIGURE 3. *Special bulb burette for milk-bottle testing.*

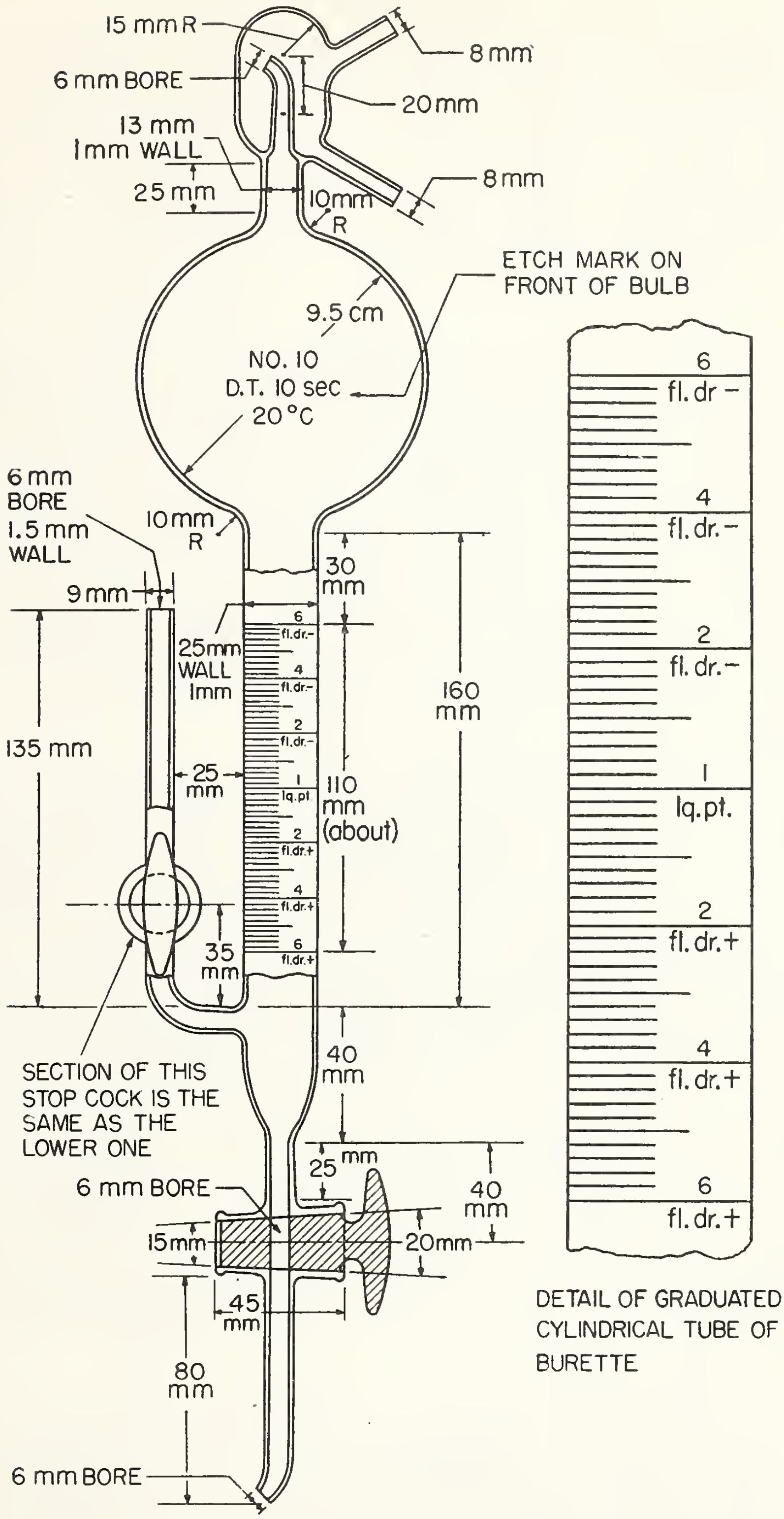


FIGURE 4. *Working drawing of special bulb burette for milk-bottle testing.*

water has been discharged through its tip. (4) Close the lower cock. (5) Open the upper cock until the burette is completely filled and a small amount of water has flowed through the overflow tip. (6) Close the upper cock. The burette is then properly filled and ready for use. So long as the burette is not drained and the delivery tube remains filled, subsequent operation is merely a succession of alternating fill (steps (5) and (6) above) and delivery operations.

Bulb burettes can be made and graduated as shown in figure 4 in any of the capacities previously suggested, merely by varying, as required, the size of the bulb. Graduation of the burette tube to 6 fluid drams above and below the "capacity" graduation, as shown, is adequate for any of the burette capacities recommended. These burettes are not known to be available from stock, and so must be made to individual order. As compared with tests made by the use of metal standards, tests of milk bottles made by the use of bulb burettes can be expected to be made with greater accuracy and convenience and in less time.

Testing Procedure.—Water is recommended as the testing medium. The code specifies standard capacities for milk bottles "when the temperature of the bottle is 20° C. (68° F.)". During tests, the bottles being tested, the testing apparatus, the water, and the atmosphere should be at approximately the same temperature, and this should not differ from the standard temperature of 68° F. by more than a few degrees. The inside walls of a bottle should be dry before transfer of measured water to the bottle.

The basic principle employed in the test of milk bottles is the transfer to the bottles of known volumes of water, determined by use of standard measures, burettes, or graduates, to establish whether or not the bottles hold correct amounts within the specified individual and average tolerances.

The code specifies that tolerances "shall be applied to the results of a test of not less than 25 bottles of the same capacity and ownership, selected at random from the whole supply available". This requirement should be interpreted to mean also "of the same pattern or design", since it is obvious that it would not be fair to combine results on bottles of two differing patterns (round and square bottles, for example), even though of the same capacity and ownership. This is testing "by sample", as discussed earlier in this chapter under "Inspection". Once tested and found to be accurate, milk bottles need not be repeatedly tested; their capacities cannot change through use, a circumstance which also explains the code provision that acceptance and maintenance tolerances are identical.

Having selected the prescribed sample of bottles, the official will test these individually, recording the sign and amount of each individual error so that the average error of the lot can be computed as prescribed in the code. If metal capacity standards are utilized, the test is conducted in exactly the same way as has been prescribed in Chapter 8 for the testing of liquid measures, with the single exception that the depth gage is used to accomplish precisely the filling of the bottles to the proper point. If the testing standard is a conventional burette or a bulb burette, the procedure differs only in that the measured volume of water is established by the burette and the error is read directly from the burette in what amounts essentially to a single operation, delivery being made without interruption from the burette to the bottle under test until the liquid surface just touches the tip of the pin of the gage. The meniscus of the liquid in the burette will be more sharply defined, and a more precise setting can be obtained, if a black shade or collar, consisting of a short, split section cut from black rubber tubing and of such diameter as almost to encircle the tube of the burette, is positioned slightly below the meniscus.

A modification of the field testing procedure in which metal standards are utilized, has been developed in one State, and this is reported to be giving good satisfaction. This is based upon the assumption that an individual bottle will seldom have an error greater than 1 fluid ounce. Instead of the regular metal standards, three special glass flasks have been provided, each of these having a capacity of 1 fluid ounce less than the nominal capacity of the milk bottle with which it is to be used; thus the capacities of these flasks to the graduation marks on their necks are 7 fluid ounces, 15 fluid ounces, and 31 fluid ounces, for the testing of ½-pint, 1-pint, and 1-quart bottles, respectively. (See fig. 5.) A 2-fluid-ounce cylindrical graduate is used in the conventional manner or, to adapt it particularly to this special use, it may have its half-capacity graduation designated "0", with graduations above this central graduation numbered upward from zero and designated "minus", and graduations below the central graduation numbered downward from zero and designated "plus". The use of this equipment is as follows: Assume that a 1-pint bottle is being tested. Fifteen fluid

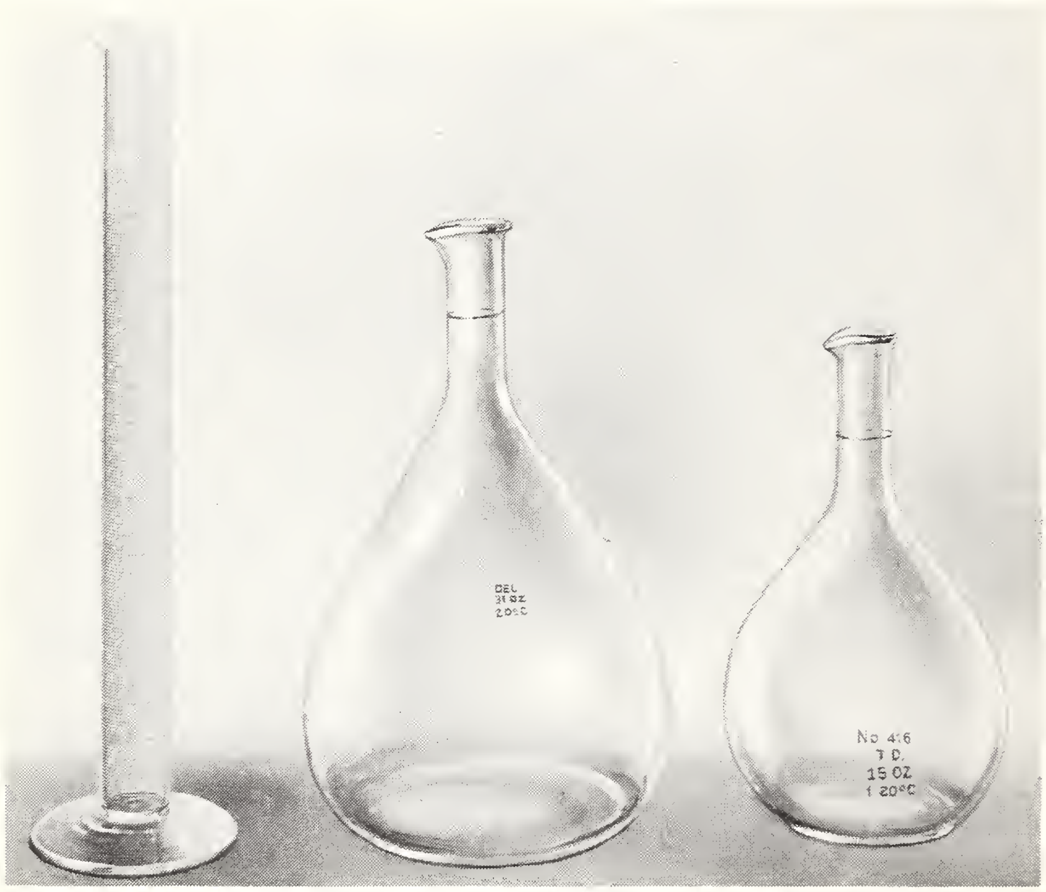


FIGURE 5. *Special flasks and graduate for milk-bottle testing.*

ounces of water, as determined by the flask, is at once transferred to the botttle, after which the depth gage is placed in position. The graduate is filled to its top graduation, and water is then added to the bottle from the graduate until the liquid surface just touches the tip of the gage pin. If the graduate has a conventional series of graduations, the error of the bottle is then computed from the sum of 15 fluid ounces and the amount transferred from the graduate; if the graduations on the graduate are specially numbered as suggested above, the bottle error is read directly from the graduate. It is said that the special flasks are not very expensive, and that occasional replacement of flasks broken in the field is more than compensated for by the greater facility of this method as compared with the use of regular metal standards.

Testing Outlines

(For tests of milk bottles by weights and measures officials.)

Case I.—When metal liquid measures are used as standards:

1. Fill standard with water to proper point.
2. Remove any water adhering to outside of standard.
3. Pour measured water into bottle being tested, until the surface of the liquid just touches the tip of the pin of the depth gage or all measured water is transferred. (Transfer most of the water before placing the depth gage in position. Transfer remaining water to graduate, draining the standard for 10 seconds, so that final transfer to the bottle may be slowly made from the graduate through the opening in the gage.)
4. If the bottle is too small, the water remaining in the graduate represents the error "in deficiency", of the bottle.
5. If the bottle is not properly filled after all of the measured water has been transferred to it, fill the graduate to its capacity graduation and pour from it into the bottle until this is properly filled. The difference between the amount of water remaining in the graduate and the capacity of the graduate represents the error "in excess", of the bottle.
6. Check the error for compliance with the "individual" bottle tolerance, and record it for later computation of the average error on the lot of not less than 25 bottles.

Case II.—When burettes are used as standards:

1. Fill burette.
2. Position depth gage on bottle.
3. Deliver from burette to bottle until the surface of the water just touches the tip of the gage pin or until the water has been drawn down to a precise setting at the lowest graduation on the burette.

4. If the bottle is too small, its error "in deficiency" can be read directly from the bulb burette (or derived from the reading of the conventional burette as the difference between the amount delivered and the amount which should have been delivered.)
5. If the bottle is not properly filled at the conclusion of step 4, refill the burette to the top graduation on the tube, and then continue delivery to the bottle until the surface of the water just touches the tip of the gage pin. From the total amount of water delivered, compute the error "in excess", of the bottle. (When using only the graduated tube of a bulb burette, as in this step, do not "read" the amount delivered according to the figures on the scale, but *count* the number of drams and fractions between the top graduation and the meniscus at the conclusion of the delivery; the total error is then the sum of this amount and the 6 drams more than the standard amount which was delivered in step 4.)
6. Check the error for compliance with the "individual" bottle tolerance, and record it for later computation of the average error on the lot of not less than 25 bottles.

Supervision Over Use.—The criterion of proper "use" of milk bottles, from the weights and measures viewpoint, is accurate filling of the bottles with the liquid they are used to distribute. It is not enough that the official insure the accuracy of the bottles themselves through a program of inspection and testing of new supplies of bottles reaching his territory, as has been recommended earlier in this chapter. In addition he should systematically examine filled bottles in process of distribution to insure that these are being filled accurately.

For sanitary reasons it is unwise to open bottles of milk or cream or other dairy products to inspect the height to which they have been filled. Fortunately, in the case of glass bottles a satisfactory alternative is found in a method of sighting through the bottle to locate the meniscus of the liquid and measuring its distance below the plane of the sealing surface. By relating this distance to the "capacity point" for the particular variety of bottle under examination, the distance (if any) by which the liquid surface fails to reach the capacity point of the bottle can readily be arrived at, and if desired this can readily be translated into a shortage expressed in volumetric units.

It has been found that if a fairly strong flash-lamp beam is directed against the back side of the neck of a glass bottle, the position of the meniscus of the contained liquid can be observed with sufficient precision for these inspections unless this falls directly behind a "roll" at or near to the top of the bottle. Measurement of the height of the meniscus is facilitated by the use of a simple inspection gage, one form of which is illustrated

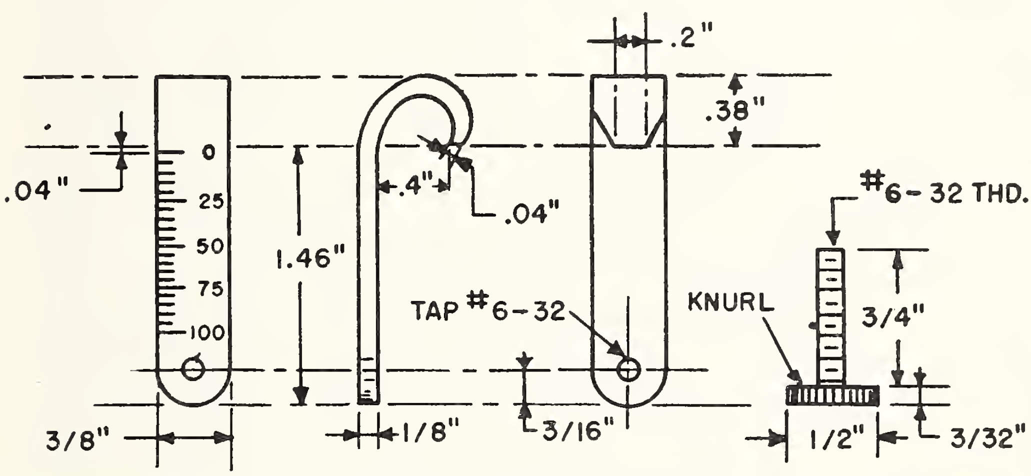


FIGURE 6. *Working drawing of check-up gage for examining bottles filled with milk.*

by the working drawing shown in figure 6. The gage shown was originally designed for use with the type of bottle which employs the familiar paper "cap" and which does not have an auxiliary paper-board hood or skirt covering the entire top of the bottle. From figure 6 it will be seen that the zero on the graduated length scale on the gage is to be 0.04 inch lower than the tip end of the hook; when the gage is "hooked" over the top of the bottle, with the tip of the hook resting on the top of the bottle cap, the zero on the scale then corresponds with the position of the surface of the cap seat—the "plane of the sealing surface" for this variety of bottle. By increasing the separation of the tip of the hook and the zero on the scale from 0.04 inch to 0.29 inch, distances between the meniscus and the "quarter-inch" capacity point prescribed by the milk-bottle code may be read directly. The scale is subdivided in 0.05-inch intervals. The adjustable screw at the bottom of the gage is to be so positioned that when its end touches the side of the bottle with the gage in place, the gage will rest in a vertical position.

Crown caps such as are used with milk bottles are approximately 0.015 inch thick. When the cap is applied to a bottle the top surface of the cap is 0.015 inch or slightly more above the top surface of the bottle. Accordingly, when the inspection gage just described.is used with milk bottles sealed with crown caps, a correction of about 0.02 inch should be applied, the observed readings being increased by this amount.

Bottles the tops of which are hooded or skirted can only be inspected for liquid level after removal of these auxiliary covers, unless the liquid level is below the bottom of the hood or skirt. If the gage is used with the auxiliary hood in place, a correction must be applied for the difference in height between the top of the hood and the top of the sealing cap, the observed reading being decreased by the correction factor; the official can readily determine the amount of this correction for each kind of hood with which he may have to deal. Before the official undertakes to remove the hoods from bottles of milk which are in process of delivery or in the hands of a retailer for resale, in order to check the height of the milk in the bottles, he should determine from the proper authorities in his jurisdiction whether such removal would violate any existing health regulation or would automatically lower the official "grade" of the milk. In any event, it may be found practical to conduct useful inspection at bottle plants before the protecting hoods are applied to the bottles.

The degree of success with which the inspection gage can be used with paper-board milk bottles will depend on the opacity of the material of which the bottle is made.

References

The following references are to papers and discussions on the general subject of milk bottles, appearing in the Reports of the National Conference on Weights and Measures. Citations include designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M55, Sixteenth Conference Report, 1923, pages 43–45, 47–49.

Chapter 12.—LUBRICATING-OIL BOTTLES

Description.—The code of specifications and tolerances for lubricating-oil bottles defines such a bottle as:

> Any bottle used for the measurement of lubricating oil for direct delivery to the crankcase of a motor vehicle, whether or not the bottle is sealed with a cap or some other device.

It is probable that lubricating-oil bottles are much less widely used than they were some years ago, having been supplanted to a considerable extent by sealed metal cans. A characteristic of lubricating-oil bottles is a detachable metal spout or an integral top of reduced diameter, to facilitate delivery to a crank case. At one time ordinary Mason jars fitted with metal spouts were used for the measurement and dispensing of lubricating oil to automobiles; such bottles were never designed for use as commercial measures, they did not conform to the requirements of the code, and their use as measures should not be permitted. Although other sizes are permissible under the code, the manufacture of lubricating-oil bottles is practically confined to the 1-quart size. Originally required to be made of "clear, uncolored glass", lubricating-oil bottles were permitted during the war years to be made of colored glass; the original requirement is now restored, but is made non-retroactive as a protection to colored-glass bottles legally manufactured which may still be in service.

Inspection.—Lubricating-oil bottles are mass-produced, just as milk bottles are, and so may be inspected (and tested) "by sample". Each make, pattern, and capacity should be separately treated. Inspection should precede testing. Bottles should comply with the applicable provisions of general specifications G–S.1. and G–S.6., and with all applicable specification requirements of the code for lubricating-oil bottles. Bottles which have once been found acceptable need not be reinspected (or retested) since their character will not change with use. It is recommended, however, that a suitable check be maintained on new bottles entering a jurisdiction, in the manner previously outlined in chapter 11 for milk bottles. If an official has in use in his territory only a small number of lubricating-oil bottles, it is recommended that he inspect (and test) all such bottles, rather than to follow the sampling procedure.

Testing Apparatus.—The standards provided for the testing of milk bottles are all that will be required for the testing of lubricating-oil bottles.

Testing Procedure.—Water is specified as the testing medium. Field testing will be found satisfactory, although office tests will be somewhat more convenient.

The basic testing principle is the same as in the case of milk bottles, and the testing procedure is the same as outlined in chapter 11 for the individual milk bottle, with one important exception. In paragraph N.1. of the lubricating-oil bottle code it is specified that in the test of a lubricating-oil bottle, the *top* of the meniscus of the water shall be brought into coincidence with the *bottom* of the capacity graduation. (This is a departure from the normal rule of using the *bottom* of the meniscus as the index.) The purpose of this requirement is to provide automatically a degree of compensation, with respect to the amount of oil delivered from a bottle, for the amount of oil which adheres to the sides and spout of the bottle. Further compensation of this kind is provided by the tolerances for lubricating-oil bottles, which are prescribed as "in excess" only, no tolerance in deficiency being recognized. Moreover, the value of the tolerance in excess is double what it would have been had tolerances been prescribed in both excess and deficiency, the entire normal tolerance range being covered by the tolerance in excess. All errors on lubricating-oil bottles will therefore be in the direction of oversize, the amount of permissible oversize is greater than normal, and no bottle is permitted to be smaller than its nominal capacity. It should also be noted that the tolerances are for individual bottles, no tolerances on average capacities being prescribed.

Supervision Over Use.—The criterion of proper "use" of lubricating-oil bottles, from the weights and measures viewpoint, is accurate filling of the bottles with oil and proper drainage of the bottles when oil is dispensed. Filled bottles, ready to be used in servicing motor vehicles, should be checked by the official to insure that the level of the oil is at least as high as the capacity graduation on each bottle. Bottles which have been emptied in the course of normal use and have not yet been refilled should be checked to observe whether or not an abnormal amount of oil remains in the bottles. In use, the bottle should be left up-ended in the oil fill pipe of the motor vehicle for a reasonable period—10 seconds or more—to permit proper drainage. Even so, some oil will remain in the bottle, and if the bottle is set back in the rack in an upright position, the retained oil will gradually drain down the sides of the bottle and collect at the bottom. A few experiments by the official will establish in his mind a practical guide to the amount of retained oil to be anticipated in a bottle which has been drained for a reasonable period. If, then, bottles are found containing excessive amounts of retained oil, this will demonstrate that sufficient time for drainage is not being allowed, and suitable corrective steps can be taken.

Lubricating oil is an expensive commodity, and unscrupulous operators will be tempted to remove bottles from fill pipes as soon as the main flow from the bottle has ceased, in order to retain as much oil as possible and thus increase profits. It should be viewed as a suspicious circumstance if at any filling station the practice prevails of up-ending emptied bottles, immediately following delivery to a crank case, on a drain-rack or otherwise for recovery of retained oil.

References

The following references are to papers and discussions on the general subject of lubricating-oil bottles, appearing in the Reports of the National Conference on Weights and Measures. Citations include designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M74, Nineteenth Conference Report, 1926, pages 17–22.

M129, Twenty-fourth Conference Report, 1931, pages 15–27; 138.

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Chapter 13.—LIQUID-MEASURING DEVICES

NOTE.—Liquefied petroleum gas—LPG—is measured in the liquid phase through metering devices similar to those used for measuring more stable varieties of petroleum products. The fact that LPG is not stable as a liquid at ordinary temperatures and atmospheric pressures, necessitates that it be kept under considerable pressure to maintain its liquid state, and introduces a definite hazard from the standpoints of accurate measurement and of safety in handling. The methods of testing LPG measuring devices and particularly the testing apparatus for this purpose are now in a state of evolution. Testing apparatus based upon volumetric determinations and upon gravimetric determinations have been developed experimentally and are being used in a very limited number of jurisdictions at this time, apparently with varying degrees of satisfaction. Until more experience has been acquired it seems best to make no definite recommendations regarding testing procedures and apparatus for devices measuring LPG as a liquid. Current suggestions and information on this subject may be obtained from the Reports of recent meetings of the National Conference on Weights and Measures.

In this chapter, therefore, liquid-measuring devices for measuring LPG will not be considered.

Description.—Liquid-measuring devices comprise one of the most diverse single groups of measuring instruments with which the weights and measures official has to deal. This is not surprising when one considers the very broad terms of the definition of the code for liquid-measuring devices, which reads as follows:

> Liquid-Measuring Device.—A mechanism or machine designed to measure and deliver liquid by volume, which may or may not include means to indicate automatically the total money value of liquid measured, for one of a series of unit prices.

It will be well to emphasize at the outset that there are separate codes for grease-measuring devices and for vehicle tanks. Each of these groups will be separately discussed in a subsequent chapter. It should also be mentioned that water meters are specifically excluded from the purview of the code for liquid-measuring devices. On the positive side, practically all of the devices of this group which the weights and measures official is called upon to examine are used for the measurement of petroleum products. This preponderance is so great that this discussion will be limited to units designed for the dispensing of petroleum products. If the official should need to examine a liquid-measuring device intended for the measurement of some other product, he should have no difficulty in applying the principles presented herein and devising an adequate inspection and test procedure.

