DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 8

TESTING OF THERMOMETERS

(3d Edition)
AUGUST 11, 1921

PRICE, 5 CENTS
Sold only by the Superintendent of Documents, Government Printing Office
Washington, D. C.

WASHINGTON
GOVERNMENT PRINTING OFFICE
1921

TESTING OF THERMOMETERS

CONTENTS

1. INTRODUCTION

This Circular is designed to give such information as is useful to those who wish to send thermometers to this Bureau for test. The testing of clinical thermometers is described in Circular No. 5. Quite detailed information relating to the laboratory technique of thermometry and to the construction, standardization, and use of temperature measuring instruments, adapted for temperature measurements from -200 to $+550°$ C, will be found in another publication entitled "Thermometry."[1] Similar information relating to the measurement of higher temperatures will be found in a publication entitled "Pyrometric Practice."[2]

2. STANDARD SCALE OF TEMPERATURE

The fundamental scale upon which the Bureau's temperature measurements, in the above-mentioned range, as well as outside of that range, are based, is the thermodynamic centigrade scale.

[1] C. W. Waidner, E. F. Mueller, H. C. Dickinson, and R. M. Wilhelm, Thermometry, B. S. Sci. Paper No. 5.

[2] Paul D. Foote, C. O. Fairchild, and T. R. Harrison, Pyrometric Practice, B. S. Tech. Paper No. 180.

For laboratory use, the standard scale of temperature is defined in the interval −40 to 550° C by the aid of platinum resistance thermometers calibrated at the ice point (0° C), the steam point (100° C), and the sulphur boiling point (444.6° C at normal atmospheric pressure) interpolation being made by means of a parobolic formula (Callendar equations). Below −40° the working scale is also realized by means of platinum resistance thermometers, calibrated at a number of fixed points. Further details relating to the standard scale of temperature may be found in the publications already referred to.

3. KINDS OF THERMOMETERS ACCEPTED FOR TEST

The types of thermometers regularly accepted for routine tests include clinical thermometers and all ordinary thermometers of the type commonly employed in temperature measurements in the laboratory and commonly known as laboratory and special thermometers, including laboratory and working standards, clinical standards, calorimetric, Beckmann, hypsometric, hygrometric, flash point, distillation, and viscosimeter thermometers, and special low-temperature thermometers down to −50° C. The necessary facilities have not been installed to put tests below the latter temperature on a routine basis. If the demands on the thermometric laboratories permit, such tests will be accepted as special tests to be arranged for by correspondence. At present the indications of such special low-temperature instruments will be checked at a few points only in the range −50 to −190° C. Thermometers of the so-called industrial or mechanical types—that is, thermometers provided with special mountings to adapt them to various industrial uses—will not, in general, be accepted for test, for the reason that the indications of such thermometers under actual conditions of use may differ by a very significant amount from their indications in the laboratory testing baths, as has been more fully explained in the publication referred to. Ordinary household and meteorological thermometers will not, in general, be accepted for test unless the scale is graduated on the stem so that the thermometer can be detached from its mounting and inserted into the testing baths.

Platinum resistance thermometers, if of suitable construction, will be accepted for standardization for use at temperatures from −40 to 600° C or higher, and by special arrangement, when time permits, for use down to −200° C. Resistance thermometers

of unusual construction and provided with special mountings to adapt them to specialized industrial applications will not, in general, be accepted for test, especially where the nature of the mounting and the conditions of use of the thermometer seem likely to cause differences in its indications when tested and when subsequently used.

The standardization of rare metal and of so-called base metal thermocouples for use at high temperatures (above 300 to 1500° C) is a regular routine test made by the high-temperature laboratories, but the demands thus far made for the standardization of thermocouples in what is here arbitrarily designated as the thermometric range of temperatures (−200 to +550° C) have not been sufficient to warrant putting such tests on a routine quantity basis. Such tests should therefore be arranged for by correspondence, since they must be adapted to the regular work of the thermometric laboratories.

Thermometers of the pressure gage type have not been submitted for test in sufficient quantity to warrant the installation of facilities for routing testing. Such thermometers will not, in general, be accepted for test, except in special cases where an investigative test may yield information relating to the type of instrument submitted. The special tests of this kind that have been made in the past are tests of selected thermometers intended for the airplane service and were made as an independent check on the testing and inspection service of the military bureaus or to furnish information on types of instruments for the assistance of manufacturers.

4. NUMBER AND CHOICE OF TEST POINTS

Some of the thermometers sent to the Bureau for test are accompanied by requests for tests at an unreasonably large number of test points. If these requests were always complied with, it would preclude the possibility of testing a number of thermometers simultaneously and would result in unduly increasing the cost of such work and in cutting down the output of the testing laboratory. Where a thermometer is to be used for ordinary laboratory requirements, the selection of the test points should be left to the testing laboratory. If a large amount of careful work has been done with a thermometer and it is desired to know some portion of the scale with particular accuracy, a statement to that effect should accompany the thermometer when it is sent

in for test, and arrangements will be made, when possible to increase the number of test points in that part of the scale.