For purposes of this chapter, liquid-measuring devices will be subdivided into two main divisions, retail devices and wholesale devices. A "wholesale" device is defined in the code as one which is obviously designed for single deliveries of 100 gallons or more; a "retail" device, then, is one designed for unit deliveries which are not expected to reach a value of 100 gallons, the code definition being "a device obviously designed for retail deliveries to individual customers."

Further differentiation of liquid-measuring devices can be effected upon the basis of details of design and construction, or installation. The code carries definitions of five "types", namely, wet-hose, dry-hose, pressure, gravity, and visible; "piston" and "meter" types are so well understood that definitions of these were not written into the code. Wholesale-type liquid-measuring devices are almost invariably large-capacity meters, and these are commonly referred to as "wholesale devices" or "wholesale meters"; these expressions will be so used in this chapter. Also, for the sake of brevity in this chapter, the term "device" will be used to mean "liquid-measuring device" unless the context clearly indicates some other meaning.

In practically all cases there will be found associated with retail and wholesale devices, as essential parts of the complete installations, elements such as foot valves, check valves, pumps, strainers, and air separators. In the case of retail devices, most of these elements may be expected to be combined into a complete, compact unit assembly; in the case of wholesale devices, however, these elements are ordinarily installed as separate units which, taken together with the meter, comprise a complete installation. It should in all cases be clear from the context, either in this chapter or in the code, whether reference is being made to all of the elements of a complete installation or only to the strictly measuring elements of an installation.

The earliest type of retail device to be widely used was a hand-operated piston-type unit. These were single-cylinder, reciprocating-piston pumps, the length of the piston stroke being adjustable. Operation was by means of a crank, geared to a rack connected to the piston rod. Normal zero position of the piston was its lowest position in the cylinder. There was a poppet valve in the cylinder and a foot valve at the bottom of the suction line in the supply tank. The seal between the piston and the cylinder walls was maintained by piston leathers. After the system had been properly filled with liquid, raising of the piston forced out through the discharge line the liquid above the piston and drew liquid into the cylinder below the piston by suction from the supply tank. A full discharge cycle was completed when the piston had been raised from its lowest to its highest position and returned to starting position; the main discharge took place on the up-stroke of the piston and a dribble flow, caused by displacement of liquid by the descending piston rod, occurred during the down-stroke. Ratchet counters, which could be reset to zero reading, were provided to totalize the number of complete strokes comprising an individual delivery.

At first these piston-type units were made to have a capacity of 1 gallon per stroke, and they were used largely for the sale of kerosene. Later their use became common for the sale of gasoline and lubricating oil. As a group, these devices came to be known as "measuring pumps", an apt designation, because they were pumps and they did measure. People came to differentiate them on the basis of the commodity dispensed, and "kerosene pump" and "gasoline pump" became accepted expressions. So firmly did the term "pump" become associated with the dispensing units that when the visible type of dispenser was developed this came to be called a "visible pump" and today many persons refer to meter-type units as "meter pumps". A pump of some sort is necessary, except in a gravity or pressure installation, to cause liquid to pass through the system, but the pump is the measuring element only in the piston-type device; to refer to other types as "pumps" is careless usage and essentially incorrect, and it is recommended that such usage be discontinued.

Reverting to the consideration of piston-type devices, their versatility was soon increased by two modifications designed to adopt them better to the uses to which they were being put. One modification was to increase the stroke capacity of units used for gasoline and to decrease the stroke capacity of units used for lubricating oil. Units having 1-quart and even 1-pint strokes came into use for sales of lubricating oil, and units having 5-gallon strokes became common for sales of gasoline. Also, an intermediate capacity of 2½ gallons was popular for a time.

Associated with the changes in stroke capacities was the introduction of means for accurately measuring deliveries of fractional parts of a stroke. Adjustable, intermediate stops were provided, whereby the up stroke of the piston could be mechanically terminated at any one of several points. Thus a device having a 1-gallon stroke might have three intermediate stops whereby deliveries of 1 quart, 2 quarts, or 3 quarts could be made. Similarly, the 5-gallon unit was equipped to deliver 1, 2, 3, or 4 gallons as well as its full-stroke capacity of 5 gallons. To permit a reading when a delivery was unexpectedly interrupted, a graduated vertical scale and indicator combination was commonly provided.

Piston-type devices were designed for deliveries through a rigid outlet (as to a portable container) or through a hose (as to the fuel tank of a motor vehicle), or both. If the delivery was made through a hose, this was of the dry-hose type, intended to be drained at the conclusion of a delivery; since the measuring cylinders of these units were mounted relatively low, and since the inlet end of the hose needed to be high enough to make drainage possible, discharge from the cylinder was through a rigid "stand pipe", to the upper end of which the hose was attached. An automatic "vacuum breaker" was installed at the highest point of this stand-pipe-and-hose discharge line to facilitate drainage of the hose.

Piston-type devices may be installed for use with underground supply tanks and also for use with inside floor tanks or portable tanks mounted on wheels. There was one early effort to approach automatic operation of a piston-type device by providing for operation by means of compressed air, but this design was not widely used. Piston-type devices are still in widespread use for the measurement of kerosene and lubricating oil, but for the measurement of automotive fuels they have largely been replaced by other types of liquid-measuring devices.

The next major development in retail liquid-measuring devices to follow the piston-type device, was the "visible" device, popularized for sale of motor fuel upon the concept that the customer should be able to see what was being measured in order to assure himself that he was actually receiving what he paid for. The principal distinguishing characteristic of the "visibles" was an elevated glass chamber, exposed to the view of operator and customer, into which gasoline was elevated and in which the measurement was made. The measuring capacity of the cylindrical glass chamber was at first 5 gallons. Soon a 10-gallon capacity became practically standard construction, and some few 15-gallon units were manufactured. Liquid was elevated from the supply tank to the measuring chamber by means of electrically-operated pumps, hand-operated pumps, or air pressure.

There were two basic designs for visibles, the "measure-in" design and the "measure-out" design, the former being outnumbered by the latter. In both designs, subdivision by gallons became standard practice, although some units were designed for an initial ½-gallon delivery. In the measure-in design the principle of operation was to measure in the cylinder or "bowl" the exact amount to be delivered and then to discharge the entire contents of the cylinder. Measurement was accomplished by means of a sliding overflow tube which could be mechanically positioned at various heights corresponding to even gallons; gasoline was elevated to the cylinder until the liquid level was somewhat above the top of the tube, after which the liquid leveled-off at the height of the top of the tube, the excess returning through the tube to the supply tank.

In the measure-out design the principle of operation was always to fill the cylinder to a proper "zero" level by means of a fixed overflow pipe, and then to discharge the quantity desired. In one basic design, the discharge took place through a sliding or otherwise adjustable discharge tube (or tubes) which could be mechanically positioned for the desired delivery; for the final gallon on a capacity delivery, all of the gasoline in the cylinder might be discharged, or the "capacity" position of the delivery mechanism might be such that liquid would still be visible in the cylinder at the conclusion of such a delivery. The other variation of the measure-out design was simpler in construction and correspondingly less expensive to manufacture, and for economic reasons gradually became more popular than the "sliding-discharge-tube" design. This came to be known as the "eye-measure visible". It had a fixed overflow tube for establishing the proper zero filling, but the amounts delivered were determined by the operator making a visual setting of the descending liquid surface as nearly as practicable in coincidence with some one of a vertical series of indicators. Usually this design did not contemplate the emptying of the cylinder for a capacity delivery.

Originally the actual discharge flow on any visible device was controlled by a discharge valve at or near the inlet end of the hose, and the hose was of the dry-hose type, intended to be drained at the conclusion of a delivery. Later the "wet hose", intended to be kept full of liquid at all times, and equipped with a discharge valve at its outlet end, was introduced for use on those eye-measure devices in which the liquid remained in sight in the cylinder following a capacity delivery.

During the heyday of the piston-type device some few attachments were developed to give visual indication that the system was filled to the top of the standpipe before a delivery was commenced and that liquid was actually flowing during the period of operation. On the visible types the starting condition was clearly shown by the basic design of the unit, but on all except the eye-measure visibles there arose the necessity for an indication to show when the system had drained to the point at which it would be proper to close the discharge valve, so that liquid ostensibly being delivered would not be trapped in the system. Accordingly there were developed various designs of "sight glass", "visigage", or "bulls-eye" for this purpose, these being installed adjacent to the inlet end of the "dry" hose.

Although the visible-type of liquid-measuring device has now very largely been displaced by the meter type, especially in centers of large retail distribution, a great many visibles, in the aggregate, are still in service, having been retired to rural and small urban locations.

The meter type of retail liquid-measuring device was introduced a good many years ago as a measuring instrument for motor fuels. At first it was merely an adaptation from existing fluid-meter designs, and its first appeal is probably to be found in its increased capacity, increased speed and convenience of operation, and increased precision of indication as compared with the then popular visibles. The meter unit had one of the characteristics of the piston-type unit—as to the basic device itself it was as "blind" as the so-called "blind pump"; from its early days, therefore, the necessity for "visible" accessories on a meter unit was apparent.

Early meters were constructed on the principle of the nutating disk or "wobble plate", adjustment for accuracy being made by controlling the amount of unmetered liquid permitted to flow through a small by-pass. Later developments included measuring elements employing rotary and reciprocating pistons, and provision for accuracy adjustment by changing the length of piston strokes or by changing gears in the train connecting the measuring and indicating elements.

A fluid meter differs from a piston-type liquid-measuring device in one basic respect. The piston-type device performs both pumping and measuring operations. The meter is a "driven" member—never a "driving" member except with reference to the indicating elements of the assembly; its function is to measure, and it never does any lifting of the liquid from a supply tank. The meter is actuated by the passage of liquid through it, and so, necessarily, there is associated with it a pumping element or the liquid is otherwise supplied under sufficient pressure to maintain the desired flow. The vast majority of retail meter-type devices now have associated with them electrically-operated pumps, by-passed to permit pump operation even when no liquid is passing through the meter. There have been gravity and air-pressure installations, and for a time one company marketed a hydraulic system operated by water pressure.

A meter will register the passage of air or vapor as well as liquid. For this reason the code for liquid-measuring devices requires that a meter device be equipped with an "effective mechanical air eliminator or other effective means to prevent passage of air or vapor through the meter." The air eliminator on a gasoline-dispensing unit is located between the pump and the meter. It is basically a chamber in which the passage of the liquid is slowed down to the point where the entrained air has an opportunity to separate from the gasoline. The released air is then vented to the atmosphere (or in some cases back to the supply tank) and air-free gasoline passes on to the meter. The air vent from the separator must not be closed or obstructed; closure will make the separator inoperative. A detail in the design of air-separator units is the provision for the return to the suction side of the pump, from the final settling chamber, of the small accumulation of liquid which results from the final separation operation.

On the discharge side of the meter there is a "pressure-relief" valve, installed to maintain essentially the normal operating pressure in that portion of the system between the meter and the discharge valve at the end of the hose. Customarily this valve is basically a check valve, but it contains a reverse, spring-loaded, needle valve which will permit a very slight amount of liquid to pass in a backward direction to relieve any excessive pressure which may be built up as a result of an increase of temperature. By maintaining the operating pressure in the discharge line, the formation of vapor is prevented. Without this, a temperature increase would produce excessive vapor formation in the line, the vapor would collect at the high point in the line, displacing liquid which would be forced backward through the system, and, because the line on the discharge side of the meter would not be full of liquid, short measure would result on the subsequent delivery from the device.

The indicating elements of the meter-type device are directly connected to the meter and are actuated by its operation. Provision is made for resetting the indicating elements to zero following a delivery. Practically all retail meter-type devices for gasoline now being manufactured are equipped with interlocks which make it necessary, once the pump motor has been cut off, to reset the indicating elements to zero before the motor can be restarted. Because of a patent monopoly on the "zero set-back interlock", its incorporation in the assembly is not required by the National Conference code, although its advantages are fully recognized.

Figure 7 is a schematic diagram of the assembly of a meter-type device, illustrating the relation of the parts and the flow of liquid during operation. The identification of the parts is as follows:

A. Hose hook and control for motor switch.
B. Pump motor.
C. Pump.
D. Foot valve.
E. Pump by-pass valve.
F, G, and H. Air-separator assembly. F is the primary settling chamber, receiving the flow from the pump. G is the sump chamber, receiving air-laden liquid from F. H is the air vent.
J. Meter.
K. Pressure-relief valve.
L. Sight glass.
M. Indicating elements.
N. Discharge nozzle.

A more detailed diagram of an air eliminator is shown in figure 8, the parts here being combined into a single unit. The identification of the parts is as follows:

A. Inlet line from pump.
B. Primary settling chamber.

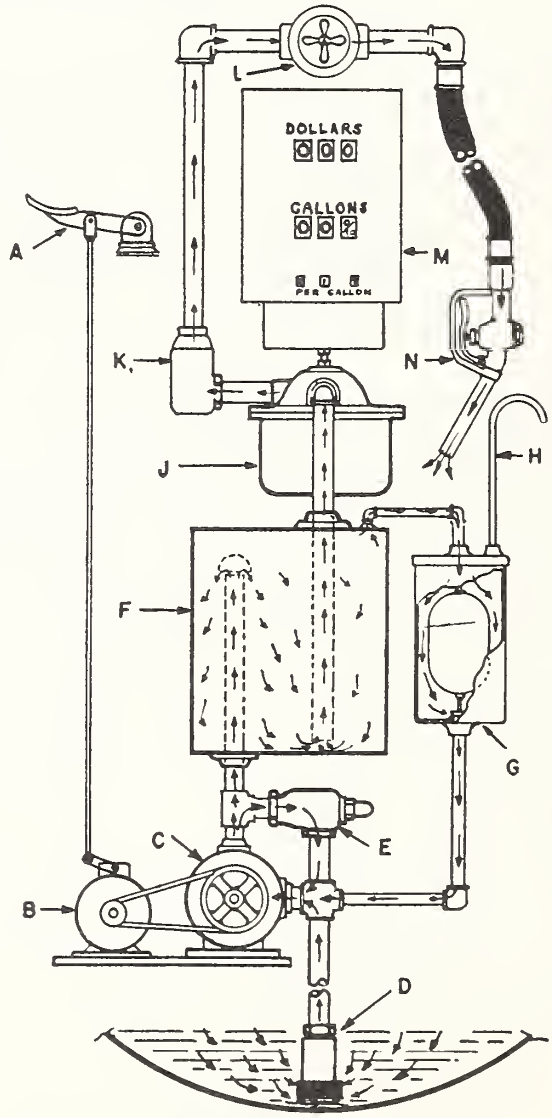

FIGURE 7. *Schematic diagram of meter-type retail gasoline-dispensing device.*

C. Discharge line to meter.
D. Port for passage of air-laden liquid to sump chamber.
E. Sump chamber.
F. Float for actuating valve G.
G. Float-actuated valve to allow accumulated liquid to return to suction line.
H. Liquid-discharge line from sump chamber.
J. Air vent from sump chamber.

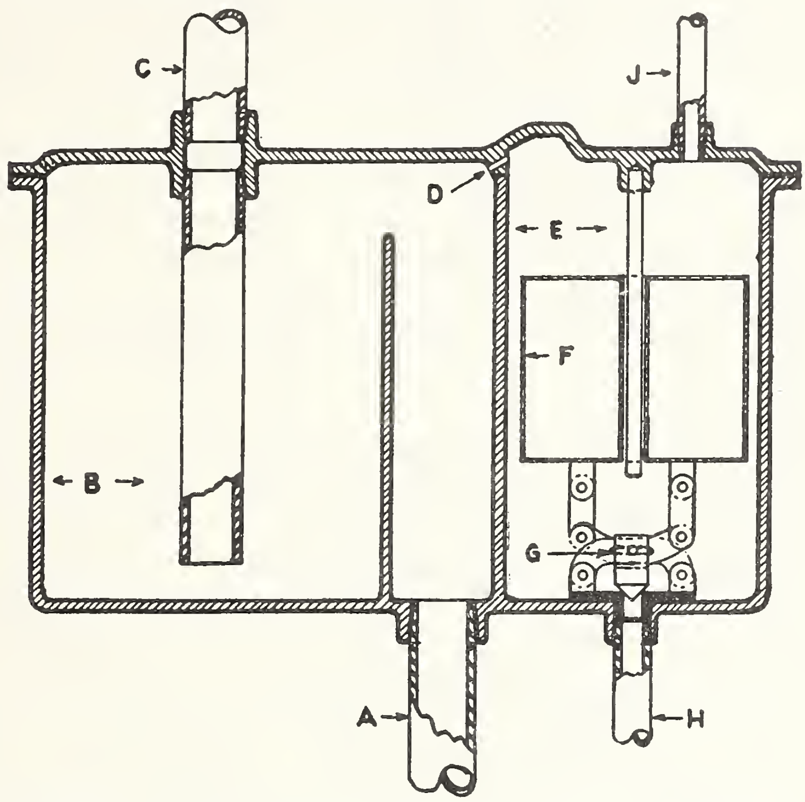

FIGURE 8. *Schematic diagram of air eliminator of meter-type retail device.*

In addition to indicating the gallonage discharged, the modern "computer" design of retail meter-type device for gasoline indicates the total selling price of the amount discharged, based upon the unit price for which the device is set, and the unit price upon which the total price is computed is also shown. Computation is accomplished through a series of gear combinations actuated by the meter and connected with indicating drums carrying figures much as in the case of any straight-reading counter. The unique feature of this mechanism is the means for connecting in train the appropriate gears for any price per gallon from 0.1 cent to 99.9 cents, by 0.1-cent steps, and for indicating automatically the price per gallon for which the mechanism is set at any time.

In the field of "wholesale" measurements, the only type of liquid-measuring device to be encountered today is the meter. In basic design the wholesale meter may duplicate the retail meter, but the wholesale meter will be characterized, as compared with the retail type, by heavier construction to withstand harder service and higher working pressures, by larger size, by much higher discharge rates, and by the absence of price-computing accessories. Wholesale-type meters will be found on vehicle tanks, at petroleum-product bulk plants, in pipe-line service, and in many industrial applications. Partly because of the weight and size of the elements and partly because of the special circumstances at many wholesale installations, such elements as pumps, strainers, air eliminators, pressure reducing valves, operating valves, check valves, relief valves, manifolds, ticket-printing attachments, etc. are separately marketed and are separately installed as required.

Inspection.—Liquid-measuring devices should be separately inspected, and inspection should precede testing. The more complicated the assembly or the installation, the more important is it that a thorough inspection be made. Care should be exercised to insure that all required or necessary elements are present and that these are functioning as intended. In the case of retail devices, special care should be exercised with respect to any "home made" additions or other modifications which have been made by owner or operator, particularly modifications which have removed or made inoperative elements supplied by the manufacturer. Such changes may have been made with the best of intentions; on the other hand, the few unscrupulous operators frequently display considerable ingenuity in doing things to a dispensing unit to produce for themselves an illegal gain. The official should be particularly alert with respect to the possibility of diversion of measured liquid back to the supply tank (or elsewhere) during the process of a delivery to a purchaser. It behooves the official to make certain that commercial equipment is really what it appears to be, and that it meets all applicable specification requirements.

Any part of a device which involves a glass window or chamber through which operator or customer is supposed or required to observe certain indications, must be sufficiently clean and unobstructed to permit these observations to be made with ease and accuracy. If the glass surfaces have become dirty or discolored, cleaning should be required. On an eye-measure visible device the protective screen around the outside of the measuring chamber should be cut away to permit a clear view of each set of indicators.

Liquid-measuring devices should be inspected for compliance with general specifications G–S.1., G–S.2., G–S.3., G–S.4., and G–S.6., with general regulations G–R.1., G–R.2., G–R.3., and G–R.5., and with all applicable specification requirements and regulations of the code for liquid-measuring devices. With respect to this code, it should be kept in mind that the specification requirements are in three groups. The first group, beginning with specification S.1., applies to both retail and wholesale devices; the second group, beginning with specification S.10., applies to retail devices only; and the third group, beginning with specification S.20., applies to wholesale devices only. The code covers devices of all mechanical types, and the official must select those requirements—and disregard others—which are properly to be applied to the particular type of device under examination. Specifications S.2.6., S.3.2., S.5.1., S.11.3., and S.12. may be mentioned particularly with respect to meter-type devices.

Testing Apparatus.—In chapter 8 on liquid measures, the procurement of certain volumetric standards has been recommended, including standards having capacities of 1 liquid quart, 1 gallon, 2 gallons, 3 gallons, 4 gallons, and 5 gallons. All of these will be required if all types of retail liquid-measuring devices are to be properly tested. The 1-quart standard should be of metal, and conical or cylindrical in shape. The other standards should be metal "field standards", having graduated necks. The entire series of gallon measures will be required for the complete testing of piston-type and visible-type devices; the testing of meter-type devices for dispensing motor fuels will normally require only the 5-gallon standard. The testing of devices for dispensing lubricating oil will require use of the 1-quart and possibly the 1-gallon standard. All of these standards can be procured readily "from stock". It is recommended that there be procured also a cylindrical glass graduate of a capacity of several cubic inches with ¼-cubic-inch subdivisions.

For the testing of wholesale-type devices, special, large-capacity standards are required. The recommendation of the code relative to the testing drafts for a wholesale device is that these "should be equal to at least the amount delivered by the device in 1 minute at its maximum discharge rate, and shall in no case be less than 50 gallons". (See code paragraph N.1.2.) The tentative ASME-API "Petroleum P. D. Meter Code" (API Code No. 1101) goes further than the National Conference code and requires that the "measuring volume of the prover tank shall be not less than the volume delivered in one minute through the meter to be tested and it is preferable that the measuring volume be one and one-half to two times as large as the rated volume delivered per minute by the largest meter to be proved." (Paragraph 2018).

The capacity of the large-capacity standard, or "prover" to use the term now commonly applied, to be procured by the official will depend upon the capacities of the devices to be tested. Where any considerable amount of this work is to be done on meters of different sizes, two or more standards may well be provided, their capacities being suited to the testing of commercial devices falling into different size groups. In general, the larger the prover the greater will be the time required for a test and the difficulty and cost of using and transporting the prover, circumstances which suggest that a 1,000-gallon prover be not used, for example, for the testing of a meter rated at 50 gallons per minute.

It is recommended that any jurisdiction having any large-capacity meters to test, procure a prover of not less than 100 gallons capacity. If the meters to be tested do not exceed 100 gallons per minute in rated capacity, such a prover will be adequate for all such testing. However, if some or all of the meters to be tested have rated capacities in excess of 100 gallons per minute, a prover of 500 or 1,000 gallons capacity, depending upon the capacities of the largest meters to be tested, is recommended. If there is a very considerable amount of large-capacity meter testing to be done, two large provers may be required to supplement the 100-gallon prover, these to be of the same or of different capacities according to the capacities of the meters to be tested.

The type of large-capacity meter testing here under consideration is the testing of meters permanently installed at various locations in a jurisdiction. It follows that the provers to be used by the official for this work must be of the portable variety. (Fixed prover installations suitable for the testing of large-capacity meters installed on vehicle tanks are discussed in chapter 15.) It is believed that it will be found practicable to design provers of 100-gallons and of 500-gallons capacity for mounting upon two-wheeled trailers, although the use of four-wheeled trailers may be somewhat more satisfactory. For provers having capacities in excess of 500 gallons, four-wheeled trailers or four-wheeled self-propelled vehicles will be required. (See figs. 9, 10, 11, and 12.)

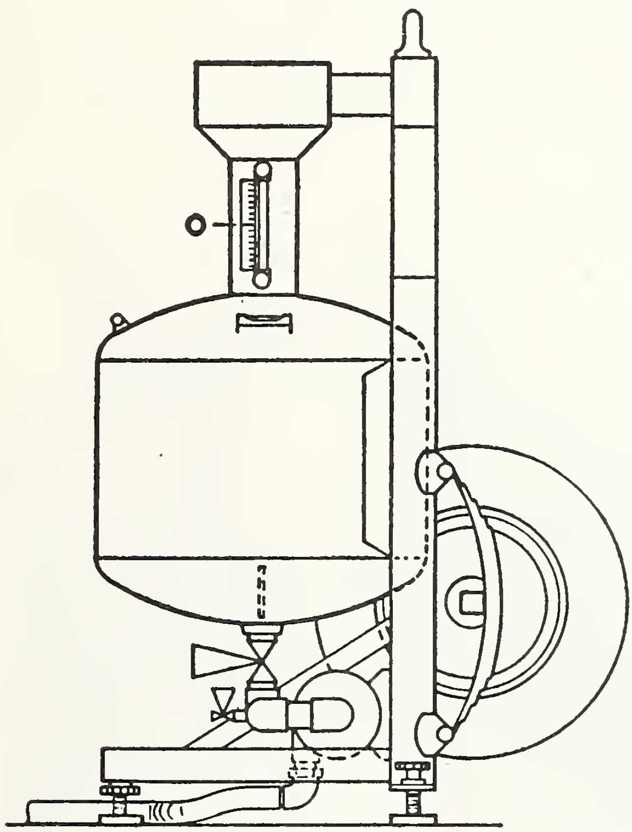

FIGURE 9. *Schematic diagram of tip-up, trailer-mounted prover.*

The general characteristics required of a prover may be summed up by saying that the prover is essentially a large-scale reproduction of a "field standard", with the addition of special means for emptying the standard. In its simplest form the prover has a cylindrical body with a bottom sloped to a discharge valve at its lowest point and with a top sloped to a cylindrical, graduated neck of relatively small diameter. The nominal capacity of the prover is defined by the "zero" graduation midway of the graduated portion of the neck. Because of the foaming characteristics of petroleum products and the relatively high discharge rates of wholesale-type meters, there should be fitted at the top of the prover neck a section having a diameter considerably larger than the neck diameter; this "splash dome" will prevent overflowing the prover near the termination of a discharge. (See figs. 9 and 10.) To prevent swirling of the liquid during the final stages of a discharge from a prover, and thus to speed up the discharge, a baffle plate should be installed inside the prover at the bottom.

The prover must be in level when it is in use. Accordingly two levels, spaced 90° apart, should be permanently attached in positions convenient for observation, and three leveling feet should be provided for establishing a

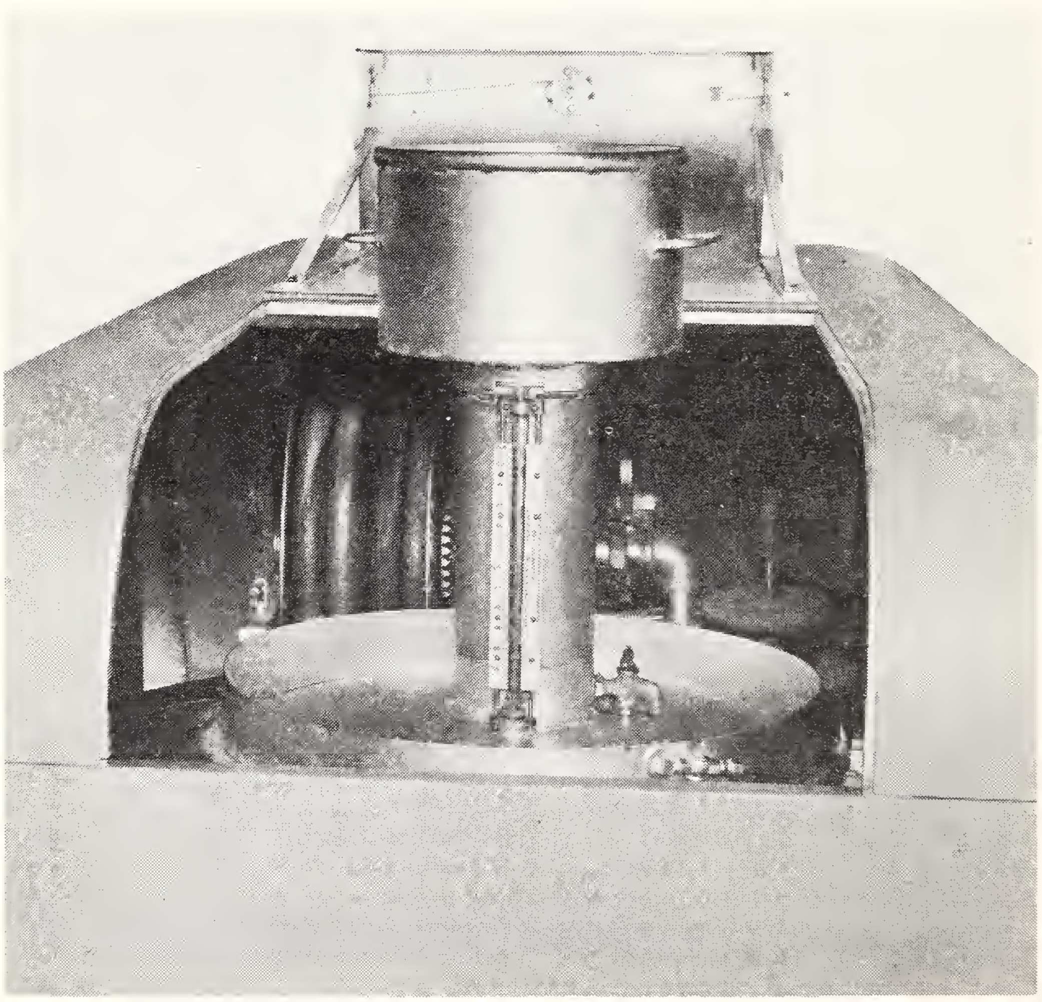

FIGURE 10. *Detail of one-hundred-gallon, trailer-mounted prover, State of Massachusetts.*

level condition. The prover discharge valve should be of the quick-acting type and *must close tightly* to prevent *any* leakage through the valve in either direction; this valve should be in a vertical line from, and as close as practicable to, the discharge orifice of the prover.

It will frequently be necessary to dispose of the discharge from the prover by elevating this to a point considerably above the level of the prover. Accordingly a pump must be provided—a rotary pump is recommended—connected to the discharge side of the prover discharge valve, and a power source for operation of the pump should be provided, for which an explosion-proof electric motor is recommended. A hose line to accommodate this discharge is necessary. There will be some cases in which discharge from the prover may be made by gravity; if desired, a piping arrangement may be made to by-pass the pump in cases where gravity discharge is possible.

In the ASME–API code previously cited, it is specified that the volume of the graduated portion of a prover neck shall be at least 2 percent of the capacity of the prover, and that the inside diameter of the prover neck shall be such that 1/16 inch in vertical height represents not more than 0.01 percent of the prover capacity. These provisions are considered to be sound. It is also considered reasonable to limit the length of the graduated portion

FIGURE 11. *Five-hundred-gallon, trailer-mounted prover, State of Illinois.*

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of the prover neck to 15 inches, 7½ inches above and 7½ inches below the capacity, or "zero", graduation. Translating these requirements into dimensions for prover necks, it is recommended that the inside neck diameters for provers of 100-gallon, 500-gallon, and 1,000-gallon capacities be, respectively, in the order of 6¼ inches, 14 inches, and 20 inches. For the same series of provers it is recommended that the graduated scales be divided, respectively, into 5-cubic-inch, 25-cubic-inch, and 50-cubic-inch subdivisions; this will result in graduations spaced approximately six to the inch in each case. Thus, on the basis of a total graduated length of approximately 15 inches, the 100-gallon prover would be graduated to ±230 cubic inches by 5-cubic-inch subdivisions, the 500-gallon prover would be graduated to ±1,150 cubic inches by 25-cubic-inch subdivisions, and the 1,000-gallon prover would be graduated to ±2,350 cubic inches by 50-cubic-inch subdivisions. Graduations throughout in terms of

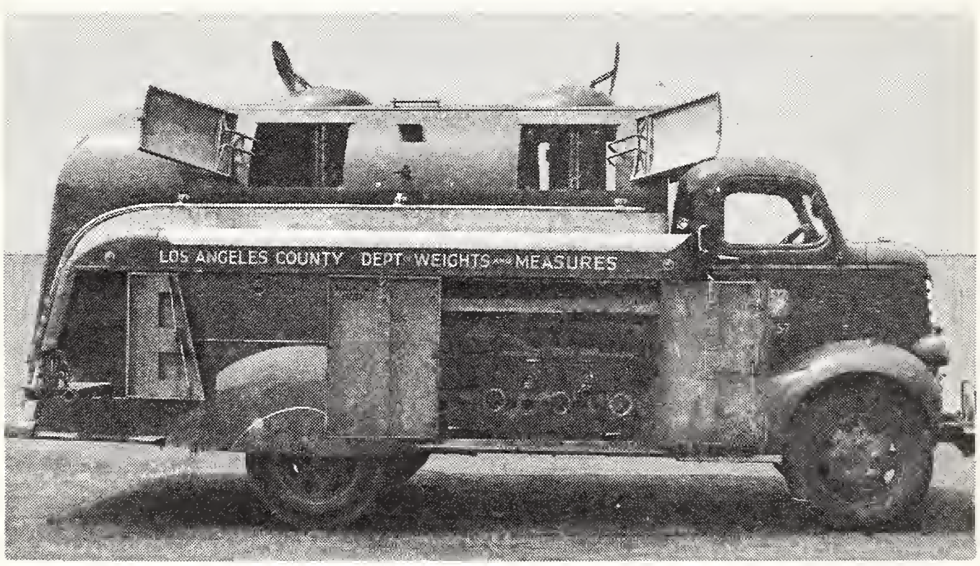

FIGURE 12. *Twelve-hundred-gallon, two compartment (400 gallons and 800 gallons) prover on self-propelled chassis. County of Los Angeles, Calif.*

cubic inches rather than of other units is recommended because all tolerances are expressed in cubic inches and computations will be avoided if errors are similarly expressed.

At first thought, 25-cubic-inch and 50-cubic-inch graduated intervals may seem unduly large. As a matter of fact, however, these intervals for the 500-gallon and 1,000-gallon provers, respectively, agree as to percentage sensitiveness with the 5-cubic-inch interval for a 100-gallon prover, and all three are four times as sensitive, percentagewise, as the customary 1-cubic-inch interval on a 5-gallon field standard. Moreover, the smallest tolerances to be applied on 100-gallon, 500-gallon, and 1,000-gallon test drafts—the acceptance tolerances on "normal" deliveries—are 37½ cubic inches, 137½ cubic inches, and 262½ cubic inches, respectively, corresponding to more than five intervals in every case.

A prover should be built of steel, and should be of substantial construction to withstand the normal vicissitudes of use without damage. The thickness of the metal in the body of the prover should be such that no distortion will occur when the prover is filled; it is recommended that the thickness of the metal be not less than ⅛ inch for the 100-gallon prover, $5/32$ inch for the 500-gallon prover, and $3/16$ inch for the 1,000-gallon prover. The inside of the prover should be smooth and without crevices, pockets, or obstructions other than the baffle plate, in order to facilitate complete and rapid drainage. The slope of the walls toward the top and the bottom of the prover should be steep enough to facilitate the rise of gas bubbles to the top during the filling operation and the rapid drainage of the walls during the emptying operation. It is believed that for a vertical 100-gallon prover with cylindrical body, the walls of the top and bottom sections should be straight rather than curved in vertical cross-section—that is to say, these sections should not be dished into the general form of a section of a sphere, but should be formed from flat plate into the shape of a truncated cone; the limiting value for the safe slope of these walls has not been determined but it is recommended that the slope be in the order of 10° or 15° from the horizontal. For portable provers of 500-gallon and 1,000-gallon capacities, consisting essentially of horizontally mounted tanks on vehicle chassis, every precaution should be observed in designing these to avoid the possibility of formation of air or gas pockets and to facilitate drainage.

A prover should be calibrated "to deliver" at 60° F.

The calibration should be made with water, on the basis of a 30-second drainage period following the completion of the principal discharge under conditions of normal use. This means that the prover should first be completely filled and should then be emptied by means of the discharge pump. At the conclusion of the main discharge, the prover discharge valve should remain open and the pump should continue to run for an additional 30 seconds. The discharge valve should then be closed, the pump should be stopped, and the prover should then be calibrated by a measuring-in operation, using a properly calibrated 5-gallon or 10-gallon standard. This procedure should be duplicated on repeat observations. (This calibration method will control the important drainage factor and will duplicate to a satisfactory degree the normal use of the prover.)

At large bulk plants and at other locations where wholesale-type meters are in service, it will be found with increasing frequency that fixed-location provers have been provided by the meter owners for the periodic testing of their own meters. Where such provers are available, their use by weights and measures officers for their official tests of the meters is entirely satisfactory provided that the accuracy of the provers has been officially established. It would not be proper for the official merely to assume that these provers are accurate. He must in some positive way assure himself, and make this a matter of record, that the provers are accurate before he can properly use these as standards. This can be accomplished (1) by actually calibrating the provers as prescribed above for the official's own prover, (2) by testing the provers with his own standard prover and other official standards as required, or (3) by participating in and verifying the calibration of the privately-owned provers as conducted by the prover owners.

Mention may be made of that type of prover which is equipped with a small-diameter, graduated section between the bottom of the prover body and the discharge valve, this section corresponding in general with the graduated neck at the top of the prover although having a much smaller capacity. This bottom section may have a series of graduations, or only a single graduation marking the position of the liquid level corresponding to an "empty" prover; obviously, the "capacity" of the prover is its volume between the top and the bottom "zero" graduations. A prover of this design is suitable for use in testing meters, where deliveries are made *into* the prover, but the design is not well suited to operations in which deliveries of measured amounts are required to be made *from* the prover. For the latter use, the prover design which contemplates complete drainage of the prover is recommended. (This latter design is, of course, also satisfactory for meter testing.)

Testing Procedure. — A liquid-measuring device is tested by measuring the amounts of liquid delivered by the device as this is installed for commercial service. The testing medium is the liquid for the dispensing of which the device is regularly used. Liquid-measuring devices are invariably "installed" in some way, being connected with a source of supply of the liquid to be dispensed; if for any reason the liquid supply becomes exhausted, it is not practical to conduct a test until this supply is replenished. The delivery is made directly into the standard (except in the case of viscous liquids) and errors are read directly from the standard when "field standards" are employed.

Standards of capacities of 1 gallon and over, and provers, should be wetted with the test liquid and then drained for the standard drainage period immediately before use; the standard drainage period recommended for field standards is 10 seconds and for provers is 30 seconds. (These standards and provers are calibrated "to deliver" and when wetted and drained may be used "to contain". In the test of a particular device, the standards (or the prover) are necessarily used "wet" unless they are dried between observations, a wholly impracticable procedure.) When a standard or prover is emptied following an observation, the same standard drainage period should always be observed. The field standard should stand upon a level surface or should be suspended by its bail so that it hangs plumb, when a reading is made, and a prover should be leveled before use. The reading is made to the bottom of the meniscus of the liquid. When gasoline is the testing medium, the reading should be made promptly following a delivery to avoid errors which otherwise might result from evaporation or from change of volume resulting from change of temperature of the liquid.

In the case of any device utilizing a "dry hose", a standard condition with respect to hose drainage should first be established by delivering a small quantity from the device—in order to wet the inside of the hose—and then carefully draining the hose for 10 seconds after the main flow from the hose has ceased. This same hose-drainage procedure should then be followed after each test delivery.

When a device is being used to measure a relatively viscous product such as lubricating oil, it is recommended that deliveries from the device be not made into the metal standards of the official, because of the difficulty of thoroughly cleaning these standards between observations and at the conclusion of a test. The alternative procedure is recommended, of first carefully calibrating with water one or more commercial measures, as required—these are almost certain to be conveniently available—and then of using the calibrated commercial measure or measures, as secondary standards, to receive the deliveries from the device; errors may be determined directly by means of the glass graduate, which can readily be cleaned.

If a device is found upon test to be satisfactory, security seals should be affixed to protect the adjustable elements of the device, as provided for by code specification S.4.

In the discussion which follows, liquid-measuring devices will be considered in the three groups previously discussed, that is, piston-type devices, visible-type devices, and meter-type devices, the latter group being broken down into retail meter-type devices, and wholesale meters.

PISTON-TYPE DEVICES: In a piston-type device, the system is supposed to be filled with liquid from the inlet end of the suction line to the top of the standpipe. Measurement takes place in the measuring cylinder, but the amount of liquid actually measured by one complete piston stroke is not all discharged, some of this liquid going to fill the standpipe to its point of overflow into the discharge hose or nozzle. Thus a particular discharge is made up largely of liquid actually discharged from the measuring cylinder and, to a small extent, of the liquid originally above the cylinder which is pushed out ahead of the stream from the cylinder. The importance of the system being full at the start of a delivery is apparent; if the system is not so filled, the delivery will be short.

If the fit between the piston and the cylinder walls is not tight, the piston can be raised without displacing all of the liquid above it; in other words, there will be slippage of liquid between piston and cylinder walls, and again the delivery will be short, for the indicating and registering elements of the device are actuated by the rise of the piston and not by the actual passage of liquid into the discharge line. The same result will occur, and for the same reason, if there is leakage through the piston valve during the upstroke of the piston.

Assuming a full system and an absence of leakage, as the piston rises the entire column of liquid in the system is in motion, liquid above the piston being pushed upward and liquid being drawn in below the piston from the supply tank. If the piston is operated at a very fast speed, this liquid column may be given sufficient momentum to cause it to continue in motion momentarily after the upward movement of the piston has ceased; this will result in overmeasure.

The condition of "prime" of the system, that is, whether or not the system remains properly filled following a delivery, is one index of the tightness of footvalve (at the inlet end of the suction line) and piston valve. (But it must be remembered that if a device has stood unused for some time and if the temperature has risen and later has fallen, the liquid in the system will first have expanded and overflowed into the discharge hose at the point of overflow from the standpipe and later will have contracted so that the level will be below the top of the standpipe. The same final result will follow a drop in temperature without the preliminary rise. These results are occasioned by natural causes, for which the device itself is not responsible.) Uniformity of deliveries at reasonably slow and reasonably fast operating speeds is an index of the tightness of fit of the piston and of the tightness of the piston valve. (But note the comment in the preceding paragraph regarding the possible overmeasure effect of very fast operation.)

It must be remembered that on a piston-type device, the operation for a complete or partial stroke is not complete until the piston has been returned to its starting position; the small "dribble flow" caused by the displacement of the piston rod on the return stroke is a normal and necessary part of the delivery.

The device should first be tested for accuracy on a capacity discharge, corresponding to a complete piston stroke; at least two observations should be made at a reasonably fast rate and two more should be made at the specified minimum rate or, if a minimum is not specified, at a reasonably slow rate. If intermediate stops are provided, accuracy of each intermediate delivery for which provision is made should be determined. (See code paragraph N.1.2.) If the device has been found satisfactory on both fast and slow deliveries at capacity, intermediate deliveries need be tested only at a single normal rate. If a device is equipped with a reading scale and intermediate stops, the scale readings should be checked for agreement with capacity and intermediate-stop indications. If a reading scale is provided but intermediate stops are omitted, the scale reading should be checked to see that it gives a correct capacity indication when the piston is at its highest point, and at least two tests for accuracy should be made at intermediate points on the scale.

If two delivery outlets are provided, a delivery at normal rate should be made from each outlet following a delivery from the other outlet to insure that delivery from one outlet does not adversely affect the accuracy of the delivery from the other outlet. (See code paragraph S.2.4.)

In the course of the test the correct functioning of the tallying element, designed to register the number of complete strokes or the total number of gallons comprising a delivery, should be checked. Registration should occur at the instant at which the up-stroke of the piston is completed. (See code paragraphs S.11.1. and S.11.2.)

If before a test is begun on a piston-type device for dispensing gasoline it is observed that the pump is not properly "primed", that is, that the liquid level is not at the top of the standpipe, indicating leakage back through the system, it will be advisable to make at once a delivery of one complete piston stroke without regard to the customary preliminaries of wetting the standard and establishing a standard drainage condition for the hose. If the shortage on this delivery is found to be excessive—much more than the normal tolerance plus the leakage permitted by paragraph T.2. of the code for the period since the preceding delivery from the device—faulty mechanical condition of the device is indicated and rejection is in order without further testing.

A supplementary test which it is seldom necessary to use is the "elapsed-time" test. If it is necessary to establish definitely the amount of leakage back through the system when the device is standing unused, or in other words the performance of the device under the requirement of clause (c) of paragraph P.1. of the code—accuracy "irrespective of the time elapsing between operations"—this can be done by making a complete elapsed-time test after the regular test has been concluded. For purposes of illustration, assume a 5-gallon gasoline pump "in use" which has been found to have a consistent error of underregistration of 3 cubic inches on 5 gallons. The system being properly filled with gasoline to top of the stand pipe, and the piston being at its lowest or "zero" position, the device would be allowed to stand unused for a number of hours—perhaps over night; assume that this period of non-use is 15 hours. At the expiration of the period of non-use a *single* 5-gallon delivery is made from the pump. (The normal operations of first wetting the standard and the hose should be omitted; the errors resulting from use of a dry standard and a dried-out hose are not significant on this test.) This delivery must be made without any previous "priming" of the system, the piston being merely operated through one complete cycle from its lowest to its highest position and back to starting position. If there has been leakage back to storage during the period of non-use, if the temperature is essentially the same at the end as at the beginning of the period of non-use, and if during this period the temperature has not risen above the temperature at the beginning of the test, the amount by which this first delivery is less than a normal 5-gallon delivery from the pump will be considered as the amount of the leakage. Assume that this first delivery is 20 cubic inches less than 5 gallons, and that the temperature has been essentially unchanged during the period of non-use; since the normal delivery has been found to be 3 cubic inches *more* than 5 gallons (the assumption stated earlier), the leakage over the 15-hour period is 23 cubic inches, or approximately 1½ cubic inches per hour. The maintenance tolerance on the elapsed-time test of a retail device being 2 cubic inches per hour (paragraph T.2. of the code), this device is acceptable on this test.

In the test outlined above, had there been no temperature rise above the initial temperature but if the temperature at the time of the first delivery after non-use had been, for example, 15° F. below the initial temperature, an additional shortage would have resulted solely from this temperature drop. The gasoline above ground, amounting to about 7 gallons in the case of a 5-gallon piston-type pump, would have contracted about 1½ times 0.6 percent (paragraph N.1.3. of the code), or about 15 cubic inches, and this entire shortage would be reflected on the first subsequent delivery. Due allowance for this shortage should be made in computing the leakage of the pump. If during the period of non-use the temperature rose above the initial temperature, the gasoline would expand and an amount equivalent to this expansion would enter the hose and could not subsequently be entirely recovered. Suitable correction should be made for the amount so lost from the system, and before making the test delivery following non-use, any gasoline in the hose should be drained out and discarded.

VISIBLE-TYPE DEVICES: The testing procedure for visible-type devices may be summed up by saying that test observations should be made at each amount which the device is designed to deliver. (See code paragraph N.1.2.) Each stop or graduation or indicator is, ordinarily, individually adjusted for position, and it is not an adequate test of one of these devices to make observations at a single delivery only—for example, at 5 gallons. Stops and graduations are ordinarily provided for successive gallons; therefore, a 10-gallon device, for example, should be tested at each gallon from 1 to 10, inclusive.

The recommended method of making these tests requires the use of all five of the recommended field standards. The first five observations are on total deliveries of 1 gallon, 2 gallons, 3 gallons, 4 gallons, and 5 gallons, the device being properly refilled to the "zero" point before each delivery. The error in each case is read directly from a single standard. In the case of a 10-gallon device, additional total deliveries of 6 gallons, 7 gallons, 8 gallons, 9 gallons, and 10 gallons are made, the device being refilled to "zero" before each delivery. These deliveries above 5 gallons are necessarily made in two parts, the first part of the delivery being made into one standard and the second part being made into another standard, except when the 5-gallon standard is used twice for a 10-gallon delivery. The error on the total delivery in each case is arrived at by combining algebraically the "error" readings on each part of the delivery.

For these deliveries of 6 gallons and over, the procedure recommended is always to make the second part of the delivery into the 5-gallon standard. The first part of the delivery is made to bring the liquid approximately to the zero graduation on the standard. But wherever the liquid level happens to be in the graduated portion of the neck of the standard when the first part of the delivery is terminated, the measure is read to the nearest one-half or even one-quarter cubic inch, and this reading is recorded, with its appropriate sign, to be combined later with the second reading to arrive at the error on the total delivery being made. (Should it so happen that the first reading is zero, the error on the total delivery will, of course, be represented by the second reading.)

Should the official have available only standards of capacities of 1, 3, and 5 gallons, it is still practicable to make the test described above, although the number of observations will be somewhat increased. The 2-gallon delivery will be made in two parts, using the 1-gallon standard twice. Similarly, the 4-gallon delivery will involve using first the 1-gallon standard and then the 3-gallon standard. For the 7-gallon delivery it will be required first to use the 1-gallon standard twice and then to use the 5-gallon standard. For the 9-gallon delivery the sequence in which the standards will be used is 1 gallon, 3 gallons, and 5 gallons.

A different testing procedure from that described above has been used by many officials, primarily to avoid procurement and carrying of standards of several capacities and to speed up the testing. In this procedure, observations are made on successive 1-gallon drafts, starting with the device properly filled to the "zero" point, but without any subsequent refilling of the device until the capacity point is reached. The error on the first gallon drawn is determined and recorded. The error on the second gallon drawn is determined and recorded and is then combined algebraically with the error recorded for the first gallon to arrive at the error on a 2-gallon delivery. This process is repeated until errors are computed for each delivery up to the capacity of the device. This test method is not recommended. The principal objection to it is the probability that computed errors for the larger deliveries will be inaccurate by significant amounts as a result of the cumulative effect of small inaccuracies in the reading of the errors on individual 1-gallon drafts. A second objection is that under this method the walls of the measuring chamber of the device have a much longer time to drain than under conditions of normal commercial use of the device, a circumstance which will introduce some degree of inaccuracy in the results.

In all visible-type devices, one element of the operation is the automatic leveling-off of the liquid in the measuring chamber, accomplished by means of an overflow tube communicating with a return line to the supply tank. Liquid is introduced into the chamber until its level is above the top of the overflow tube; the excess of liquid then drains back through the tube. The final amount of this excess drains back relatively slowly, and enough time must be allowed—about 10 seconds after the level of the liquid in the chamber has apparently stopped falling—for this drainage to be complete. The introduction of liquid into the chamber usually involves some agitation of the liquid and the formation of bubbles. Sufficient time must be provided for the bubbles to rise to the surface before the leveling-off operation is completed in order to avoid a final level which is actually below the top of the overflow tube; this will normally be accomplished automatically if the liquid is initially raised one-half inch or more above the top of the tube.

In the measure-in, dry-hose type of visible device, the measuring operation is completed when the liquid levels off at the point corresponding to the amount for which the device is set. It remains then to discharge all of the liquid in the chamber. A period of 10 seconds after the delivery appears to have been completed should be allowed for drainage from the chamber, after which the discharge valve should be closed. The customary drainage period for the hose should then be observed to complete the discharge. (See code paragraph S.10.3.)

In the measure-out types of visible devices, the initial leveling-off of the liquid establishes the "zero" condition preparatory to making a delivery, the measuring chamber being so filled to the proper zero or starting point. In the mechanical-stop, dry-hose variety of device, the mechanism is then set for the desired delivery by means of the sliding discharge tube, selective valve assembly, or other mechanism, and the amount of the delivery is mechanically determined through drainage of the liquid in the measuring chamber down to the appropriate level. The precautions relative to drainage periods should be observed as explained in the preceding paragraph.

In the eye-measure variety of device, use of the wet hose is believed now to be universal. The measuring chamber is filled to the proper zero or starting point as previously explained, and the system is then full from the discharge valve at the discharge end of the hose to the zero point in the measuring chamber. The amount of a delivery is determined by discharging liquid from the measuring chamber until the liquid level appears to be in coincidence with the proper graduation or indicator on the inside of the measuring chamber. The setting should be made, using as an index the dark line of the meniscus of the liquid. When it is realized that the measuring chamber of a visible device is above the eye level of the operator and that the position of the operator when making a setting is at the end of the discharge hose perhaps several feet away from the device, the difficulty of making a precise setting is obvious. It follows that the greatest care should be exercised in making these settings.

All visible devices have at least two sets of indicators, and it is common for eye-measure visibles to carry three sets. The positioning of the indicators on a mechanical-stop visible device is not critical as in the case of the eye-measure visible, but these indicators should give indications in substantial agreement with the mechanically-measured deliveries, and the indications of corresponding indicators of each set should be in essential agreement. On the eye-measure visible, the positions of corresponding indicators of each set should be in exact agreement. It is essential, therefore, that observations be made on each indicator of each set provided, as a test proceeds.

Particularly with respect to an eye-measure visible device, a question will sometimes be raised about the device being operated on test by the weights and measures official rather than by the relatively more experienced commercial operator. To be satisfactory a commercial device must be susceptible of accurate performance when operated in an ordinarily skillful manner. The weights and measures official may be presumed to possess at least that degree of skill. Therefore, if a device will not perform satisfactorily when operated by the official, its rejection is entirely in order.

RETAIL METER-TYPE DEVICES: By far the greatest amount of attention required from weights and measures officials with respect to retail meter-type devices is in connection with gasoline-dispensing devices. The discussion which follows is accordingly directed primarily to such devices. In the aggregate, however, considerable numbers of lubricating-oil meters will be found in service, and these should, of course, be officially examined. The principles developed in the discussion on the testing of gasoline-dispensing meters are generally applicable to the testing of lubricating-oil meters, and with regard to the latter it need only be suggested that the testing draft be 1 gallon and that a "secondary" standard, consisting of a commercial measure which has been carefully calibrated with water, be used for testing purposes to avoid contamination of the regular standard. Other necessary modifications of the testing procedure for lubricating-oil meters should be obvious, and further specific reference to these devices will be omitted.

The cycles of operation of a meter are not indicated or recorded as such on an assembled meter-type device. One complete operating cycle of a retail meter produces a delivery of only a fractional part of one of the primary delivery units. The indicating elements are gear-driven from the meter, and these operate ordinarily in repeating cycles. Meter-type devices need not be tested, therefore, at each of a long series of indicated deliveries; it will be sufficient to utilize only 5-gallon drafts on gasoline-dispensing devices, and, similarly, only drafts of a single amount, appropriate to the design and normal delivery, on devices for dispensing other liquids.

A testing draft is made by operating the meter until an exact indication of an even gallon is given. For example, on a nominal 5-gallon draft, the delivery is terminated when an even 5 gallons is indicated. The error of the delivery is then read from the graduated neck of the standard. Discharge rates for use in testing retail meter-type devices are specified in code paragraph N.1.1. For the "normal" test, made at the "maximum discharge rate developed under the conditions of installation", the effort should be to maintain maximum flow with the fully-opened discharge valve for as much of the delivery as practicable; some "tapering off" close to the end of the delivery will be necessary to obtain an exact indication of the desired amount and perhaps also to avoid overflowing the standard as a result of the foaming characteristics of the liquid, but this slowing down of the delivery should be kept at a minimum and any considerable amount of trickle-flow should be avoided. The "special" test at slow flow should be fairly accurately timed, and for this test the effort should be to maintain the delivery at the constant rate, for a gasoline-dispensing device, of 5 gallons per minute.

Before actual testing is begun the indication of the "visigage" or "sight glass" designed to show that the system is properly filled should be checked; if this element is not full, leakage has occurred, or some liquid has been withdrawn from the hose, or there has been a normal contraction of the gasoline as a result of a temperature drop. If it is considered necessary to make an elapsed-time test, the general procedure previously outlined for piston-type devices should be followed. At intervals throughout the test the character of the liquid visible in the sight glass should be observed; if the liquid contains bubbles, this indicates that the air eliminator is not functioning properly. At some stage of the test, the discharged valve should be opened and the nozzle shaken while the pump motor is cut off, to check on the presence and proper functioning of the anti-drain valve required by specification S.2.5. In the course of the test the indicating elements should be cleared to zero reading from some higher reading several times, to check on the accuracy with which the elements are returned to a true zero indication, and to check on the correct functioning of the zero-set-back interlock mechanism if the device is one equipped with such a mechanism. (G–R.2.) This interlock mechanism is designed to require that once the hose has been hung up on the hose hook, the indicating elements must be cleared to zero before the pump motor can again be started.

If the device computes the money values of deliveries, the accuracy of the money-value indications is just as important as the accuracy of the indications of gallons delivered. However, since both sets of indicators are geared to the meter, it is highly improbable that the money-value indications will get out of phase with the gallonage indications; if the money values are properly related to gallonage indications at a few points, it is reasonable to assume that proper relation will be maintained at other points. Accordingly it will be adequate to check the accuracy of the money-value computations at only two or three different gallonage indications, at whatever price-per-gallon the device happens to be set at the time of the test.

Duplicate observations are recommended, particularly if a device is found to be inaccurate. As minimal procedure on a gasoline-dispensing device, it is recommended that two 5-gallon drafts be made as "normal" tests and two 5-gallon drafts be made at the slow discharge rate. In making these observations, the indicating elements should be reset to zero following each 5-gallon draft. There is no particular advantage in running the indications up beyond the 5-gallon point insofar as the repetitive cyclic operation of the mechanism is concerned. However, a 10-gallon test draft (or even a larger draft) will be advisable if the performance is found to be in error at either fast or slow speed by an amount very close to the applicable tolerance, for the reason that the prescribed tolerances are proportionately greater on small deliveries than on large deliveries. This greater tolerance on small deliveriés permits a slight initial error in addition to the "multiplying" error resulting from the basic condition and adjustment of the meter assembly. But if a meter has, for example, a negligible initial error and a multiplying error slightly greater than that contemplated by the tolerances, this might perform within tolerance on a 5-gallon test draft but be in error in excess of the tolerance on a larger test draft. It is recommended, therefore, that when the 5-gallon error approaches the tolerance limit, a supplementary pair of observations be made on test drafts of at least 10 gallons. In making such observations, the first 5 gallons (approximately) of the delivery is made, the reading on the graduated neck of the standard is recorded, and the standard is emptied and drained; without stopping the pump or resetting to zero, the remainder of the 10-gallon draft is then drawn, and the reading of the standard is recorded. The two readings are then combined algebraically to arrive at the error on the total nominal delivery of 10 gallons.[12] A duplicate 10-gallon draft should then be made. Should the errors on these 10-gallon drafts be in excess of the applicable 10-gallon tolerance, rejection is in order.

Code paragraph S.2.6. requires on a meter-type device, either retail or wholesale, "an effective mechanical air eliminator or other effective means to prevent passage of air or vapor through the meter." The effective functioning of such an element can be demonstrated by the artificial introduction of air into the system (as by loosening a connection in the line, such as a union, on the supply side of the pump) and comparing the accuracy of the deliveries under this condition and under normal condition. This special procedure is wholly impracticable, however, as a routine testing operation; normally it is not necessary; and it is recommended that it be followed only when a device is being examined for pattern approval, or in those special cases of devices in service where erratic performance of the device or other indication of trouble with the means for air-elimination makes it advisable to locate definitely the source of the difficulty. In any event, the official should not himself take the responsibility for "cracking a connection" or otherwise artificially introducing air into the system of a commercially installed device; this should be done only by a service man or representative of the owner of the device under the supervision of the official. If the air-vent line from the air eliminator is plugged or constricted, it is obvious that the air eliminator can not operate as designed; in such a case no demonstration is required, and immediate correction of the fault should be ordered.

WHOLESALE METERS: The amount of liquid discharged by a wholesale meter per cycle of its operating parts is, of course, greater than in the case of a retail meter, the wholesale meter, generally speaking, being a much larger instrument than the retail meter. The situation as to the general character of the test is the same, however, for

[12] Give each individual reading its proper sign—plus or minus. If both readings have the same sign, the error on the 10-gallon draft is the sum of the individual readings. If the two readings have opposite signs, the error on the 10-gallon draft is the difference between the two individual readings, this difference being given the sign of the larger reading; for example, if the individual readings were +3 cubic inches and —15 cubic inches, the 10-gallon error would be —12 cubic inches.

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wholesale as for retail meters; that is, it is not necessary that tests be made at each of a long series of indicated deliveries. For the wholesale meter, tests are customarily made at deliveries of only a single nominal amount, this amount being the capacity of the prover being utilized. Reference is made again to code paragraph N.1.2., which carries the statement, "For wholesale devices, testing drafts should be equal to at least the amount delivered by the device in 1 minute at its maximum discharge rate", and to the discussion on prover sizes in an earlier portion of this chapter under the side title "Testing Apparatus".

The discharge rates for use in testing wholesale meters are specified in code paragraph N.1.1. for both normal and special tests, the normal tests to be made at the maximum discharge rate developed under the conditions of installation, and special tests to be made at slow discharge rates. The slow rate is specified as 15 gallons per minute for a meter smaller than 2 inches in rated size, that is, one designed for installation in a line having a pipe size of less than 2 inches; for larger meters the slow rate is specified as 20 percent—one-fifth—of the maximum rate marked on the meter. But in either case, if the meter is marked to show a minimum discharge rate less than the slow rate specified, the lower marked rate should be utilized for the tests at slow rate. Other "special" tests may be made as circumstances dictate "to develop the operating characteristics of meters".

In the preceding discussion covering testing procedures for retail meter-type devices, recommendations have been made or cautions expressed with respect to maintaining constant the discharge rate which applies in a particular test, overflowing of the standard (prover), return of the indicating elements to accurate zero positions, duplicate observations, and functioning of the air eliminator; the same principles apply when testing wholesale meters.

If reasonable care is exercised to avoid using a prover under conditions conducive to temperature changes of the testing medium, temperature measurements need not be made in connection with the testing of wholesale meters by the weights and measures official.

Testing Outlines

(For tests of liquid-measuring devices by weights and measures officials.)

Note.—The following outlines are specifically for the testing of gasoline-dispensing devices. Such modifications as are appropriate for the testing of liquid-measuring devices used for dispensing other liquids will be apparent.

See text, beginning on page 128, for the special case of a device which shows evidence of leakage back to storage.

Case I.—Piston-type dry-hose device, 5-gallon capacity: [13]

1. Discharge about 1 gallon of gasoline into the 5-gallon standard, return the piston to zero position, and drain the hose for the standard 10-second drainage period.
2. Thoroughly wet the inside of the 5-gallon standard with the gasoline which it contains, dump the contents, and drain the standard for the standard 10-second drainage period.
3. At a fairly rapid rate, operate the piston through a complete stroke, to the capacity stop and back to zero position, discharging through the hose into the 5-gallon standard, and drain hose as in step 1. As the piston approaches its top position, check the tallying element (counter) to see that it does not register prematurely.
4. Read the error of the delivery from the graduated neck of the standard. (The standard must rest on a level surface or be suspended from its bail when a reading is made. Read to the bottom of the meniscus of the liquid.)
5. Dump the contents of the standard and drain this as in step 2.
6. As a check observation, repeat steps 3, 4, and 5.
7. If the device is equipped with a special can-filling outlet, operate the piston through a complete stroke, discharging through this special discharge outlet into the standard, and repeat steps 4 and 5. Then repeat steps 3, 4, and 5.
8. At a rate closely approximating 5 gallons per minute (1 gallon per 12 seconds) operate the piston through a complete stroke, discharging through the hose into the standard, and repeat steps 4 and 5.
9. As a check observation, repeat step 8, except that when emptying the 5-gallon standard

[13] Necessary modifications of this outline for devices having capacities smaller than 5 gallons will be apparent.

some gasoline should be poured into one of the other standards. (Each of the standards to be used in carrying out step 10 or step 11 should be thoroughly wetted on the inside and drained for the standard 10-second period, immediately prior to its use.)

10. As in step 3, using the appropriate standard, test the device for accurate delivery at each intermediate mechanical stop provided. (Such stops will probably be provided for deliveries of 1, 2, 3, and 4 gallons.)
11. If no intermediate stops are provided but there is a graduated vertical scale, test the latter, as in step 3, at not less than two points, for example, at 1 gallon and 3 gallons, terminating the up-stroke of the piston according to the indication on the scale.
12. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Case II.—Mechanical-stop, measure-in, dry-hose, visible-type device:

1. Discharge about 1 gallon of gasoline into the 1-gallon standard, and drain the hose for the standard 10-second drainage period.
2. Thoroughly wet the inside of the standard with the gasoline which it contains, dump the contents, and drain the standard for the standard 10-second drainage period.
3. "Measure-in", into the visible chamber, by means of the mechanism provided, 1 gallon of gasoline, initially filling to a point at least ½ inch above the overflow and allowing at least 10 seconds for the liquid to level-off. Check the accuracy of the visual indication of this amount according to all indicators provided.
4. Discharge the contents of the visible chamber into the 1-gallon standard, closing the discharge valve 10 seconds after the main flow has ceased. Drain the hose as in step 1.
5. Read the error of the delivery directly from the graduated neck of the standard. (Note cautions as in step 4 of case I.)
6. Dump the contents of the standard and drain

this for the standard 10-second drainage period.

7. As a check, repeat steps 3, 4, 5, and 6, except that if a 2-gallon standard is to be used on the next observation, the 1-gallon standard is to be emptied into the 2-gallon standard and the latter is then to be thoroughly wetted, emptied, and drained for the standard 10-second drainage period. (Each new standard to be used is to be similarly wetted and drained just prior to its use.)
8. Proceed as in steps 3, 4, 5, 6, and 7 to make duplicate observations on nominal deliveries of 2 gallons, 3 gallons, and so on up to the capacity of the device, utilizing the appropriate standard or combination of standards.
9. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Case III.—Mechanical-stop, measure-out, dry-hose, visible-type device, and eye-measure, wet-hose, visible-type device: [14]

1. Discharge about 1 gallon of gasoline into the 1-gallon standard, and if the device is of the dry-hose type drain the hose for the standard 10-second drainage period.
2. Pump gasoline into the measuring chamber to a point ½ inch or more above the zero overflow, allowing at least 10 seconds for the liquid to level off.
3. Thoroughly wet the inside of the 1-gallon standard with the gasoline which it contains, dump the contents, and drain the standard for the standard 10-second drainage period.
4. Make a nominal 1-gallon delivery into the 1-gallon standard, draining the hose as in step 1 if the device is of the dry-hose type. Check the accuracy of the visual indications of this amount according to all indicators provided.
5. Read the error of the delivery directly from the graduated neck of the standard. (Note cautions as in step 4 of case I.)

[14] This outline is based upon the availability of standards of capacities of 1, 2, 3, 4, and 5 gallons. Modifications to adapt the outline to circumstances in which fewer standards are available are suggested by the text on page 131.

6. Dump the contents of the standard and drain this as in step 3.
7. As a check, repeat steps 2, 4, and 5.
8. Dump the contents of the 1-gallon standard into the 2-gallon standard. Thoroughly wet the inside of the 2-gallon standard with the gasoline which it contains, dump the contents, and drain the standard for the standard 10-second drainage period.
9. Repeat step 2.
10. Make a nominal 2-gallon delivery into the 2-gallon standard, draining the hose, if appropriate, as in step 1 and checking visual indications as in step 4, and read the error and drain the standard as in steps 5 and 6.
11. As a check, repeat steps 2 and 10, except that the contents of the standard is to be dumped into the 3-gallon standard.
12. Wet and drain the 3-gallon standard as in step 3.
13. Proceed as in steps 2, 10, and 11 to make duplicate observations on nominal deliveries of 3 gallons, 4 gallons, and so on up to the capacity of the device, utilizing the appropriate standard or combination of standards. Whenever a delivery must be made in two parts, make the second part of the delivery into the larger standard, and combine the "error" readings of both standards, algebraically, to derive the error on the total delivery.
14. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Case IV.—Retail meter-type device:

1. Without starting the pump motor, open the discharge valve and shake the nozzle to check the presence and proper functioning of the required anti-drain valve.
2. Discharge about 1 gallon of gasoline into the 5-gallon standard, thoroughly wet the inside of the standard with the gasoline which it contains, dump the contents, and drain the standard for the standard 10-second drainage period.
3. Make a nominal 5-gallon delivery into the 5-gal-

lon standard at "normal" (maximum) rate. Keep the discharge valve fully open for as much of the delivery period as practicable, slowing the delivery only to avoid spillage and to make an accurate setting of the indicating elements of the device at 5 gallons.

4. Read the error of the delivery directly from the graduated neck of the standard. (Note cautions as in step 4 of case I.)
5. Dump the standard and drain this as in step 1.
6. If the device is a "computer", check the computed price for the indicated gallonage at the price per gallon for which the device is set.
7. Clear the indications of the device to zero, checking the accuracy of the resulting zero indication for both gallons and money value.
8. As a check, repeat steps 3, 4, 5, 6, and 7.
9. At a discharge rate closely approximating 5 gallons per minute (1 gallon per 12 seconds), make a nominal 5-gallon delivery into the standard, and repeat steps 4, 5, and 7.
10. As a check, repeat step 9 except as follows: If the device is a "computer", interrupt the discharge at a nominal delivery of 3 gallons and note the computed price; later, check the accuracy of this computation.
11. If the value of the error at either the normal or the slow discharge rate, as determined by the observations prescribed above, closely approaches the value of the appropriate tolerance, make a nominal 10-gallon discharge at the normal rate or at the slow rate, as the case may be, as follows: First deliver into the standard approximately 5 gallons of gasoline, but do not stop the pump motor. Record the reading of the graduated neck of the standard, dump the standard, and drain this as in step 2. Continue the discharge into the standard until the device indicates exactly 10 gallons. Record the reading of the graduated neck of the measure and combine this algebraically with the error recorded for the first portion of the delivery to arrive at the error for the total 10 gallon delivery. Repeat steps 5 and 7.

12. If on step 11 the error is found to exceed the tolerance, repeat step 11 as a check.
13. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Case V.—Wholesale meter:

1. Level the prover in a position to receive the discharge from the meter under test.
2. Without starting the pump motor, open the discharge valve and shake the nozzle to check the presence and proper functioning of the required anti-drain valve.
3. With the prover discharge valve closed, thoroughly wet the inside of the prover with the product dispensed by the meter. (This is best accomplished by filling the prover to capacity, but if thoroughly done the prover walls may be wetted by means of a hose or by spraying.)
4. Start the prover discharge pump, open the discharge valve, and continue to pump, with open discharge valve, for 30-seconds after the main discharge from the prover has ceased. Then tightly close the discharge valve. Finally, stop the pump.
5. If the meter is equipped with a set-back counter to tally individual deliveries, reset this to zero reading; if the meter is not so equipped, record the meter reading and note the reading to be obtained in step 6—original reading plus prover capacity.
6. At "normal" (maximum) rate, make a delivery from the meter into the prover corresponding in nominal amount to the capacity of the prover. Keep the meter discharge valve fully open for as much of the delivery period as practicable, slowing the delivery only to avoid spillage and to make an accurate setting of the indicating elements of the meter at the indication corresponding to the prover capacity or at the indication as computed in step 4.
7. Read the error of the delivery directly from the graduated neck of the prover. (Read to the bottom of the meniscus of the liquid.) The tolerance is that on "normal" test.

8. Dump the contents of the prover, following exactly the procedure outlined in step 4.
9. As a check, repeat steps 5, 6, 7, and 8.
10. Repeat step 5. At a rate of 15 gallons per minute for a meter smaller than 2 inches in rated size, 20 percent of the marked maximum rate for a meter 2 inches or over in rated size, or any lower minimum rate marked on the meter, make a slow delivery into the prover corresponding in nominal amount to the capacity of the prover. Make an accurate setting of the indicating elements of the meter at the desired reading.
11. Repeat steps 7 and 8. The tolerance is that on "special" test.
12. As a check, repeat steps 5, 10, and 11.
13. Make any additional "special" tests considered necessary or advisable to develop the operating characteristics of the meter, applying the "special-test" tolerances.
14. If the meter is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Supervision Over Use.—The opportunities for short measure in the retail sale of gasoline through liquid-measuring devices of any type are such that supervision over such sales is strongly recommended. The opportunities mentioned result largely from the carelessness of the purchasers in exercising reasonable diligence to protect their own interests, thus leaving the way open to a dishonest operator to perpetrate a fraud and gain an illegal profit. Mechanical safeguards against fraudulent operation of a retail device and means for self-protection by the customer are provided to the maximum extent considered practicable; but the effectiveness of these safeguards and means is impaired or nullified when the customer, as all too often is the case, pays no attention to the operator or to the device when a delivery of gasoline is being made to him.

The official can do something in the direction of supervision by observing from time to time certain conditions with respect to the gasoline-dispensing devices themselves which indicate carelessness on the part of the operator, or a "set-up" for an unobservant customer, or a faulty mechanical condition of the device. Examples of this sort of thing are pistons left in raised position, below-zero level of liquid in visible measuring chambers, and empty or low liquid level in sight glasses. Containers around a filling station partially filled with gasoline would be viewed with suspicion. Large shortages, however, are more apt to result from deliberate delivery of less than the amount represented, as by stopping the up-stroke of a piston short of full stroke, starting a delivery from a visible device from the 1- or 2-gallon point rather than from zero, making an intentional "mistake" in announcing the money value of a delivery, and the like. Such "errors" as these will not be made on every delivery, but will only be tried when an unobservant or inattentive customer is making a purchase.

In order to take effective steps, possibly including prosecution, to stop practices such as are mentioned above, definite evidence must be obtained. The best way to get this evidence is through actual test purchases, made under conditions duplicating those which prevail in ordinary commercial transactions. For this purpose one or more automobiles must be specially fitted to adapt them for use in making the try-out purchases. A special, concealed tank is supplied to hold necessary fuel for operation of the automobile. The fuel line is disconnected from the regular gasoline tank and concealed means are provided for completely draining from this tank any gasoline placed therein, or the tank is made removable so that its contents may be drained out. In some cases, a special form of removable measure is employed to receive the delivery, the arrangement being such that this measure is concealed from an ordinary observer. In use, the automobile, with regular tank empty, and driven by someone who will not be recognized by a filling-station attendant as associated with the weights and measures office, is served in normal manner with, for example, a nominal delivery of 5 gallons of gasoline. Within a few minutes the automobile will be driven to a rendezvous with the weights and measures official, who measures the delivery of gasoline with his standard measures.

Try-out purchases of this sort should be made when particular stations are suspected by the official of giving short measure in sales of gasoline. Also, it is recommended that spot checks or general surveys be made from time to time, as a part of the general supervisory program of the department.

References

Booklets descriptive of their products are issued by manufacturers of liquid-measuring devices, and not infrequently such booklets include diagrams, cut-away illustrations, operating and installation instructions, and other data which will be very useful to the weights and measures official. Sometimes material is prepared by a manufacturer particularly for the purpose of supplying information to officials.

The Petroleum P. D. Meter Code referred to in the preceding text was issued in July, 1946 as a tentative code under the full title of "ASME–API Code for Installation, Proving and Operation of Positive Displacement Meters in Liquid Hydrocarbon Service." It is also known as API Code No. 1101. Sponsor organizations are the American Society of Mechanical Engineers, 29 W. 39th Street, New York, N. Y., and the American Petroleum Institute, 50 W. 50th Street, New York, N. Y. Much useful general information may be obtained from a study of this code.

The following references are to papers and discussions on the general subject of liquid-measuring devices and associated topics (including liquefied petroleum gas), appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M43, Thirteenth Conference Report, 1920, pages 59–64.
M48, Fourteenth Conference Report, 1921, pages 64–72.
M51, Fifteenth Conference Report, 1922, pages 111–120.
M55, Sixteenth Conference Report, 1923, pages 50–53.
M74, Nineteenth Conference Report, 1926, pages 57–59, 95–103.
M80, Twentieth Conference Report, 1927, pages 95–102.
M87, Twenty-first Conference Report, 1928, pages 104–128.
M101, Twenty-second Conference Report, 1929, pages 79–82, 104–116.
M129, Twenty-fourth Conference Report, 1931, pages 41–42, 138–139.
M156, Twenty-fifth Conference Report, 1935, pages 54–59.
M157, Twenty-sixth Conference Report, 1936, pages 110–116.
M161, Twenty-eighth Conference Report, 1938, pages 17–18.
M164, Twenty-ninth Conference Report, 1939, pages 45–48.
M167, Thirtieth Conference Report, 1940, pages 48–59, 62–77, 121–129.
M170, Thirty-first Conference Report, 1941, pages 21–33.
M186, Thirty-second Conference Report, 1946, pages 56–63, 71–72.
M189, Thirty-third Conference Report, 1947, pages 79–94.
M195, Thirty-fourth Conference Report, 1949, pages 22–42, 75–76.
M199, Thirty-fifth Conference Report, 1950, pages 30–36, 53–79.

Chapter 14.—GREASE-MEASURING DEVICES

Description.—A grease-measuring device is defined in the code for such devices in the following terms:

> A mechanism or machine designed to measure grease or transmission oil and to deliver such material by definite volume.

The code also carries the following limiting statement:

> This code does not apply to (a) devices constructed to weigh grease or transmission oil and to deliver such material by weight, (b) devices obviously designed solely for the high-pressure lubrication of bearings and similar parts, and (c) devices used solely in operations for which a flat rate is charged, no variation in the charges being made because of the varying amounts of lubricant delivered.

These limitations will be observed in the discussions in this chapter.

A number of years ago hand-operated, piston-type grease-measuring devices were in rather widespread use. These were similar in basic design to piston-type liquid-measuring devices except that intermediate stops were not provided. The nominal amount discharged was usually 1 pint per stroke. Some devices were equipped with tallying devices to register the number of strokes comprising a delivery, but others were not so equipped. Many units were of the so-called "bucket" type, these being portable units attached to containers holding about 25 pounds of lubricant. There have been units which employed relatively larger piston-and-cylinder combinations equipped with means to indicate the amount discharged as the piston rose in the cylinder; in this design the maximum "charge" of the unit was the total effective volume of the cylinder. "Measuring gears" instead of other measuring means have also been employed; this design was on somewhat the same measuring principle as a meter, the lubricant being drawn through the gear system and the movement of the gears being indicated in terms of volumetric units. Small meters for measuring and indicating the amount of lubricant dispensed were also developed. The use of air pressure to cause operation of the units became common, and at least one design was equipped with an electrically-operated pump. Some units were designed for installation on commercial containers having various capacities, up to a maximum of perhaps 100 pounds; complete dispensing units were also marketed.

Meter units, operated by air pressure or by means of hand pumps, now seem largely to have superseded other types of devices, although "non-measuring" piston-type units are still being manufactured.

Inspection.—Grease-measuring devices should be individually inspected for compliance with the applicable provisions of general specifications G–S.1., G–S.2., G–S.3., G–S.4., and G–S.6., general regulations G–R.2., G–R.3., and G–R.5., and the specifications of the code for grease-measuring devices. Inspection should precede testing.

Testing Apparatus.—It is obvious that it is impracticable because of the contamination which would result, to use regular standards to receive deliveries of transmission oils and gear lubricants from grease-measuring devices. Accordingly, some form of "secondary" standard must be utilized. The secondary standard may be a special testing device designed for this particular service or it may be a reusable commercial measure which has been specially calibrated.

Considering the factors of accuracy, convenience of use, and ease of cleaning, probably the most satisfactory type of secondary standard is an adaptation of a special "plunger-type" tester which has given good service over a period of years in at least one State. This is illustrated by the drawings in figure 13. The tester is essentially a partially-graduated piston-and-cylinder combination designed to receive a nominal 1-pint delivery of grease and to measure directly the number of cubic inches by which the delivery exceeds or falls short of 1 pint. The piston is fitted with a piston leather to provide a tight seal with the cylinder walls. When the piston is withdrawn to the maximum extent the cylinder capacity is greater than 1 pint, and the tester is then in condition to accommodate a nominal 1-pint delivery of lubricant. Following the delivery the piston is advanced until the surface of the lubricant in the cylinder is raised to the top edge of the cylinder wall; this point can be determined accurately by use of a small metal "striking bar" or spatula to level off the surface of the lubricant. The error of the delivery in cubic inches is then read directly from the graduations on the piston rod. Following the measurement the

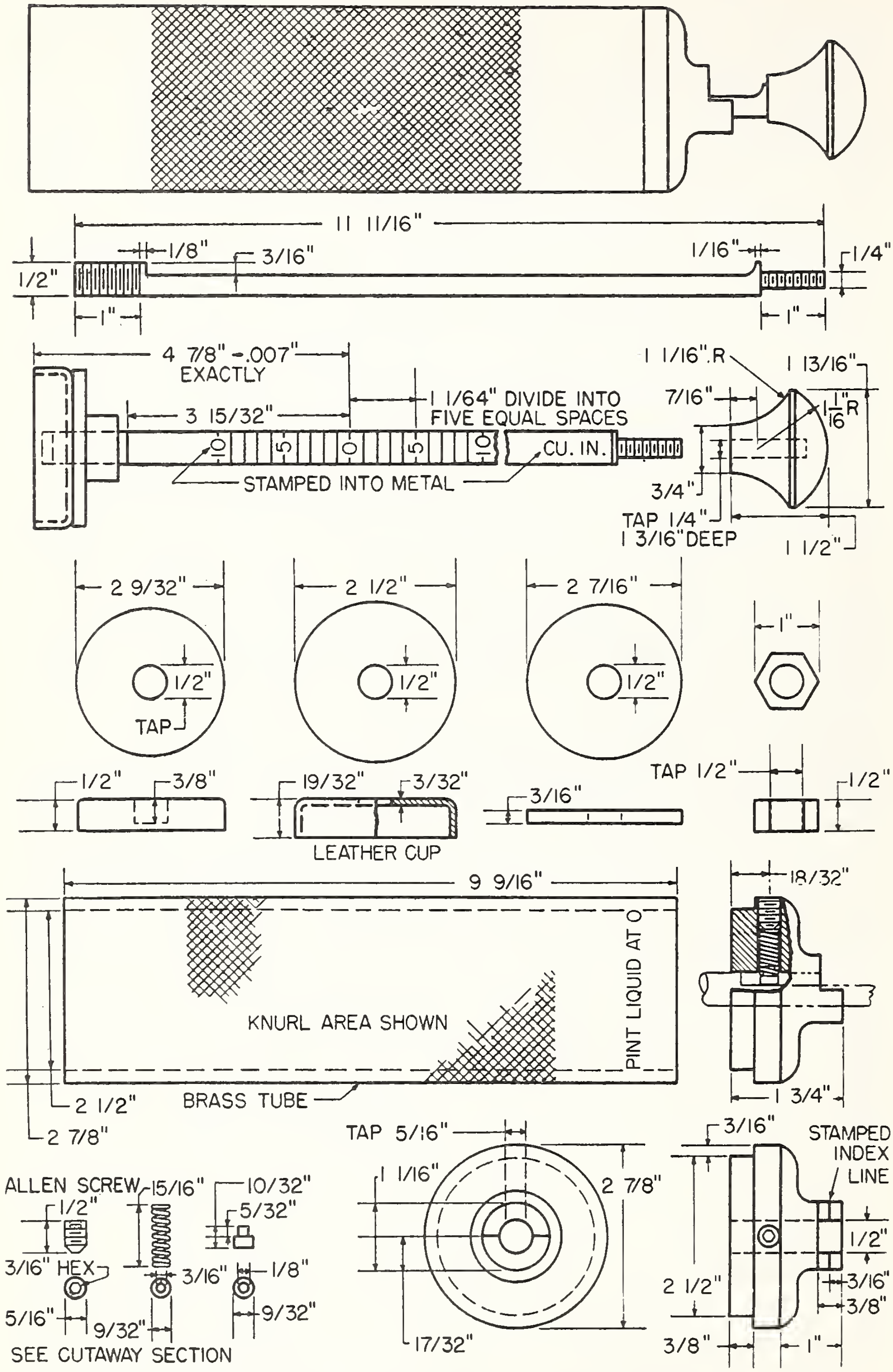

FIGURE 13. *Working drawing of special 1-pint plunger-type tester for grease-measuring devices.*

contents of the cylinder is readily expelled by advancing the piston to the maximum extent, which will bring the top of the piston to the level of the top edge of the cylinder wall.

The drawings in figure 13 have been dimensioned to produce an accurate tester, but a tester having dimensions different from these may be designed and this would be satisfactory if the essential characteristics of the design are maintained. The basic requirements are (1) that when the piston is so positioned that the zero graduation on the piston rod and the index line are in coincidence, the level-full capacity of that portion of the cylinder above the top of the piston shall be exactly 28.875 cubic inches (1 liquid pint), and (2) that a change in the position of the piston in the cylinder equal to any one division on the graduated scale on the piston rod shall produce a change in the capacity of that portion of the cylinder above the top of the piston equal to exactly 1 cubic inch. It should be noted, however, that the internal diameter of the cylinder should be kept reasonably close to the 2½-inch dimension shown on the drawing; if this diameter is considerably increased, sensitiveness will be sacrificed, and if this diameter is considerably reduced, convenience of operation of the tester will be sacrificed.

A commercial, metal, 1-pint measure may be calibrated carefully with water and may then be used as a secondary standard. Such a measure should be of small diameter, without a pouring lip or rim, and should be accurate when filled "level full". A small auxiliary cylindrical "cup" having a capacity of 1.25 cubic inches when filled flush with the top, will be required as a tolerance measure, since the error of a delivery can not be read on the 1-pint measure. A "striking bar" will be needed to level-off the lubricant in the standard; a spatula having a narrow blade about 5 inches long is recommended. The spatula will also be useful in removing the lubricant from the standard and from the tolerance measure, and for maximum utility for this purpose the end of the spatula should be cut square, with square corners. The inconvenience and difficulty of cleaning both the secondary standard and the tolerance measure between observations is unavoidable when using this apparatus.

As an alternative to the secondary standard discussed in the preceding paragraph, some jurisdictions have used disposable paperboard measure-containers. It may be possible to obtain 1-pint cylindrical paperboard measure-containers of sufficiently uniform accuracy that these can safely be used as secondary standards. They must be of rigid construction to avoid any distortion during use, the lot must be adequately sampled, and the samples must be carefully tested to establish beyond question their *uniform* accuracy, before the official is justified in using these measure-containers as secondary standards. The reason for going to the paperboard container for this purpose is to avoid the cleaning necessary in the case of a metal standard; the paperboard container would be used once and would then be discarded. The necessity remains for the use of the tolerance measure. The method is definitely open to the question of the accuracy of the paperboard container within the close limits appropriate for a standard. In view of this question, the method is of doubtful reliability and is not to be recommended.

Testing Procedure.—It is considered that "testing drafts" of 1 pint will give satisfactory results when testing grease-measuring devices. The testing medium is necessarily the lubricant being dispensed by the device under test. The speed of operation for testing purposes is treated in code paragraph P.1. For routine testing it is recommended that deliveries be made at fast and at slow speeds. On a hand-operated piston-type device the fast speed would be one resulting from a reasonably vigorous operation of the operating crank or lever, and the slow speed should be from one-half to one-fourth of this. On an air or power operated unit, the fast speed should be the maximum speed of which the installation is capable (but within any maximum air-pressure limitation shown on the device), and the slow speed should be from one-half to one-fourth of this. Duplicate observations should be made in all cases except as noted. The "initial" pint should be separately checked at fast and at slow speed, the mechanism being reset to zero reading before each delivery. After the last of these deliveries, and without resetting to zero, the "second" and the "third" pints should be separately checked, the speed of operation being whatever is believed to be normal for the installation. If the results on these tests are in good agreement with the results on tests of the "initial" pint, duplicate observations may be omitted; otherwise reset the mechanism to zero reading and, as a check, test again, separately and without further resetting to zero, the initial, the second, and the third indicated pint.

In all cases where the amount delivered is determined by bringing an indicator into coincidence with a graduation—as on a meter—care should be exerted to make a precise setting. If, inadvertently, the indicator is caused to advance too far, the observation should be repeated.

Actual manipulation of the volumetric testing apparatus has been described sufficiently in the section on such apparatus to make it unnecessary to discuss that subject further. Mention may appropriately be made at this point, however, of a gravimetric method of testing grease-measuring devices which offers some distinct advantages, although it necessarily involves some complications. The official may decide between volumetric and gravimetric methods upon the basis of his own evaluation of their relative advantages.

In brief, the gravimetric method of testing a grease-measuring device contemplates the weighing, rather than the measuring, of the amounts of lubricant delivered. In the case of any particular device the weight per pint of the lubricant being dispensed by the device must first be known. Thereafter it is necessary only to weigh the deliveries and, by simple arithmetic, to compute the amounts of the deliveries and their errors in terms of pints and cubic inches.

The equipment required for testing by the gravimetric method presents no complications. A cylindrical measure of the slicker-plate type having a capacity of 1 pint or one quart, preferably the latter, will be needed for use in determining the weight per pint of the lubricant. The weighings can be made on a good over-and-under scale such as the official regularly uses for the check-weighing of packages, on which determinations can be made to $\frac{1}{16}$ ounce. Test deliveries from the device can be received in any container which is available at the location where the test is being made; the only requirements are that the container be large enough to contain the testing drafts and small enough to be accommodated on the commodity platter of the scale.

The only really troublesome factor in this gravimetric method is determining the weight per pint of the partic-

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ular lubricant being dispensed by the grease-measuring device being tested. The densities of gear lubricants made from different formulas vary considerably—enough so that it is not safe, for testing purposes, to use any single value for all gear lubricants. Furthermore, the weight per unit volume of a particular lubricant will vary depending upon its temperature, and it is not convenient to determine temperatures and make temperature corrections in any event. It follows, therefore, as a practical matter, that the official should determine the weight per pint of the lubricant involved each time a grease-measuring device is to be tested by the gravimetric method. This operation is not a complicated one and does not require much time. It is performed as follows:

Assume that the capacity of the standard is 1 quart. First determine the tare weight of the empty, clean standard and its slicker plate, to the nearest $1/16$ ounce. This value should be permanently recorded and the determination need not be repeated each time a device is to be tested. Accurately fill the standard with lubricant from the device to be tested, using the slicker plate, and carefully removing any lubricant which may accidentally get on the outside of the standard. Weigh, to the nearest $1/16$ ounce, the standard and its contents and the slicker plate. Deduct from this gross weight the tare weight of the empty standard and the slicker plate. The result is the net weight of 1 quart of lubricant; divide this value by 2 to derive the weight per pint of lubricant. Then divide this weight per pint by 23 to derive the weight equivalent of the maintenance tolerance, per pint, or 1.25 cubic inches (4.33 percent); half of this value will be equivalent to the acceptance tolerance per pint.

From data said to be representative of transmission and differential lubricants, it appears that the weights per pint at 60° F. range from 0.9340 to 0.9945 pound, and that the approximate coefficient of expansion of these lubricants at 60° F. is 0.0004 per degree Fahrenheit. Based upon these limiting values, the weight of 1.25 cubic inches (the prescribed maintenance tolerance per pint) of the heaviest lubricant at 40° F. would approximate 0.70 ounce, and the weight of 1.25 cubic inches of the lightest lubricant at 80° F. would approximate 0.64 ounce; the mean of these weights is 0.67 ounce. The decimal equivalent of $11/16$ is 0.6875. For routine field testing by the gravimetric method, the value of the maintenance tolerance may safely be assumed to be $^{11}/_{16}$ ounce for any lubricant having a weight per pint within the limits stated above, at any temperature between 40° and 80° F. For similar conditions, the acceptance tolerance may be assumed to be $^{5}/_{16}$ ounce. However, in any case where precise results are required, the weight corresponding to the applicable tolerance should be computed from the weight per pint of the lubricant, as described in the preceding paragraph.

Having arrived at the weight per pint of lubricant, the test of the device can proceed rapidly as follows: Select some suitable container which will hold somewhat more than one pint, weigh it, and record its tare weight. Operating the device at fast speed, make a nominal 1-pint delivery into this container. Determine the gross weight of container and contents. Deduct the original tare weight of the container. The remainder is the net weight of the delivery, which can then be compared with the weight per pint of lubricant to determine the weight of any excess or shortage. Reference to the appropriate tolerance figure previously computed will show at once whether or not the error on the delivery is within tolerance.

Before the next observation the container is emptied, but it is not necessary that it be cleaned; most of the contents having been removed, it is only required to establish and record a new tare weight for the container and whatever lubricant remains in it. The next delivery is then made into the container, the net weight of the delivery is computed using the new tare weight, and the error is determined as before. The test then proceeds in this manner until all observations have been completed, one tare-weight observation and one gross-weight determination being made for each observation. The recommended sequence of observations is the same as has been recommended for the volumetric tests; that is, duplicate observations on nominal 1-pint deliveries of the first indicated pint at fast and slow speeds, single observations on nominal 1-pint deliveries of the second and third indicated pints at normal speed, and, if considered necessary, observations on an additional series of 1-pint deliveries, made at normal speed, representing, successively, the first, second, and third indicated pints.

In this gravimetric procedure, it may be found more convenient to balance out the container on the scale before each delivery into the container, instead of determining and recording in each case the tare weight of the container. In this case the net weight of each delivery will be determined direct, instead of being computed from gross and tare weights as previously described.

A step-by-step outline of procedure under the gravimetric method will not be appended because of the simplicity of the method once the basic information on weight per unit volume has been obtained.

Testing Outlines

(For tests of grease-measuring devices by weights and measures officials.)

Case I.—When the secondary standard is a plunger-type tester:

1. If the device is manually operable, bring the crank or lever to the proper "zero" position. Set the indicator of the device at zero reading. Withdraw the piston of the tester to the limit of its travel.
2. Make a nominal 1-pint delivery into the cylinder of the tester at a moderately fast speed if the device is manually operable or at maximum speed if the device is operated by air pressure or power.
3. Carefully advance the piston of the tester to bring the level of the lubricant even with the top edge of the cylinder wall, using the striking bar or spatula to verify the accuracy of this operation.
4. Read the error on the delivery directly from the graduations on the piston rod of the tester.
5. Expel the contents of the tester.
6. Reset the indicator of the device to zero reading and, as a check, repeat steps 2 through 5.
7. Reset the indicator of the device to zero reading and repeat steps 2 through 5 except operate the device at from one-half to one-fourth the former speed.
8. As a check, repeat step 7.
9. Without resetting the indicator of the device to zero reading, make a delivery of the second indicated pint, operating the device at normal

speed, and repeat steps 3, 4, and 5. In the same manner determine the error on the delivery of the third indicated pint.

10. If the errors so far determined are not in reasonable agreement, reset the indicator of the device to zero reading and, without subsequent resetting of the indicator, successively determine as in step 9 the errors on deliveries of the first, second, and third indicated pints, operating the device at normal speed.
11. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Case II.—When the secondary standard is a conventional measure:

Note.—The following outline is based upon a test to which maintenance tolerances are applicable. Modifications needed to apply acceptance tolerances should be apparent. One-half the contents of the tolerance measure may be estimated, as representing the acceptance tolerance on a 1-pint delivery.

1. If the device is manually operable, bring the crank or lever to the proper "zero" position. Set the indicator of the device at zero reading.
2. Begin a nominal 1-pint delivery by operating the device slowly until the tolerance measure is filled; then complete the delivery into the standard, operating the device at a moderately fast speed if it is manually operable or at a maximum speed if it is operated by air pressure or power.
3. Attempt to level-off the contents of the standard even with its top edge, using the striking bar or spatula.
   - (a) If there is an excess of lubricant in the standard, the delivery is in error in excess of the maintenance tolerance.
   - (b) If the standard is not filled wtih lubricant, add to the standard the contents of the tolerance measure; if this addition is enough or more than enough to fill the standard, the error on the delivery is within the maintenance tolerance.
   - (c) If following sub-step (b) the standard is still not filled with lubricant, refill

the tolerance measure from the device and then add its contents to the standard. If this addition is enough or more than enough to fill the standard, the original delivery is within the maintenance tolerance; otherwise, the error of that delivery exceeds the maintenance tolerance.

4. Clean out the standard and the tolerance measure and, as a check, repeat steps 1, 2, and 3. (If the first delivery was found to be short, the filling of the tolerance measure in step 2 may be omitted, in the expectation that the check delivery will also be short.)
5. Clean out the standard and the tolerance measure, and repeat steps 1 through 4, operating the device at from one-half to one-fourth the former speed.
6. Clean the standard and tolerance measure, as before. Without resetting the indicator of the device to zero reading, and operating the device at normal speed, successively determine the errors on deliveries of the second and third indicated pints as in steps 2 and 3.
7. If the errors so far determined are not in reasonable agreement, reset the indicator of the device to zero reading and, without subsequent resetting of the indicator, successively determine as in step 6 the errors on deliveries of the first, second, and third indicated pints, operating the device at normal speed.
8. If the device is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.

Chapter 15.—VEHICLE TANKS

Description.—The code for vehicle tanks defines a vehicle tank as "an assembly used for the delivery of liquids, comprising a tank, which may or may not be subdivided into two or more compartments, mounted upon a vehicle, together with its accessory piping, valves, meters, etc.", and a compartment is defined as "the entire tank when this is not subdivided; otherwise, any one of those subdivisions of a tank designed to hold liquid."

The weights and measures official is almost never called upon to deal with vehicle tanks other than those used for handling refined petroleum products, specifically kerosene, gasoline, and heating oil. Also, the official is concerned only when the vehicle tank is used for making commercial quantity measurements. Accordingly this discussion will be limited to vehicle tanks designed for the measurement of kerosene, gasoline, or heating oil.

A primary grouping of vehicle tanks may be made upon the basis of the two primary means provided for measuring the product carried. In the one case the vehicle-tank compartments are used as measures, being equipped with indicators to define their capacity fill points, and being calibrated much as in the case of any large-capacity liquid measure. In the other case the vehicle tank is equipped with one or more large-capacity fluid meters similar in general design to the wholesale-type meters discussed in the chapter on liquid-measuring devices. A design now very commonly employed is a combination of the two basic types described; that is, the vehicle tank is meter-equipped, but is designed to permit discharge of liquid through the meter or not at the option of the operator. Thus, with this combination design, full-compartment deliveries may be made and billed upon the basis of the calibrated compartment capacities, and partial-compartment deliveries may be made and billed upon the basis of the meter indications. In the code for vehicle tanks there are three groups of specifications, this division being brought about by the design differences just mentioned. The first group comprises "general specifications applicable both to vehicle tanks used as measures and to vehicle tanks equipped with meters". The second group comprises "additional specifications applicable only to vehicle tanks used as measures". The third group comprises "additional specifications applicable only to vehicle tanks equipped with meters". Obviously, all of the specifications apply to the combination design of vehicle tank intended for measurement either by compartment or by meter.

Another basic grouping of vehicle tanks may be made upon the basis of the character of the discharge from the compartments. Discharge by gravity can be made when the delivery is to an underground storage tank below the level on which the vehicle tank stands. If the delivery is to a receptacle above the level of the vehicle tank, the discharge must be made under pump pressure, and for such service (except in a few special cases) the vehicle tank is equipped with a pump, usually powered from the truck motor through a take-off from the transmission. In some instances the pump may be powered from its own small gasoline engine or may be electrically driven, power being generated by a small engine-driven generator. (In some locations such as bulk storage plants receiving deliveries from large transport trucks, where deliveries must be elevated, the necessary pumping is accomplished by means of portable or permanently-installed pumps separate from the vehicle tank.) Here again the combination unit is encountered, designed for either gravity or pump discharge as required by circumstances.

Present-day vehicle tanks are an evolution from a simple tank equipped with a draw-off faucet and mounted upon a wagon bed. Such tanks were used in early days for the delivery of kerosene, and measurement of the product was effected by means of 5-gallon measures—the so-called "tank wagon buckets". Some kerosene is still handled by vehicle tanks, but these devices are very largely used in the following services:

1. The transportation of gasoline and fuel oil between refineries or pipe-line terminals and bulk storage plants. The vehicle tanks used in this service are of relatively large capacity, ranging from 4,000 to 7,000 gallons, and are spoken of as "transport trucks" or "transports".

2. The wholesale delivery of gasoline to retail filling stations and garages. This is sometimes referred to as "metro-

politan delivery". The vehicle tanks used may be semi-trailers of relatively large capacity, comparable to some of the transports, (4,000 to 6,500 gallons) or single vehicles of medium or relatively small capacity ranging from 1,200 to 3,500 gallons.

3. The delivery of industrial, heavy fuel oil. The vehicle tanks used correspond roughly in capacities to the single vehicles used for metropolitan deliveries of gasoline (1,500 to 4,000 gallons).

4. The delivery of domestic fuel oil. The vehicle tanks used are usually of relatively small capacity, although they may occasionally approach the "medium" capacities of the vehicle tanks used for metropolitan deliveries of gasoline; the range is from 1,000 to 3,500 gallons.

5. The delivery of gasoline and domestic fuel oil in rural areas, including retail deliveries of gasoline to farms and other large private users. The capacities of the vehicle tanks used range from 400 to 2,300 gallons.

6. The delivery of gasoline directly to airplanes. The capacities of the vehicle tanks used range from 200 to 5,000 gallons.

The capacities of vehicle tanks are usually, but not invariably, rated to an even 100 gallons. Manufacturers will build tanks to the special order of the customer, but all regular designs except for the very small tanks provide for division into from 2 to 10 compartments. Compartment capacities range upward from 600 gallons for transports and from 100 gallons for other classes, according to available catalog information.

Pumping units, meters, and hose reels are ordinarily considered as accessories, to be supplied by the manufacturer as ordered by the customer. An exception is the "airplane refueler", which is always equipped with pumping means and at least one meter and hose reel; two independent meters and pumps, which may be operated simultaneously, are practically "standard" for these units. (It may be noted in passing that airplane refuelers may be equipped to remove gasoline from the tanks of an airplane as well as to deliver it to such tanks; the meter piping may be so arranged that these "reverse flows" can be metered, or reversible meters, designed to "subtract" the reverse flow, may be supplied.)

Metropolitan deliveries of gasoline are ordinarily made by gravity into underground storage tanks, so that pumping units are not to be expected on vehicle tanks in this class of service. Hose lines are short and of relatively large diameter. There appears to be a definite trend toward larger storage tanks at filling stations, and this makes possible a larger proportion of "full-compartment drops" than was formerly the case. Many tanks in this service are equipped with one or two meters, designed for operation under gravity flows. Piping and valves on these vehicle tanks are normally such as to permit, at the option of the operator, delivery through the meter or delivery without passage through the meter.

The transport truck in strictly "transport" service delivers at destination its entire load. As a vehicle tank, the transport is normally designed for gravity discharge only and is not equipped with a meter. Delivery may be from the rear or the side of the vehicle. However, some companies use vehicles which combine the functions of transports and vehicles for metropolitan deliveries. The vehicles essentially duplicate the true "transport" in size and general characteristics, and carry gasoline and other products from refinery, pipe-line terminal, or water terminal direct to large service stations, thus eliminating rehandling through a bulk station. Such vehicles may be expected to be equipped with meters.

Vehicle tanks in fuel-oil service frequently are required to deliver into tanks higher than the vehicle tanks themselves and at considerable distances from the vehicle tanks. Accordingly, pumps and hose reels (carrying up to 150 feet of hose) are regular equipment, and meters are to be expected. Ordinarily a vehicle tank will regularly be used for a particular kind or grade of oil, and so need be equipped with only one pump and one meter. If two grades of oil are carried, separate pumps and meters may be provided for each grade in order to avoid mixing and contamination. Delivery may be from the rear or the side of the vehicle. The oils used as industrial fuels are frequently very "heavy" oils which do not flow readily at ordinary temperatures; vehicle tanks used for delivering such oils may be equipped with heating coils to heat the fuel and thus facilitate its discharge from the vehicle.

Vehicle tanks in rural service are very frequently used for delivering a variety of petroleum products on a single trip. Gasoline, kerosene, and domestic fuel oil are the products normally handled. Possible contamination of one or another of these products must be guarded against, and so the piping arrangements and the meter hook-ups on these vehicle tanks may differ from those on vehicle tanks which normally carry but one variety of product. Delivery from a rural vehicle tank is ordinarily made from the rear of the vehicle.

The arrangement of piping, valves, and faucets on a vehicle tank may be simple or relatively complex. The most simple plan is a separate delivery line from each compartment terminating in a delivery faucet. When a pump is employed the pump suction line may be connected to the delivery line from any compartment by means of a short length of hose equipped with a quick-coupling fitting designed to be connected at the faucet. (See fig. 14.) Instead of having the lines from each compartment terminate in delivery faucets, these lines may

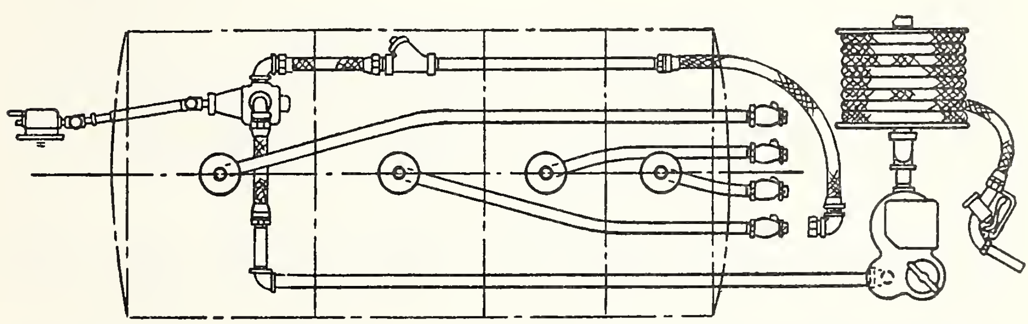

FIGURE 14. *Schematic diagram of simple piping arrangement on vehicle tank equipped for gravity or pump deliveries.*

be connected to a transverse line known as a manifold, and the manifold may have a single delivery faucet; a valve is required in each compartment line for the purpose of opening or closing off the line to the manifold. When the compartment-line valves are so interlocked that no such valve can be opened unless all other such valves are closed, the arrangement is known as a "selective" valve system.

A pumping system and hose reel can be connected with the manifold, permitting optional gravity or pump deliveries; or, the "gravity" faucet may be omitted, requiring all deliveries to be made through the pump and the "wet" hose connected to it. A meter may be introduced into the pump-discharge line, and the piping may be so arranged that all liquid from the pump must pass through the meter, or a by-pass line around the meter may be provided. Means may be provided for connecting the pump-suction line to an outside source of supply, permitting the pumping of liquid *into* a compartment through the hose line. Whenever one of these variations is introduced, the necessary valve or valves must be installed to control the flow of liquid as required. (See fig. 15.)

Immediately adjacent to the discharge orifice from a compartment, an "emergency" valve is ordinarily in-

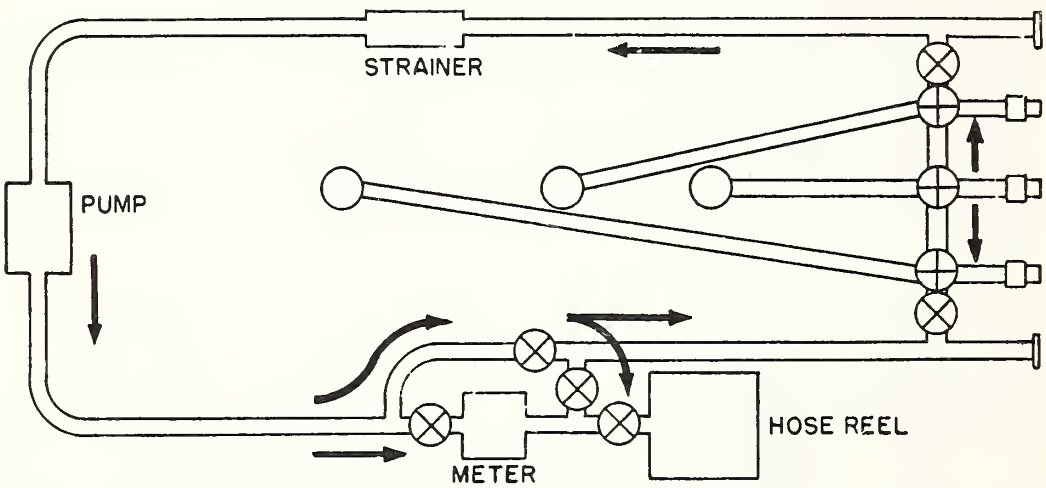

FIGURE 15. *Schematic diagram of manifolded piping on vehicle tank equipped for gravity, pump, and/or metered deliveries.*

stalled. The purpose of this valve is to close off the compartment from the delivery line so that in case of accident and damage to the vehicle lines the contents of the compartment will not be spilled onto the pavement or highway. Emergency valves may be controlled separately, either from the top of the tank or from the rear of the vehicle. Sometimes provision is made for automatic "gang" closing of all opened emergency valves when the cabinet doors are closed, or for similar "gang" closing by means of a control located near the front of the tank.

Inspection.—Before the official can competently inspect a vehicle tank, he must thoroughly understand the arrangement of piping, valves, and auxiliary equipment. Such information can ordinarily be gained by inquiry from the representative of the vehicle owner, but this should be supplemented by the personal scrutiny of the official.

Some officials have reported vehicle tanks in service on which the piping and valve arrangements were considered conducive to the perpetration of fraud because of the possibility of diversion of measured liquid. Two specifications can be invoked in such cases, general specification G–S.2. and vehicle-tank specification S.20.2. Other general requirements in relation to which a vehicle tank should be inspected are general specifications G–S.3., G–S.4.1., G–S.5., and G–S.6., and general regulations G–R.2., G–R.3., and G–R.5. Also, meters on vehicle tanks should comply with all of the applicable provisions of general specification G–S.4. In addition, vehicle tanks and meters installed on vehicle tanks should be inspected for compliance with all applicable specification requirements of the code for vehicle tanks, and it should be noted that a meter is required, in general, to meet the requirements for wholesale-type meters as set forth in the code for liquid-measuring devices.

With respect to vehicle-tank specification S.10.2., it may be stated that the requirement that "the compartment capacity shall be construed as excluding the capacity of the piping leading therefrom" was adopted by the National Conference after extended consideration. When the code was tentatively adopted in 1923 the requirement was as it is today, the thinking being that if the capacity of the piping were to be included in the capacity of the compartment, emergency valves could be closed at the time of the filling of a compartment and the compartment would give an indication of being completely filled whereas actually the lines leading from the compartment would be empty. In the situation described, there would be a shortage equivalent to the capacity of the lines. In 1925, when the tentative code was fully adopted, the Conference reversed the requirement, providing for *inclusion* of pipe line capacity, this action being predicated upon representations that the emergency valves would not remain tightly closed and that filling of the line was inevitable a short time after a compartment had been filled in spite of a closed emergency valve. This version of the requirement remained in the tentative code until 1935, when the question was again reconsidered and, as a result of extended debate, the original requirement was restored.

Some vehicle-tank owners now ask that the capacity of the line from each compartment be separately determined, and that this value be shown in each case or that the compartment capacity be shown as *including* as well as *excluding* the capacity of the line leading therefrom. This dual marking is not recognized by the code, but is believed to be unobjectionable provided that the marking of the two capacities is such that each of the two values is clearly defined and identified.

The requirement in vehicle-tank specification S.10.4. for "an expansion space of at least 0.75 percent of the nominal compartment capacity" is a *minimum* requirement. That is, an expansion space greater than 0.75 percent is not in violation of the specification. Local requirements, conditions of use, or the desires of the vehicle-tank owner frequently result in provision for an expansion space considerably greater than three-fourths of one percent of the compartment capacity.

The code is silent with respect to those attachments to meters which are designed to shut off the flow after delivery of a predetermined number of gallons. Such a predetermining attachment should, however, be clearly differentiated from the primary indicating elements of the meter, and it should be inspected to determine that its design and installation are such that it is not conducive to the perpetration of fraud. Such an attachment is associated with the primary indicating elements of the meter, and as the latter reach the indication for which the predetermining element is set at any time, the discharge valve of the meter is automatically closed.

With respect to ticket-printing attachments for meters, the attachments themselves and the recorded representations which they issue should be inspected under the provisions of general specification G–S.5.

Testing Apparatus—General Considerations.—Because of the wide variation in the conditions which affect vehicle-tank testing, as between relatively small areas with large numbers of vehicle tanks (such as large cities) on the one hand and relatively large areas in which comparatively few vehicle tanks are in use (such as thinly populated States) on the other hand, no single recommendation for testing apparatus for vehicle-tank testing is practicable. Moreover, some jurisdictions are totally unable to obtain adequate funds for completely satisfactory testing apparatus. Accordingly, in the discussion which follows several suggestions for testing equipment will be made, from which the weights and measures official may choose according to the conditions prevailing in his jurisdiction. Whenever the official, for compelling reasons, must accept less than the most satisfactory type of testing apparatus, this should be considered as a temporary compromise only, and a continuing effort should be made to improve this at every opportunity.

The requirements for compartment testing and for meter testing are not the same. As has been pointed out earlier in this chapter, some vehicle tanks are not equipped with meters, some vehicle tanks make all their deliveries through meters, and some vehicle tanks are equipped for both compartment deliveries and meter deliveries. Apparatus which is adequate for calibrating compartments may be useless for the testing of meters. Also, vehicle-tank meters may be designed for delivery under pump pressure or for delivery by gravity; testing apparatus which is well suited for the one may be quite unsuited for the other. Apparatus must be designed or assembled, therefore, to meet the needs which exist. If something must be sacrificed, the apparatus procured should be best adapted for the service which is the most important in the particular jurisdiction in question.

Testing Apparatus for Compartment Calibration.—It is at once apparent that the apparatus must be susceptible of wide flexibility in the matter of the gallonage involved in a particular calibrating operation. Values must be determined, under the code, to the nearest half-gallon, and the nominal capacity of a compartment may be anywhere between 100 gallons and 7,000 gallons. For a particular jurisdiction, of course, the capacity range may be considerably smaller than that stated, but in any event large amounts of liquid must be measured and transferred and the determinations will in the large majority of cases involve "odd" amounts.

Accuracy of final results is a prime requisite. Speed of operation is important, because at best the calibration of the compartments of a vehicle tank is a long operation; with inefficient apparatus the time demands upon the official and the vehicle driver and the time loss for the vehicle become serious. The cost of the apparatus is usually an important factor, and the apparatus should be carefully planned to serve the particular needs of the jurisdiction to the best advantage.

For compartment testing the vehicle tank code now specifies that the testing medium shall be "water or light fuel oil". Available information indicates that the majority of jurisdictions use water for this purpose. It is sometimes suggested that it is objectionable to put water into compartments used for carrying petroleum products because of possible contamination of products carried subsequent to the test; this suggestion does not appear to have much merit in view of the specification requirement that a vehicle tank shall be so constructed that the compartments will drain completely. It may also be noted that jurisdictions using water as a testing medium seem to be doing this without objection from vehicle-tank users and with satisfaction on the part of all concerned. Although the use of a light fuel oil as a testing medium should be entirely satisfactory in itself, such use involves more complicated mechanical apparatus, with consequent increased cost, as compared with the use of water.

Of 13 representative jurisdictions recently queried on vehicle-tank testing procedures, all but one reported that with relatively minor exceptions compartments were regularly tested by measuring-in rather than by measuring-out. That is to say, the large majority followed the procedure of basing their tests on the introduction of measured amounts of the testing medium into the compartments, rather than on the measurement out of a compartment of the testing medium with which it had been filled. Theoretically, measuring-out might seem to be the preferable method. Practically, however, the capacity of a compartment can be determined on a "to deliver" basis if the compartment walls are first wetted with the testing medium, and the testing equipment needed can be materially simpler when measuring-in than it is when measuring-out.

There remains for consideration the question of portable apparatus versus apparatus mounted in a fixed location. From the viewpoint of efficiency of the testing operation, the fixed-location installation is certainly to be preferred to the portable equipment. The principal objection to the fixed installation is that when a large area is to be served, some vehicle tanks must travel considerable distances to reach the testing station. The best recommendation is that for any area in which considerable numbers of vehicle tanks are in service, testing stations be set up in sufficient number and at such locations that all vehicle tanks can reach some station without an excessive amount of dead mileage. For an area which is large and in which only a relatively small number of vehicle tanks are in service, the official must decide between the alternatives of a fixed station and a long trip for the vehicle tank, and a portable equipment to be operated throughout the area by the jurisdiction and tests under conditions which are by no means ideal.

Specifically, fixed testing stations are recommended for city and for county jurisdictions and for State jurisdictions except in sparsely settled areas. One such station each should be adequate for cities and for most counties. If the vehicle-tank testing is carried on as a State function, the number of stations needed will depend upon such factors as the number of vehicle tanks to be tested, the size of the State, the distribution of vehicle-tank operation, and accessibility as determined by the highway system.

For compartment testing at a fixed station the following is recommended: A measure-in system, water being the testing medium. A suitable structure in which to mount a series of volumetric standards at such a height that delivery of measured water may be made by gravity, through short lines, to the compartments to be tested. The following details should be observed:

1. The structure should be rigid and should provide adequate shelter from the weather for personnel, testing apparatus, and the vehicle tank under test, and should include a small office for the official's use in handling necessary paper work. A stairway rather than a ladder should be provided for access to the working level.

2. Water supply lines should be piped to each standard, and the pipe size should be large enough to permit rapid filling of the standards. Three-inch lines are suggested for the larger standards.

3. Each large standard should be equipped with a fixed "zero" overflow pipe, to level off the water, automatically, at the proper point when the standard is filled. (A gage glass to indicate the rise of the liquid level in the upper portion of the body of the standard will be helpful in avoiding overflowing of the standard during the filling operation.)

4. The large standards should discharge into a manifold with a single discharge line for delivery to the compartment under test.

5. The manifold and the discharge lines from the larger standards should be not less than 3-inch lines.

6. All discharge lines, including the manifold, should be installed with sufficient slope to insure rapid and complete drainage.

7. Discharge and supply valves should be of the quick-opening-type, of the best quality, and *must not leak.*

8. Delivery into a compartment should be by means of a pipe connected to the manifold by a swing joint or by means of a hose line connected to the manifold. The delivery line should be no longer than necessary to extend about 12 inches into the lowest compartment fill opening.

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9. Adequate means should be provided for draining away the water dumped from a compartment following a test, and the overflow from the standards should be piped to a drain.

10. A walkway which can be raised or lowered should be provided for access from the working level of the station to the top of a vehicle tank. Handrails should be provided for safety of personnel.

11. A *level* concrete area should be provided to accommodate the vehicle tank under test; this apron should be long enough to accept any vehicle tank in any position required during the testing operation. The depth of the concrete matt should be great enough to support adequately the largest vehicle tank apt to be presented, when all compartments are filled with water.

The number and capacities of the standards to be provided will be determined by the character of the vehicle tanks to be tested. If transports are to be tested, large volumes will be involved, and large-capacity standards are recommended to cut down on the time required for a test. At the other extreme, if only rural and small metropolitan vehicle tanks will be encountered, relatively small standards will be adequate. In planning the series of standards, however, it is suggested that future needs be anticipated if possible, so that the testing apparatus may be expected to meet the requirements for a reasonable time in the future.

As a general plan it is recommended that the largest standard be duplicated. This will permit the filling of one of these standards while the other is emptying, permitting the bulk of the delivery to be made in a minimum of time.

For a station to accommodate transports, it is recommended that the single-capacity standards have capacities of 500, 500, 300, (200), 100, and 50 gallons, and that these be supplemented by one small-diameter, cylindrical, 50-gallon standard graduated throughout. Another reasonable series would be 400, 400, (300), 200, 100, and 50 gallons, supplemented by a graduated, cylindrical, 50-gallon standard. For testing involving only medium- or small-sized vehicle tanks, series of 300, 300, (200), 100, and 50 gallons, or 200, 200, 100, and 50 gallons, supplemented in each case by a graduated, cylindrical 50-gallon standard, should be adequate. In the foregoing series the capacities shown in parentheses are desirable, but may be omitted. A series of field standards—10, 5, (4), 3, (2), 1, and ½ gallons—may be substituted for the 50-gallon graduated standard at some sacrifice of speed and con-

FIGURE 16. *Twin, five-hundred-gallon, graduated tanks for calibrating vehicle-tank compartments, in testing station of County of Los Angeles, Calif.*

venience. An alternative to the series of single-capacity standards, which eliminates all use of small-capacity standards, is a system comprising a pair of identical, small-diameter, cylindrical standards graduated throughout, having capacities of 300, 400, or 500 gallons. (See fig. 16.) Objectionable features of the graduated, twin-tank system are reduced sensitiveness (dictated by practical limitations on height), the necessity for the operator to climb up a ladder to read the gage-glass indications, and the greater height of the station building. On the other hand, the twin-tank system is thoroughly versatile, it probably is the simpler and faster to operate, and the delivery lines can be simpler and shorter than in the system utilizing a series of single-capacity standards.

The inlet end of the zero-overflow pipe of a standard should present a horizontal orifice not less than 3 inches in diameter (although the entire overflow line need not be that large) and should be beveled to a sharp edge, to hasten leveling-off of the liquid. The bottom of the standard should be sloped to the discharge valve to hasten delivery, and a baffle plate should be installed to prevent formation of a vortex. The large-diameter, single-capacity standard should have a neck of reduced diameter (not over 10 inches) and the capacity point should be in this neck, in order to obtain desired accuracy; the neck should be equipped with a gage glass and a scale carrying a capacity graduation, for a visual check on proper filling. For a twin-tank installation it is recommended that the effective inside diameter of the cylindrical tanks be not greater than $24\frac{1}{4}$ inches, a diameter which will produce a change of height of the liquid surface of $\frac{1}{2}$ inch per gallon; these tanks should be equipped with overlapping gage glasses, they should be graduated from zero (at the top) to capacity by half-gallon subdivisions, and a capacity delivery should be automatically defined as by complete emptying of the tank or by delivery to the level of a fixed discharge orifice; in the latter case the discharge orifice should conform to the specifications previously noted for the zero-overflow orifice.

A 50-gallon graduated standard should be cylindrical, with an effective diameter not greater than $17\frac{1}{8}$ inches; this dimension will produce a change of height of the liquid surface of 1 inch per gallon, and an overall graduated length of 50 inches. The standard should be equipped with overlapping gage glasses or with a single protected gage glass, and should be graduated from zero (at the top) to capacity by ¼-gallon subdivisions. In other respects it should conform to the specifications previously noted for the tanks of a twin-tank installation.

All of the large standards discussed above should be calibrated with water by the measure-out procedure, because they will always be used to deliver. A standard 30-second drainage period should be observed. In the case of the graduated standards, it will not be necessary to calibrate the standard at each graduation, but not less than 10 percent, and preferably 20 percent, of the graduations should be checked, and these should be evenly distributed throughout the length of the graduated scale; when originally graduating such a measure, not less than 10 percent, and preferably 20 percent, of the graduations should be fixed by means of volumetric measurements, and the intervals between these graduations may then be graduated by proportional subdivision.

Instead of equipping a testing station according to one of the systems discussed above, there may be substituted for the special standards described, a series of provers of conventional design similar to the 100-gallon prover recommended in chapter 13 for the testing of large-capacity meters. In at least some cases, such provers can be purchased as "stock" items from firms specializing in such apparatus. For use with these provers, fill lines which are not physically connected to the provers are suggested, the amounts to be established by means of a visual setting of the liquid surface to the capacity graduation of the prover. It will be difficult to control the in-flow from the fill line within close limits; accordingly it is suggested that a bleeder valve and small drain line be installed at the prover neck so that the liquid surface can readily be lowered to a position of precise coincidence with the capacity graduation of the prover.

In addition to the fixed water-supply lines for the filling of the standards, a utility hose line of perhaps 2-inch diameter should be provided. This should not be equipped with a metal nozzle unless the nozzle is grounded by a metallic connection leading back through the hose. This line will be used for the preliminary introduction of unmeasured water into a compartment, and may be useful for other purposes around the station.

As a safety precaution, portable inspection lights on extension cords should not be provided for use around the station. Instead, electric, battery-powered hand torches should be provided, these to be suitable for use in an atmosphere containing gasoline. (Portable electric torch, Class 1, Group D location, National Electrical Code.) If there is any possibility of a metallic contact between the provers and their discharge line or lines on the one hand and the vehicle tank on the other hand, the provers and lines should be bonded and the system should be effectively grounded. Even a metal nozzle on a nonconducting hose line forming a link in the prover delivery system should be bonded back to the metal provers and grounded through them. Means should also be provided for grounding a vehicle tank during its calibration; this should consist of a grounded cable equipped with a suitable clamp for attachment to the vehicle tank.

In two States, many of the features of a fixed-location testing station such as is described above have been incorporated in mobile units. In one State (Florida) the

FIGURE 17. *Mobilie testing unit for calibrating vehicle-tank compartments and for testing vehicle-tank and other large-capacity meters, State of Florida.*

apparatus is housed in the closed body of a special truck. When set up for use the large standards, which are provers of conventional design, are mechanically elevated to the roof of the body which becomes the working level of the unit, the water supply is through a hose line from a fire plug, and delivery from the standards to a vehicle-tank compartment is by gravity through hose lines. (See fig. 17.) In the other State (Texas) the operating arrangements are similar but the apparatus is carried on an open-body truck having a platform which can be elevated mechanically and on which the standards are mounted. The Florida equipment (two identical units are in service) is used for all compartment testing. The Texas equipment is used in remote areas of the State and supplements a number of fixed-location testing stations.

Some jurisdictions will find it impracticable, for one reason or another, to provide or utilize fixed-location testing stations, or to provide elaborate mobile units such as those described in the preceding paragraph. Adequate funds may not be obtainable or the locations where work is to be done may be very scattered. Under such conditions it is recommended that portable units be designed to retain as many as practicable of the advantages of the fixed-location testing station. Water is recommended as the testing medium. A 100-gallon and a 50-gallon standard should be mounted on a truck and connected through a power-operated pump with a delivery hose. The design must be such as to permit thorough drainage of the delivery line. The standards may be of conventional prover design, but the necks should be equipped with bleeder valves to permit precise settings of the liquid surface. Filling of the standards is to be accomplished by hose line from a fire plug or other source of water supply. A complement of small-capacity standards must be provided; standards having capacities of 5, (4), 3, (2), 1, and ½ gallons are recommended. It will be advisable to provide means for grounding the large-capacity standards during use. In using this equipment to calibrate a compartment a measure-in procedure is followed.

An alternative form of simple, portable equipment comprises standards of the same capacities as those recommended in the preceding paragraph, but the 50-gallon and 100-gallon standards are intended to be removed from the carrying vehicle and positioned to *receive* gravity deliveries direct from the delivery faucets of the vehicle tank. These standards must, therefore, be of special, low design. For this form of equipment no pump is required. In use, the vehicle-tank compartments are filled with water, and the contents of each compartment is then measured-out.

The use of meters for the calibration of vehicle-tank compartments is not recommended as standard procedure, because in such use the meter is a "secondary" standard.[15]

Testing Apparatus for Vehicle-Tank Meters.—A much smaller variety of apparatus is required for meter testing than for compartment calibration. The testing of meters operated by pump pressure involves the same character of apparatus as has been recommended in chapter 13 for the testing of other large-capacity meters. Vehicle-tank meter installations, however, will not be encountered with the high gpm ratings of some fixed-location meters, and testing drafts of 100 gallons will ordinarily be adequate for the testing of meters on vehicle tanks.

As a mobile unit for testing of all ordinary pump-operated meters on vehicle tanks, the 100-gallon prover previously prescribed [16] for meter testing is recommended. Unusually large meters may occasionally be encountered on vehicle tanks; if in normal operation the meter discharge rate exceeds 100 gpm, the test should be conducted with a prover of a capacity equivalent to at least one minute's discharge from the meter.

For the testing of gravity meters on vehicle tanks,

[15] In those cases in which it is found necessary or expedient to use a meter as a secondary standard for the calibration of vehicle-tank compartments, certain precautions should be observed, as follows:

(1) The testing medium should be a suitable petroleum product, such as a light fuel oil; water should not be used as a testing medium.

(2) The meter should be initially calibrated and adjusted with the same testing medium as will be used for compartment calibration, and under controlled, standard conditions of operating pressure and rate of flow duplicating those which will prevail during the use of the meter for compartment calibration.

(3) For all calibrations and check tests of the meter, an accurate prover should be utilized.

(4) Immediately before and after each uninterrupted series of compartment calibrations made with the meter, a check test of the meter should be made, under the standard conditions specified in (2), and utilizing a testing draft equal to at least the amount delivered by the meter in one minute under the standard conditions specified in (2), and in any case not less than 50 gallons.

(5) Insofar as practicable, the standard conditions of operating pressure and rate of flow should be maintained during all use of the meter for compartment calibration, and throughout each individual calibrating operation every effort should be made to avoid changes in the temperature of the testing medium.

[16] See pp. 118–125.

commercial operating conditions should be approximated in the testing operation. This requires that the end of the delivery line from the meter be at a height corresponding to its position when inserted in the fill pipe of an underground storage tank at a filling station. It is not a fair test of a gravity meter to operate it under a reduced negative head,[17] as by elevating the end of the delivery line above its "normal-use" position, or under an increased negative head, as by lowering the end of the delivery line below its normal-use position. It follows that even the lowest design of prover is not suitable for use in testing gravity meters when set on the surface on which the vehicle-tank stands. The prover should be so positioned as to accept the end of the meter delivery line at a level corresponding to that on which the vehicle tank is standing.

For mobile service, if a considerable number of small-capacity gravity meters are to be tested, operating time will be saved by providing a 50-gallon prover for such work. For general mobile service, however, the 100-gallon prover is recommended. It is to be noted that the special mobile units of Florida and Texas, previously mentioned under the discussion of apparatus for compartment calibration, carry provers which are suitable in design and capacity for the testing of vehicle-tank meters.

All mobile provers for vehicle-tank-meter testing should be of conventional type, that is, with graduated necks, and should be equipped with pumps operated by explosion-proof electric motors, and means for grounding the prover during use. Such provers should be calibrated under the procedure previously specified [18] for portable provers.

To equip the fixed-location testing station for meter testing, one or two provers of conventional design should be installed on a low level such that the top edge of the splash dome of each is approximately at the level of the apron on which the vehicle tank is intended to stand. The provers should be close enough to the normal position of the vehicle tank on the apron so that the cus-

[17] The term "negative head" means the pull exerted by a solid column of liquid on the discharge side of a meter, which produces the same kind of effect on the operating characteristics of the meter as the normal or positive head of liquid on the inlet side of the meter. Thus, disregarding such factors as friction losses, if the outlet end of the discharge line is 3 feet below the meter and the meter is being operated with the discharge line solidly filled to its outlet, the effect is essentially the same as though the meter were discharging at meter level and the head of liquid on the inlet side were increased by 3 feet.

[18] See pp. 123–124.

tomary short delivery hose for gravity-meter installations will reach either prover. The provers will thus be suitably positioned for the testing of both pump-operated and gravity meters. The discharge line from the provers should be manifolded and the manifold should be connected with a power-operated pump driven by an explosion-proof electric motor. The discharge line from the pump should be piped to a height above the level of the highest compartment fill openings and should terminate in a hose line 15 or 20 feet long to permit discharge into any desired compartment. The delivery line from the pump must be equipped with a draw-off valve at its lowest point so that at the conclusion of operations the entire line may be thoroughly drained. The discharge valve from the prover *must not leak* in either direction.

Since gasoline meters will be tested with gasoline, adequate provision must be made for ventilation around the prover installation in the testing station. Adequate explosion-proof lighting fixtures, adequate working room around the provers, means for ready personnel access to and escape from the prover working level, and strategically placed fire extinguishers of a type suitable for controlling gasoline fires should also be provided. If at all practicable, a pit closed on all four sides should be avoided, and construction having at least one open side should be designed, for purposes of maximum safety for equipment and personnel.

At least one 100-gallon prover should be provided, in the testing station. Gravity meters of the smaller sizes can be tested satisfactorily with 50-gallon test drafts, so some time can be saved if a 50-gallon prover is provided for this purpose. The provers should be grounded. The same calibration procedure should be observed for the provers as has been specified [19] for portable provers.

Testing Procedure—General Considerations.—The tolerances prescribed in the code for vehicle tanks as applicable to vehicle-tank compartments seem not to be thoroughly understood, and it is believed advisable to discuss these briefly before considering details of test procedure. Two points are involved, the magnitude of the tolerance values, and how and when tolerances should be applied.

In the code these tolerances are set up, in table 1, for

[19] See pp. 123–124.

"vehicle-tank compartments used as measures", and two sets of values are given, one to be applied "on first test", and the other to be applied "on subsequent test". These two sets of values correspond, respectively, to the "acceptance" and the "maintenance" tolerances found in other codes. Some officials have criticized the tolerance values for vehicle-tank compartments as being unnecessarily large. In examining this criticism a comparison of the tolerance values expressed as percentages of their associated compartment capacities, with similar data for two other classes of equipment, should be helpful.

For vehicle-tank compartments, the tolerance on first test of 4 pints on 400 gallons represents 0.13 percent and the tolerance of 7 pints on 1,000 gallons represents 0.09 percent. For retail liquid-measuring devices the acceptance tolerance of 1.5 cubic inches on 1 gallon represents 0.65 percent and the acceptance tolerance of 6 cubic inches on 10 gallons represents 0.26 percent. For wholesale meters, on "normal" test, the acceptance tolerance of 25 cubic inches on 50 gallons represents 0.20 percent and the acceptance tolerance of 262.5 cubic inches on 1,000 gallons represents 0.11 percent. Considering the compartment tolerances "on subsequent test" and the maintenance tolerances for liquid-measuring devices, the compartment tolerance of 2 quarts on 200 gallons represents 0.25 percent, and the tolerance of 6 quarts on 1,000 gallons represents 0.15 percent; for retail liquid-measuring devices, the tolerance of 3 cubic inches on 1 gallon represents 1.30 percent, and the tolerance of 12 cubic inches on 10 gallons represents 0.52 percent; and for wholesale meters, the tolerance of 50 cubic inches on 50 gallons represents 0.40 percent, and the tolerance of 525 cubic inches on 1,000 gallons represents 0.23 percent. These comparisons indicate that compartment tolerances are not excessive with respect to the tolerances for other devices for measuring petroleum products; in all of the examples given, the percentage compartment tolerances are the smallest.

The second point involves the *application* of compartment tolerances, and here considerable confusion seems to have arisen. These tolerances are set up, as in the case of other types of measuring devices, upon the presumption that the devices to which they apply will be submitted in finished form for examination by the weights and measures official. Specifically, the presumption is that the compartments will have been calibrated, the indicators fixed in position, and the required marking of compartment capacities supplied, by the manufacturer or by the owner of the vehicle tank, before the vehicle tank is submitted for official examination. Upon this presumption, the official examination is for the purpose of verifying a calibration previously made by someone else. In such a case, tolerances are, of course, necessary, and the "first test" tolerances apply. Also, it is anticipated that the official will be called upon from time to time to verify the continued accuracy of compartment capacities, recalibrating compartments which he or some other weights and measures official has calibrated at some earlier time; for these cases the "subsequent test" tolerances apply. In both instances the tolerance is applied to the compartment error as found, that is, to the difference between the marked capacity of the compartment and the compartment capacity as determined by the official's calibration. The tolerances establish the limits of permissible error; if the errors are found to exceed the appropriate limits, the commercial use of the compartments as measures is not to be permitted until adjustments are made or the compartment capacities are re-marked.

Should the official see fit to "adjust" a compartment by resetting the indicator or re-marking the capacity, either upon request of the owner or upon his own initiative, no question of tolerances is involved. In this case the "adjustment" should be made to produce as nearly as practicable a zero error—the resetting of the indicator should be done as accurately as may be, or the new marking should represent the true capacity of the compartment according to the best value which the official can determine. The same procedure should be followed in those cases where the official is called upon to establish the initial value for the compartment capacity or to set the indicator initially to the proper position for the compartment capacity desired; no question of tolerance is here involved, and no tolerances are made use of.

Whether or not the official is to make "adjustments" on vehicle-tank compartments or is to assume responsibility for original settings of indicators or marking of compartment capacities, are matters for administrative decision. Such actions are clearly permissible under the code. At the same time, the code recognizes the situation in which the official does not wish to take such actions, and it is for this situation that tolerances are required and, accordingly, prescribed in the code.

In general relation to compartment calibrations, it may be said that the test procedures which will be discussed below are based upon the use of water as a testing medium. Water is now used for this purpose in the large majority of jurisdictions which are active in vehicle-tank compartment calibration, and its use appears to have been entirely satisfactory. If a jurisdiction elects, however, to use light fuel oil as a testing medium, as is permissible under the code, such modifications of the recommended procedures, and such additional equipment as are necessary to adapt to the use of fuel oil, should be obvious, and these will not be mentioned in the discussion.

In general relation to vehicle-tank-meter testing, some comments are in order. One important factor is the testing medium. A meter should always be tested with the same kind of liquid, or with liquid having the same general physical characteristics, as the liquid to be commercially measured by the meter. The reason for this is that the performance characteristics of a meter may not be the same with liquids of different physical characteristics, particularly different viscosities. Officials have been known to test gasoline meters with fuel oil, and then to compute what the performance would be when the meter is used to measure gasoline, by applying a correction factor to the results of the test made with fuel oil. It is not believed that final results under this procedure can be consistently accurate, because what might be a correct differential for one particular meter could be seriously in error for another meter of a different construction or in a different state of mechanical condition. It is believed, therefore, that this procedure can not be relied upon to establish the performance of meters when they are used to measure gasoline. Similarly, it is not safe to assume or compute the performance of a meter for the measurement of fuel oil, upon the basis of test results obtained with gasoline. Specifically, therefore, a meter to be used for measuring gasoline should be tested with gasoline, and a meter to be used for measuring fuel oil should be tested with fuel oil. If a meter is intended to be used interchangeably for measuring gasoline and fuel oil, it should be tested with gasoline *and* with fuel oil, and it should be approved for such dual use only if all the errors developed when it is separately tested with each testing medium are within the applicable tolerances.

The testing draft for a vehicle-tank meter, as has already been mentioned, "should be equal to at least the amount delivered by the meter in one minute at its maximum discharge rate", and the code prescribes that this "shall in no case be less than 50 gallons". The factor of discharge rate is also involved in the application of tolerances. The code states that the "normal" test of a meter "shall be made at the maximum rate permitted by the installation". It is further prescribed that a "special" test of a meter shall be made at a slow rate corresponding to not less than 15 gallons per minute for a meter smaller than 2 inches in rated size, or corresponding to not less than one-fifth of the maximum discharge rate marked on the meter in the case of a meter 2 inches or over in rated size, or, for a meter of any size, corresponding to the minimum discharge rate marked on the meter if this value is smaller than the value previously specified.

The official may be in doubt as to the proper discharge rates to be observed when testing vehicle-tank meters. With respect to both the "maximum rate permitted by the installation", as prescribed for the "normal" test, and the slow rate prescribed as a part of the "special" test, the language of the code should be interpreted reasonably and with due regard to the installation and operating conditions of vehicle-tank meters.

For a gravity meter, the normal test must be made in two parts, with the discharge valve wide open in each case. The first test draft is made from the largest compartment of the vehicle tank, this compartment being full at the start of the delivery; the greatest positive head, and consequently the greatest discharge rate, will thus be realized. The second test draft is made from a compartment containing only a few gallons more than the nominal amount of the delivery—that is, only a few gallons more than the capacity of the prover being utilized—so that there will be reproduced the minimum positive head which may be encountered in commercial use of the meter. On both of these normal tests, the normal-test tolerance applies.

A "special" slow test is relatively unimportant for a gravity vehicle-tank meter, but such a test is permissible under the code, and if made it should be conducted within the limitations as to discharge rates which are specified in the code. It may be mentioned in this connection, however, that these limitations do not apply to the second normal test recommended in the preceding paragraph; that test is to be made as specified, regardless of the resulting discharge rate.

All tests of a gravity meter should be made, as previously recommended, under conditions which will produce a normal-use negative head, that is, with the discharge end of the delivery hose approximately at the roadway level.

For a pump-operated vehicle-tank meter, the normal, or fast, test should be made at the maximum rate permissible through operation of the special pump controls provided. If no such special controls are provided, and if there is a stop on the hand throttle of the truck engine to prevent pump operation at excessive speed, the engine speed for the normal test should be that produced with the throttle opened to the stop. If no pump control of any kind is provided, it will be appropriate for the official to insist that one be provided. In the absence of such a control the official should *not* race a truck engine to produce an abnormally high speed of pump operation; pending the installation of a suitable control, "fast" operation should be at a reasonable rate mutually agreed upon between official and truck operator. Arriving at the proper rate for a slow test of a pump-operated meter offers no difficulties.

It may be mentioned parenthetically that a vehicle-tank meter should not be operated to deliver at a rate in excess of the maximum rate marked on the meter. If the official encounters an installation in which the pump controls are so established that when the pump is operated at the maximum speed permitted by such controls the discharge rate of the meter is greater than its marked maximum rate, it will be appropriate for him to call this situation to the attention of the vehicle-tank owner as in violation of general regulation G–R.5., and to require such modification of the installation as is necessary to avoid misuse of the meter.

It should be emphasized that whenever a delivery is "throttled down" to produce a slow flow, the valve used for this purpose should be the discharge valve located *on the discharge side* of the meter. Any valve on the inlet side of the meter in the supply line being utilized should be fully opened during commercial use and during test.

The code provides that "special" tests, in addition to those at slow rate, shall be made as circumstances require "to develop the operating characteristics of a meter and the operating elements associated therewith". The reference to operating elements associated with the meter is particularly to the air eliminator and the valves on the inlet side of the meter through which connection is made to one or another of the compartments. The air eliminator should be capable of removing the air which might be introduced (1) when the valve from an empty compartment is opened while delivery is being made from a compartment containing liquid, (2) when the operation is continued after the liquid is exhausted from a compartment, and (3) when a normal "switch-over" is made from a compartment which has been emptied to another compartment containing liquid. If condition (1) is not met satisfactorily, a larger or more efficient air eliminator, or selective valve controls, are indicated as necessary. Tests to determine performance under these conditions, and any others which might result in short-measure deliveries, shall be made by the official as a part of his "special" tests of a meter "as circumstances require". The details of such special tests are not spelled out in the code, nor will they be further described in this discussion.

It should be noted that on all "special" tests the special-test tolerances apply, and that these have the same values on both acceptance and maintenance tests.

Testing Procedure—Compartment Calibration.—Testing procedure will first be discussed upon the assumption that the calibration is to be made at a "testing station" as described earlier in this chapter, and that the vehicle tank to be calibrated is equipped with emergency valves.

The vehicle tank should reach the station with its compartments empty. The vehicle should be spotted on the level apron in a position to receive into its forward compartment the discharge from the standards. The ground connection should then be made to the vehicle tank. The fill caps and the emergency valves of all compartments should then be opened, and about 10 gallons of water should be run into each compartment, using the utility hose line, which is not connected with the standards; during this operation the walls of the compartments should be thoroughly "wetted". Assuming that two inspectors are on duty at the station, one may now proceed to fill with water such of the standards as are expected to be used in the calibration. The other inspector will draw from each compartment, and discard, several gallons of water, in order to fill these delivery lines with water. All emergency valves will then be closed. Using small field standards, as required, the capacity of the delivery line from each compartment will be separately determined by drawing off and measuring the water which it contains, and these values will be recorded. (This withdrawal operation will be a slow one because air to replace the liquid in the line must work into the line from the faucet; ample time should be allowed for complete drainage of the line.) All emergency valves will then be opened and the water remaining in each compartment will be drawn off and discarded. All emergency valves will then be closed.

At this point a visual inspection of each compartment should be made to determine whether or not any water remains in any compartment; use only the safety electric torch to illuminate the compartment. If water is found to be trapped in any compartment, the code requirement for complete drainage is not met (see specification S.10.6.) and the vehicle tank may be rejected until this condition is corrected. If the compartments are found to have drained properly, the actual calibration of the compartments will then be carried out.

Compartments should be completely calibrated one at a time. For verification of a previous calibration the following procedure is recommended. From the appropriate standard a delivery into the forward compartment is made. If the station is equipped with a series of single-capacity standards, the first, as well as each subsequent, delivery from such a standard should be one which can be completely accepted by the compartment; the final delivery should be from the graduated standard. Inspection of the liquid level in the compartment will enable the inspector to determine in each case which standard to use for the next delivery into the compartment. When making the final delivery into the compartment to bring

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the liquid level to the bottom of the compartment indicator, care should be exercised to avoid running in more than the proper amount of water.

At this point, with a container in position to receive any discharge, the delivery faucet from the forward compartment should be opened to check on possible leakage from the compartment through the emergency valve into the delivery line. Any liquid that may have leaked into the line is part of the measured volume that is supposed to be in the compartment, and should be withdrawn from the line, measured, and corrected for. A leaking emergency valve violates general regulation G–R.2., and should be repaired or renewed.

Having determined and recorded the capacity of the compartment when properly filled to the indicator, it can readily be determined whether or not the appropriate tolerance requirement is met. If it should be decided to reset the indicator to agree with the marked capacity of the compartment, this should be done at once, the correct amount of water being added or removed depending upon whether the marked capacity is greater or less than the determined capacity, and the indicator being repositioned in relation to the new liquid level. If it should be decided to re-mark the capacity of the compartment to agree with the determined capacity, the actual re-marking should be deferred until all of the compartments have been calibrated.

For record purposes, and purposes of subsequent field checking, the vertical distance from the bottom of the indicator upward to some definable point of an element which is permanently attached to the tank (such as the top edge of a permanently attached dome or a manhole ring) should next be determined to the nearest $\frac{1}{16}$ inch, and recorded. (Such a measurement made to a removable element, such as a manhole cover that may be interchanged or that may be regasketed, serves no useful purpose.)

The next step is to determine the sensitiveness, as required by specification S.10.4. This may be done with sufficient precision by determining the amount of water required to be added to raise the liquid level in the compartment by $\frac{1}{4}$ inch; if one-sixth of the amount so added is not more than the tolerance "on first test" for a compartment of the capacity of the one being calibrated, the sensitiveness requirement may be assumed to have been met.

The next step is to determine if the expansion-space requirement of specification S.10.4. is complied with. This is done by (1) determining the additional amount of water required to be added to the compartment to fill it completely, (2) adding to this figure the figure representing the amount of water added to the compartment in the test for sensitiveness, and (3) determining by computation that this total figure is at least three-fourths of one percent of the capacity of the compartment when this was filled to the indicator. The adjacent empty compartment should then be checked to detect any leakage from the filled compartment.

During the operations involved in the foregoing procedure, each single-capacity standard utilized should be drained for 30 seconds each time it is emptied, after which its discharge valve should be closed. If a standard that has been emptied is to be used again, time will be saved by refilling it while another standard is being emptied.

If, inadvertently, more than the desired amount of water is run into a compartment during a calibration, the excess may be drawn off. For this operation the emergency valve is opened, a sufficient amount is withdrawn through the delivery faucet, the emergency valve is closed, and the delivery line is then completely drained. All water so removed may be measured and accounted for; this would be done if the amount withdrawn from the compartment were such as to produce exactly the desired compartment indication. On the other hand, if the delivery to the compartment is being made from the graduated standard, more than the necessary amount can be withdrawn from the compartment, all of the liquid withdrawn can be returned to the standard from which delivery was being made, and the delivery can then be resumed from the standard to the compartment as in the original instance.

The calibration of the forward compartment having been completed, the water is left in the compartment until all remaining compartments have been calibrated. The vehicle is advanced, if necessary, to bring the fill opening of the next compartment into position to receive a delivery from the standards. Following the same procedure as has been outlined for the calibration of the forward compartment, the next compartment toward the rear is calibrated. When this calibration is completed the water is left in the compartment and the next compartment in order is calibrated, and these operations are continued until all compartments have been calibrated.

The level of the water in all compartments to the rear of the forward compartment should next be noted, after which the contents of the forward compartment should be dumped. The liquid level in the remaining compartments should then be checked for any change that might have occurred as a result of distortion of the bulkhead between the two forward compartments. Specification S.1. requires that no such distortion shall be permitted. The contents of the next compartment is then dumped, and again the liquid level in each of the remaining compartments is checked. This operation is continued until all compartments are emptied. It should be noted in this relation that if, as compartments are successively filled in the course of the calibration, the water level in the filled compartment adjacent to the one being calibrated is caused to rise or that compartment is caused to overflow, this is positive indication of a springing bulkhead between the two compartments. When such a condition is found to exist, the calibration may properly be discontinued and the vehicle tank rejected for repair.

Any adjustable indicators, or removable elements (such as detachable parts of the manhole assembly) to which indicators are attached, should be sealed in position with lead-and-wire seals. (Specification S.10.3.) The report on the calibration should be prepared to identify fully the vehicle tank in question and each compartment thereof, and, among the other pertinent data, should include for each compartment its capacity, the capacity of its delivery line, and the distance of the bottom of its indicator from the reference point selected; this reference point should be clearly defined in the report.

The last operation before the vehicle tank leaves the testing station should be removal of the ground connection.

With one exception, the operations specified above for the verification of a prior calibration are essentially duplicated for a calibration designed to fix the positions of compartment indicators to conform to a series of desired compartment capacities. The exception is that instead of introducing water into a compartment until the liquid surface is in coincidence with the bottom of an indicator already positioned, water to the desired amount is introduced into the compartment and the indicator is then positioned so that its bottom is just in contact with the liquid surface.

When vehicle-tank compartments are calibrated with mobile equipment, the effort should be to duplicate as nearly as practicable the procedure that has been outlined for calibrations conducted at a testing station. The first operation should be the establishment of metallic connections between the vehicle tank and the ground and between the testing apparatus and the ground. During a calibration the vehicle tank and the standards should not be exposed to the sun, so that excessive changes in the temperature of the vehicle tank and of the standards (causing changes in capacity) and of the testing medium (causing changes in volume) may be avoided.

If a graduated standard is not available—such a standard is strongly recommended—the measurement of the final increment of water added to a compartment will—except in the accidental case—require the use one or more times of small-denomination field standards. To take a simple example, assume that the actual capacity of a compartment is 280 gallons, and that provers of 100-gallon and 50-gallon capacities (plus small field standards) are available. Obviously, the first three increments run into the compartment are 100, 100, and 50 gallons. The remainder of the required water would then be added to the compartment from field standards, the 5-gallon standard being used until the use of smaller standards becomes necessary. Or, the 50-gallon prover could be refilled, and from it water could be run into the compartment to the desired amount. The amount of this last increment would then be determined by measuring out from the prover the water that remains in it or by measuring into the prover the amount of water required to refill it. By the first method the amount of the final increment added to the compartment would be 50-gallons minus the amount withdrawn from the prover. By the second method the amount of the final increment added to the compartment would be the amount added to the prover.

If a vehicle tank is not equipped with emergency valves, the procedure for its calibration will differ only slightly from that already outlined. The preliminary introduction into each compartment of 10 gallons or so of water will be made, after which each compartment will be drained through its delivery faucet and the water so withdrawn will be discarded. Each compartment will then be inspected for possible trapping of liquid. Following this, the actual calibration is begun. To avoid any trapping of air in the delivery line from the compartment and insure its complete filling with water, the first 5 gallons or so of water should be run into the compartment slowly. An alternative method of insuring a filled delivery line is to make a normal, full-speed delivery of water to the compartment, but after a considerable amount of water has been introduced, to draw off about 5 gallons through the delivery faucet and then pour the liquid so withdrawn into the compartment. From this point on, any instructions for operations involving emergency valves are simply to be disregarded.

Testing Procedure—Meter Testing.—As has been emphasized before, for meter testing the testing medium should be liquid of the same kind as will be measured by the meter in commercial service. When the vehicle tank is presented for the test of its meter or meters, it should contain a supply of the appropriate liquid to be used in making the test. For a gravity-meter installation, the largest compartment of the vehicle tank should be filled (to the indicator, if one is provided) with liquid, and at least enough other compartments to provide a combined capacity nearly equal to the capacity of the largest compartment, should be empty. For a pump-operated-meter installation, the vehicle tank should contain an amount of liquid at least 25 gallons in excess of the capacity of the prover which will be used in the test.

The testing procedure for a meter is the same whether the test is made at a testing station or elsewhere.

The general procedure for a meter test is the same for gravity meters and for pump-operated meters. Whether or not gasoline is being used as a testing medium, it is advisable that provers and vehicle tank be grounded as the first step in the procedure. For purposes of the owner's accounting, a record should be made of the reading of the totalizing register on the meter before any liquid is discharged; a similar record should be made at the conclusion of the test and these data should be included on the official report. Enough liquid should be run through the meter into the prover to insure (1) that the meter and the discharge line to the point of the discharge valve are filled with liquid, and (2) that the interior walls of the prover are thoroughly wetted with liquid. The liquid in the prover is then returned to the vehicle tank, the standard procedure for draining the prover, including the standard drainage period, being followed.[20] The "individual-sale" register will be used for the meter readings throughout the test, and this should be reset to zero reading at this point, as also before each test draft made in the course of the test. Actual testing operations are then begun, the "normal" tests being run first, and these being followed by the "special" tests. Deliveries into the prover should be made with the least practicable amount of slow-down or dribble flow near the conclusion of the delivery, so that the test operation may conform essentially to commercial operation. When a test is supposed to be run at a rate of a specified number of gallons per minute, such rate should be closely approximated. A test delivery should be terminated at a precise meter reading of some whole gallon and at a time when the amount of liquid in the prover is such that the liquid will level-off somewhere in the graduated portion of the prover neck; ordinary practice should be to terminate a delivery at a meter reading corresponding with the normal capacity of the prover. Errors are read directly from the graduations on the prover neck. Duplicate observations under each test condition are recommended.

For a gravity meter the regular series of test conditions is as follows: (1) Delivery from the largest compartment, the delivery being started with the compartment full of liquid, and being made with a wide-open discharge valve. "Normal" tolerances apply. (2) Delivery from a compartment containing only a few gallons (5 gallons is suggested) more than the nominal prover capacity, the delivery being made with a wide-open discharge valve. "Normal" tolerances apply. (3) (Optional.) Delivery from a filled compartment at a slow rate conforming to the limitations of paragraph N.2.1. of the code, the delivery being made with a partially-opened

[20] See pp. 123–124.

discharge valve. "Special" tolerances apply. (4) Total delivery from a compartment containing at least 10 gallons less than the nominal prover capacity, then a switchover to a compartment containing more than enough liquid to complete the test draft, both deliveries being made with a wide-open discharge valve, and the line valve from the first compartment being left open (if the construction permits this) until the delivery of the full amount of the test draft is completed. "Special" tolerances apply.

For a pump-operated meter the regular series of test conditions is as follows: (1) Delivery at the maximum rate permitted by the installation, made with a wide-open discharge valve. (But see the discussion of maximum rate on page —.) "Normal" tolerances apply. (2) Delivery at a slow rate conforming to the limitations of paragraph N.2.1. of the code, made with a partially-opened discharge valve. "Special" tolerances apply. (3) Deliveries to demonstrate the effective performance of the air eliminator and line valves, as dictated by the construction. "Special" tolerances apply.

If a meter is equipped with a ticket-printing attachment, tickets should be printed on several deliveries to verify agreement between the indicated and printed amounts and to check the recorded representations under general specification G–S.5.

Testing Outlines

(For tests of vehicle-tank compartments and meters by weights and measures officials.)

Case I.—Calibration at a testing station, with water, of the compartments of a previously calibrated vehicle tank equipped with emergency valves: [21]

1. Spot the vehicle tank in position to receive the delivery from the standards into its forward compartment.
2. Attach the ground connection to vehicle tank.
3. Open fill caps and emergency valves of all compartments.

[21] Necessary modifications of this outline to adapt it to tests made in the field with portable testing apparatus should be apparent. Necessary modifications for a calibration made for the purpose of initially establishing the positions of compartment indicators should be apparent; this situation is discussed briefly on pages 188–189. Necessary modifications for a vehicle tank not equipped with emergency valves are discussed on page 190.

4. For each compartment, use the utility hose line to wet the inside walls and add about 10 gallons of water.
5. From each compartment withdraw and discard several gallons of water.
6. Close all emergency valves.
7. Using small field standards, separately drain, measure, and record the contents of the delivery line from each compartment. Allow enough time for the *complete* drainage of each line.
8. Open all emergency valves and drain and discard the water from each compartment.
9. Close all emergency valves.
10. Inspect each compartment for pockets of liquid. (Use only a safety torch for illumination.) If compartments do not drain completely, the vehicle tank may be rejected until this condition is corrected.
11. Deliver measured water into the forward compartment from the standards until the liquid surface just touches the bottom of the indicator.
12. Open the delivery faucet from the compartment being calibrated, and recover, measure, and correct for any water which may have leaked through the emergency valve. (A leaking emergency valve should be repaired or renewed.)
13. Measure to the nearest $\frac{1}{16}$ inch, and record, the vertical distance from the bottom of the indicator upward to some permanent definable point.
14. Add measured water to raise the liquid level $\frac{1}{4}$ inch. One-sixth of the amount so added should not exceed the tolerance "on first test" for a compartment of the capacity of the one being calibrated.
15. Add measured water to fill the compartment completely. To the figure for the amount so added, add the figure for the amount added in step 14; the sum should be at least 0.75 percent of the capacity of the compartment to the bottom of the indicator.

16. Inspect the compartment next toward the rear for possible leakage from the forward compartment.
17. Leave the water in the forward compartment, advance the vehicle, if necessary, to permit delivery from the standards into the next compartment toward the rear, and calibrate this by repeating for it steps 11 through 16.
18. As in step 17, calibrate each of the remaining compartments.
19. Note the liquid level in each compartment to the rear of the forward compartment, then dump the contents of the forward compartment. Again note the liquid level in the filled compartments to check on the possibility of springing bulkheads. Repeat this operation as the compartments are successively emptied.
20. Apply lead-and-wire security seals to any adjustable indicators or removable elements to which indicators may be attached.
21. Remove the ground connection from the vehicle tank.

Case II.—Testing of a gravity, vehicle-tank meter.

Note.—The vehicle tank on which the meter is installed must be presented with its largest compartment filled (to the indicator, if one is provided) with the appropriate testing medium, and with at least one compartment empty.

1. Attach the ground connection to the vehicle tank.
2. Read and record the indication of the totalizing register on the meter.
3. Deliver from the filled compartment (referred to hereafter as "compartment No. 1") through the meter into the prover enough liquid to wet thoroughly the inside walls of the prover.
4. Pump the contents of the prover back into compartment No. 1, adhering to the standard prover-drainage procedure.
5. Reset the individual register of the meter to zero reading.
6. Deliver from compartment No. 1 through the meter into the prover, with wide-open discharge valve, until the meter registers precisely a delivery equal to the nominal capacity of the prover. Read the error from the graduations on the prover neck. "Normal" tolerances apply.

7. As a check, repeat steps 4, 5, and 6, except that in step 4, first pump about 5 gallons of liquid into an empty compartment (hereafter referred to as "compartment No. 2") that has a capacity equal to at least prover capacity plus 5 gallons.
8. Pump the contents of the prover into compartment No. 2, observing standard prover-drainage procedure, and repeat step 5.
9. Repeat step 6, except that the delivery is made from compartment No. 2. "Normal" tolerances apply.
10. As a check, repeat steps 8 and 9. (Go to step 15 if steps 12 and 14 are omitted.)
11. Pump the contents of the prover into compartment No. 1, observing standard prover-drainage procedure, and repeat step 5.
12. Optional. Deliver from compartment No. 1 through the meter into the prover, with a partially-opened discharge valve, the delivery rate conforming to the limitations of code paragraph N.2.1. Terminate the delivery when the meter registers precisely an amount equal to the nominal capacity of the prover. Read the error as before. "Special" tolerances apply. (Go to step 15 if step 14 is omitted.)
13. Repeat step 11.
14. Optional. As a check, repeat step 12.
15. Pump about half of the contents of the prover into compartment No. 2 and the remainder into compartment No. 1, observing standard prover-drainage procedure, and repeat step 5.
16. Deliver through the meter into the prover, with wide-open discharge valve, the entire contents of compartment No. 2, then switch-over to deliver from compartment No. 1. If the construction permits, leave the line valve from compartment No. 2 open while delivering from compartment No. 1. Terminate the delivery when the meter registers precisely an amount equal to the nominal capacity of the prover. Read the error as before. "Special" tolerances apply.
17. Optional. As a check, repeat steps 15 and 16.

18. Pump the contents of the prover back into the vehicle tank.
19. If the meter is equipped with a ticket-printer, print tickets for several of the test drafts in the course of the test, verify agreement between indicated and printed amounts, and check recorded representations under general specification G–S.5.
20. Repeat step 2.
21. If the meter is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.
22. Remove the ground connection from the vehicle tank.

Case III.—Testing of a pump-operated, vehicle-tank meter:

NOTE.—The vehicle tank on which the meter is installed must be presented with an adequate supply of the appropriate testing medium in one compartment (referred to hereafter as "compartment No. 1") and with at least one compartment empty.

1. Attach the ground connection to the vehicle tank.
2. Read and record the indication of the totalizing register on the meter.
3. Deliver from the filled compartment through the meter into the prover enough liquid to wet thoroughly the inside walls of the prover.
4. Pump the contents of the prover back into compartment No. 1, adhering to the standard prover-drainage procedure.
5. Reset the individual register of the meter to zero reading.
6. Deliver from compartment No. 1 through the meter into the prover, with wide-open discharge valve, until the meter registers precisely a delivery equal to the nominal capacity of the prover. Read the error from the graduations on the prover neck. "Normal" tolerances apply.
7. As a check, repeat steps 4, 5, and 6.
8. Repeat step 4.
9. Deliver from compartment No. 1, through the meter into the prover, with a partially-opened discharge valve, the delivery rate conforming to the limitations of code paragraph N.2.1. Terminate the delivery when the meter reg-

isters precisely an amount equal to the nominal capacity of the prover. Read the error as before. "Special" tolerances apply.

10. As a check, repeat steps 4 and 9.
11. Repeat step 4.
12. As dictated by the character of the installation, make such additional tests as are considered appropriate to demonstrate the effective performance of the air eliminator and line valves, observing the general procedure and precautions specified for other steps in this outline. "Special" tolerances apply.
13. Pump the contents of the prover back into the vehicle tank.
14. If the meter is equipped with a ticket printer, print tickets for several of the test drafts in the course of the test, verify agreement between indicated and printed amounts, and check recorded representations under general specification G–S.5.
15. Repeat step 2.
16. If the meter is approved, affix lead-and-wire security seals to protect all adjustable elements affecting measurement.
17. Remove the ground connection from the vehicle tank.

References

Catalogs issued by manufacturers of vehicle tanks and vehicle-tank meters contain illustrations and text which will be useful to the weights and measures official.

The following references are to papers and discussions on the general subject of vehicle tanks and associated topics appearing in the Reports of the National Conference on Weights and Measures. Citations include the designation in the series of Miscellaneous Publications of the National Bureau of Standards, the number and year of the particular National Conference, and the page reference.

M74, Nineteenth Conference Report, 1926, pages 57–59.
M116, Twenty-third Conference Report, 1930, pages 112–120.
M129, Twenty-fourth Conference Report, 1931, pages 41–42.
M157, Twenty-sixth Conference Report, 1936, pages 104-116.
M161, Twenty-eighth Conference Report, 1938, pages 17–18.
M170, Thirty-first Conference Report, 1941, pages 33–39.
M189, Thirty-third Conference Report, 1947, pages 60–72, 161–165.
M195, Thirty-fourth Conference Report, 1949, pages 126–132.
M199, Thirty-fifth Conference Report, 1950, pages 145–148.

Chapter 16.—DRY MEASURES

The use of dry measures is prohibited by law in some jurisdictions. The sale of dry commodities by weight, and the determination by weighing of amounts of dry commodities when these amounts are expressed in units of dry measure, have become so nearly universal that even in jurisdictions which have not specifically barred the use of dry measures the commercial use of such measures is believed to be comparatively rare. For completeness, however, there is presented here a brief discussion on dry measures.

Description.—Dry measures made of wood and bound with metal were formerly common in sizes of 1 peck and smaller; later these were largely superseded by measures made entirely of metal. Baskets were commonly employed for measures of ½-bushel and 1-bushel capacity. In shape, measures other than baskets are usually cylindrical, although measures in the general form of a truncated cone—that is, with the top diameter greater than the bottom diameter—are also manufactured. The capacity of a dry measure is defined by the top edge of the measure.

Inspection.—Dry measures should be individually inspected (and tested). General specifications G–S.1., G–S.2., G–S.3., and G–S.6., general regulation G–R.2., and the specifications of the code for dry measures, apply.

Testing Apparatus.—Dry measures of small capacity are usually watertight in construction and can conveniently be tested with water. For this purpose slicker-plate, metal, *dry-measure* standards, supplemented by graduates graduated in cubic inches should be available. A 35-cubic-inch, cylindrical graduate having 1-cubic-inch subdivisions, and a 5-cubic-inch, cylindrical graduate having subdivisions of 0.1 cubic inch are recommended.

For the larger sizes of dry measures, clean rape seed is recommended as the testing medium, to be used with a testing hopper, such as is illustrated in figure 18, whenever the testing is performed in the weights and measures office. Suitable metal, *dry-measure* standards are also required.

A testing method which is less precise than the volumetric method is to measure the dimensions and compute the capacity of the measure under test. For this purpose a 12-inch steel scale graduated in 0.02-inch subdivisions, and an inside caliper, are recommended.

Testing Procedure.—When water is used as the testing medium the general procedure is the same as has been outlined in chapter 8 for the testing of liquid measures, and need not be repeated here. Measured water is transferred from the standard to the measure under test, and the standard should be suitably drained.

Rape seed may be used satisfactorily as a testing medium for all except the very small measures. The seed should be poured into the standard and into the measure under test from the same height, in order to establish the same "packing" effect in each case; this is readily accomplished when the testing hopper, which is equipped with a gate at the bottom of the hopper and which is adjustable for height, is used. (See fig. 18.) A slight excess of seed is placed in the hopper, the seed is then

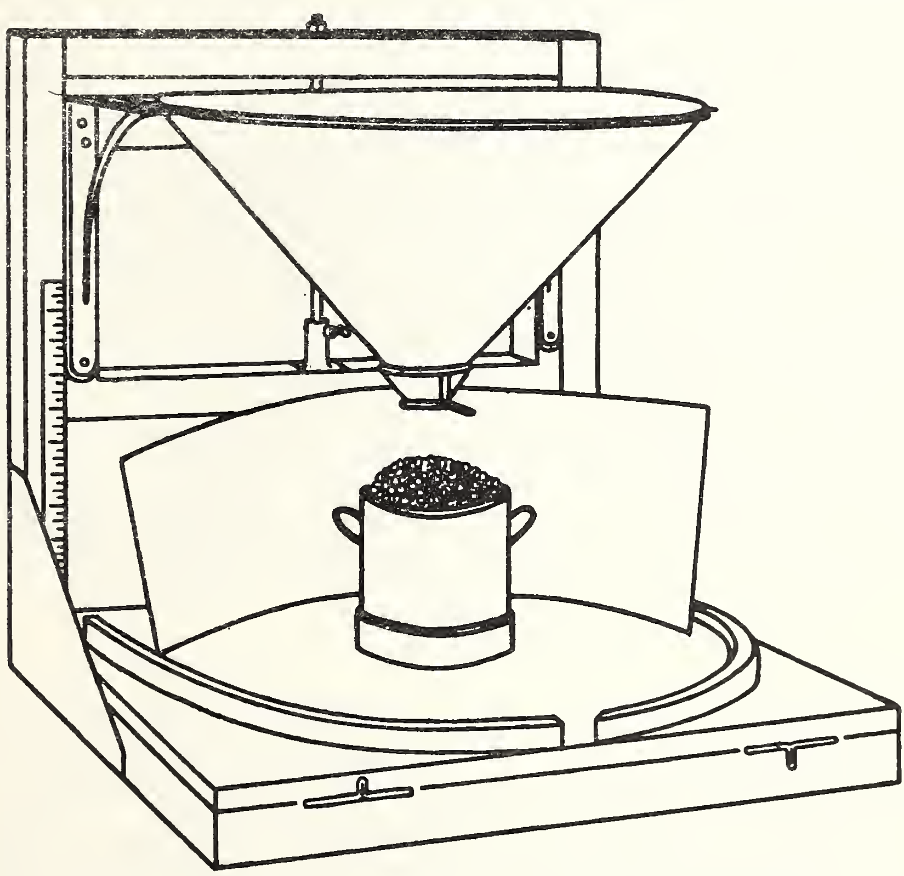

FIGURE 18. *Testing hopper for dry measures.*

run into the standard, and the heaped-up excess of seed in the standard is then struck-off by means of a beveled striking stick. The standard is set aside, the seed struck-off is returned to supply, the seed in the standard is returned to the hopper, and the previous operation is repeated as a check. The measured seed is again returned to the hopper, from which it is then run into the measure under test. Any excess of seed over that required to fill the measure level full is struck-off and measured in the graduate, and this amount represents the error "in deficiency"; if the measure is not filled, enough seed is added from a graduate to fill the measure level full, and this amount represents the error "in excess". When using rape seed an important precaution is to avoid shaking or jarring the standard or the measure while seed is being run in or while an error determination is being made; any such shaking or jarring will cause the seed to settle and will invalidate the results.

The capacity of a dry measure which is of cylindrical or conical form and which has a flat bottom may be determined by linear measurement and computation. (This method should not be used on a measure which is warped or otherwise distorted.) For a cylindrical measure the inside diameter and height are measured. It is recommended that the inside calipers be used when measuring diameters, three equally spaced diameters being measured at the top and at the bottom, and these six values being averaged. The height is measured by applying a straightedge across the top of the measure, measuring the vertical height at the center and at not less than two points near the walls, and averaging the results. It is recommended that all of these linear measurements be made to the nearest 0.02 inch. The area in square inches of a cross section can then be derived from a table of areas of circles, or can be computed from the formula

$$A = \frac{3.1416\ (D^2)}{4},$$

where A equals the area, and D equals the average diameter expressed in inches. This result multiplied by the height in inches will give the capacity of the measure in cubic inches. This result can be reduced to terms of dry-measure units by comparing it with the number of cubic inches equivalent to the nominal dry-measure size of the measure. (1 bushel=2150.42 cubic inches.) The entire computation required to determine the cubic-inch capacity of the measure can be made from the following formula

$$C=0.7854\times D\times D\times H,$$

where

C =capacity in cubic inches.
D=average inside diameter in inches.
H=average vertical inside height in inches.

For a conical measure in which the top diameter is not more than 30 percent greater than its bottom diameter, a sufficiently close approximation (accurate to 1 percent or better) of the capacity can be arrived at by following a procedure identical with that prescribed in the preceding paragraph. The average diameter derived will be the average diameter of a mid-section of the measure; in establishing this figure it is essential that the average be computed from the same number of measured diameters at the top and at the bottom.[22]

The testing procedures for dry measures are so simple that no "testing outline" need be presented.

References

In National Bureau of Standards Miscellaneous Publication M11, Report of the Eighth National Conference on Weights and Measures, 1913, a portion of the paper beginning on page 181 is devoted to dry measures.

In U. S. Department of Agriculture Miscellaneous Publication No. 75 "Method of Testing the Capacity of Fruit and Vegetable Containers under the United States Standard Container Acts", May, 1930, the use of a testing hopper is illustrated and discussed in considerable detail.

[22] The exact formula for computing the capacity of a conical measure is

$$C=0.2618\times[D_t^2+(D_t\times D_b)+D_b^2]\times H,$$

where

C =capacity in cubic inches.
D_t=average inside top diameter in inches.
D_b=average inside bottom diameter in inches.
H =average inside vertical height in inches.

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Chapter 17.—BERRY BASKETS AND BOXES

Description.—Berry baskets and boxes are single-service measures, made in sizes of 1 quart, 1 pint, and ½ pint, dry measure, and may be constructed of wood veneer, paperboard, or plastic. In shape they are square or oblong in cross-section, with either vertical or sloping sides. Boxes with vertical sides and raised bottoms were formerly widely used, but these have largely been displaced by the box of square cross-section having sloping sides and flush bottom. Plastic boxes are a recent development, and as now being made they are of lattice, or open mesh, construction. Paperboard boxes may have ventilating holes in their sides.

Inspection.—Berry baskets and boxes are mass-produced, and boxes of a particular make, design, and nominal capacity are supposed to be uniform in all respects. Inspection (and testing) is by sample; depending upon the size of the lot being examined, from 4 to 10 boxes should be inspected. Boxes should be identified as required by general specification G–S.1., and should not be warped or otherwise distorted from their designed shape.

Testing Apparatus.—For volumetric testing with rape seed, the 1-quart, 1-pint, and ½-pint standards, the 5-cubic-inch graduate, and a beveled stricking stick, as specified in chapter 16 for the testing of dry measures, are required. If reasonable care is exercised to maintain a uniform fall of the seed when filling the standard and the box under test, the use of a testing hopper will not be necessary, although its use will simplify the testing operations. For testing by linear measurement and computation, the steel scale and inside caliper previously specified for testing dry measures will be used.

Testing Procedure.—If a berry box has any openings around sides or bottom, they must be closed off before volumetric testing can take place; for this purpose, gummed paper strips may be applied to the outside of the box. The testing procedure when using rape seed as the testing medium is the same as has already been outlined in chapter 16 for dry measures.

When testing by linear measurement and computation, the average inside length, in inches, of each side at the bottom and at the top of the box is determined from at least two measurements each, taken ½ inch or so inward from the corners. From at least three measurements, one taken at the center and the others taken near opposite sides, the average inside vertical height, in inches, is determined. These measurements should be made to the nearest 0.02 inch. The square-inch area of the bottom of the box and at the top of the box are computed by multiplying together the average lengths of their two sides. These two areas are added and the sum divided by 2 to arrive at the average cross-sectional area. This average figure is multiplied by the average height of the box, and the result will be a sufficiently accurate figure for the capacity of the box in cubic inches.[23]

The testing procedures for berry baskets and boxes are so simple that no "testing outline" need be presented.

[23] The exact formula for computing the capacity of a rectangular box with sloping sides is

$$C = 1/3\ H \times [A_t + \sqrt{A_t \times A_b} + A_b],$$

where

C = capacity in cubic inches.
H = average inside vertical height in inches.
A_t = area at top in square inches.
A_b = area at bottom in square inches.

Chapter 18.—WATER, GAS, AND ELECTRICITY METERS

The number of jurisdictions in which the weights and measures officials test water, gas, or electricity meters is negligible. Such testing is ordinarily under the general supervision of State public utility commissions, public service commissions, and similar governmental agencies; routine testing is usually carried on by the utility companies themselves. In view of this situation it appears to be unnecessary to enter into any discussion in this Handbook on the testing of utility meters. However, as a matter of assistance to those weights and measures officials who may wish to learn something about the testing of water, gas, and electricity meters, either as general information or because they contemplate the possibility of undertaking the testing of one or more of the three classes of utility meters, references are given below to sources from which information on this subject can be obtained.

Water Meters.—In the Report of the 8th National Conference on Weights and Measures, NBS Miscellaneous Publication M11, 1913, pages 118 to 123, inclusive, there will be found a paper on the testing of water meters.

The "Standard Specifications for Cold Water Meters—Disc Type", as adopted by the American and the New England Water Works Associations, includes a discussion on the testing of water meters. Copies may be obtained from the American Water Works Association, 500 Fifth Avenue, New York 18, N. Y.

Dry Gas Meters.—In the Report of the 8th National Conference on Weights and Measures, NBS Miscellaneous Publication M11, 1913, pages 90 to 105, inclusive, there will be found a paper on the testing of dry gas meters. In the Report of the 35th National Conference on Weights and Measures, NBS Miscellaneous Publication 199, 1950, pages 159 to 162, inclusive, there will be found a paper descriptive of vapor meters. In NBS Circular C309, "Gas Measuring Instruments", 1926, there is included a section on the testing of dry gas meters.

Manufacturers of dry gas meters are known to have issued some literature descriptive of the household type of gas meter (dry gas meter) and apparatus for the testing of these meters. Such literature may be obtained, on a free or purchase basis, from such manufacturers.

Electricity Meters.—In the Report of the 10th National Conference on Weights and Measures, NBS Miscellaneous Publication M13, 1915, pages 52 to 58, inclusive, there will be found a paper on the testing of electricity meters.

Specifications for the performance of electricity meters are given in ASA Standard C12 "Code for Electricity Meters", 1941, as amended by Standard C12a, 1947. Copies of this may be obtained from the American Standards Association, 70 East 45th Street, New York 17, N. Y.

Procedures for the testing of electricity meters will be found in the "Electrical Metermen's Handbook" published by the Edison Electric Institute, 420 Lexington Avenue, New York, N. Y. Procurement is by purchase from the publisher, and the latest edition should be specified.

Water, Gas, and Electricity Meters.—A discussion of a State program embracing meters for all three utilities will be found in the report of the 21st National Conference on Weights and Measures, NBS Miscellaneous Publication M87, 1928, pages 54 to 60, inclusive.

HANDBOOKS OF THE NATIONAL BUREAU OF STANDARDS

The following Handbooks issued by the Bureau are available by purchase from the Superintendent of Documents, Government Printing Office, Washington 25 D. C., at the prices indicated:

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