In general, it may be stated that if the readings of a thermometer are to be trusted to one or two tenths of the smallest scale division, the interval between test points should not exceed 50 divisions and need not be less than 20. For ordinary thermometers graduated in 1 or 2° intervals, when the corrections are given only to the nearest degree, test points 100° apart are often sufficiently near together. The Bureau can not undertake to test thermometers at too frequent points. The number and distribution of the test points can only be decided after a careful inspection of the thermometer and often only after the test has been partly completed.

5. TEST REQUIREMENTS AND TOLERANCES

This section describes the practices of the thermometric laboratories of the Bureau governing the routine testing and certification of laboratory thermometers. Thermometers which meet the test requirements of this section and are found correct within the tolerances given will be certified. If thermometers submitted for test fail to meet the test requirements or are not correct within the tolerances given, a report giving the results of the test, and stating why certification was refused, will be issued.

Material and Workmanship.—The first requirement for certification is that the thermometer shall be of "good material and workmanship." The essential requirements under this heading are:

(*a*) The bulb should be made of a satisfactory thermometric glass.

(*b*) The mercury must be pure and clean and free from entrapped gas and the interior of the thermometer must be clean and free from moisture.

(*c*) High-temperature thermometers, especially thermometers graduated above 300° C or 600° F should be suitably annealed so that subsequent changes in their indications, due to continued heating, will be small.

(*d*) All high-temperature thermometers should be filled with a dry inert gas under sufficient pressure to prevent separation of the mercury at any temperature of the scale. Total immersion thermometers graduated above 150° C or 300° F should also be gas filled to minimize the distillation of mercury from the top of

the column. Gas filling of thermometers for lower temperatures is optional.

(*e*) Laboratory thermometers should have the graduation marks etched directly on the stem and so located as to be opposite the enamel back. In thermometers of the inclosed scale (einschluss) type the graduated scale should be securely fastened so that relative displacement between scale and capillary is impossible—for example, by fusing scale to inclosing tube—or else a fiducial mark should be placed on the thermometer so that relative displacements can be determined and a suitable correction applied.

(*f*) Thermometers should be graduated either in 1, 0.5, 0.2, or 0.1° intervals or in decimal multiples or submultiples of such intervals.

(*g*) The graduation marks should be clear-cut, straight, of uniform width, and should be perpendicular to the axis of the thermometer. The width of the graduation marks should not in the extreme case be more than 0.2 of the interval between graduations. The cross section of the capillary and the spacing of the graduations should be free from such irregularities as would produce uncertainties in the indications by amounts exceeding the limits otherwise set by the type of thermometer.

(*h*) The graduated part of the scale must not extend too near to the bulb or to an auxiliary reservoir in the capillary.

(*i*) The divisions should be numbered at such frequent intervals and in such a way that the identification of any graduation is not unnecessarily difficult.

Fixed Points on Scale.—In addition to the above requirements, it is necessary that certain kinds of thermometers have the ice point, or in some cases the steam point on their scales. All thermometers graduated in 0.2 or 0.1° or smaller intervals, for use in measuring actual temperatures rather than temperature intervals, at ordinary temperatures, and all thermometers graduated above 150° C or 300° F should have on their scales the ice point (0° C or 32° F) or on high-temperature thermometers, the steam point (100° C or 212° F), preferably the ice point, so that changes in the volume of the bulb can be determined from time to time and the proper corrections applied. The scale need include only the interval within which the thermometer is to be used and to avoid making the thermometer unduly long an auxiliary reservoir in the stem may be used.

Thermometers not intended for differential measurements and graduated in 0.1 or 0.2° intervals, and which have no fixed (ice or steam) point on the scale, or which have too short graduation intervals, will (if certified) be certified to a lower order of accuracy than that corresponding to precision thermometers of this class.

Marking of Partial Immersion Thermometers.—Partial immersion thermometers of the ordinary laboratory type will not be certified unless plainly marked "partial immersion" or its equivalent (as, for example, "8 cm immersion") and unless a conspicuous line is engraved on the stem to indicate the point on the stem to which the thermometer is to be immersed. This mark must not in any case be less than 13 mm (one-half inch) above the top of the bulb. Special partial immersion thermometers adapted for use in instruments which fix definitely the manner in which the thermometer is used (for example, viscosimeter and flash-point thermometers in which the thermometer is held in a ferrule or other mounting fitting the instrument), need not be specially marked, although even in this case it is desirable that the thermometers be marked "partial immersion."

Tolerances for Ordinary Laboratory Thermometers.—In order to receive certificates laboratory thermometers must comply in essential respects with the general specifications set forth above. Thus instruments showing poor design, defective or careless workmanship, etc., will not be certified. In Tables 1, 2, 3, and 4 are given the tolerances used by the Bureau in determining whether a thermometer is sufficiently correct to be awarded a certificate. The figures given in these tables are applicable to the ordinary high grades of mercury in glass laboratory thermometers, and different tolerances are established for total immersion and for partial immersion thermometers.

The tables of tolerances for partial immersion thermometers are based on the assumption that the entire stem above the ice-point graduation (0° C, 32° F) is emergent from the bath. This represents approximately the conditions for which partial immersion thermometers are generally made. If the number of degrees emergent from the bath is less than indicated above, the manufacturers should have no difficulty in keeping the errors well within these tolerances.

The tolerances for total immersion thermometers are based on the fact that in the manufacture of thermometers certain small errors in pointing and graduating are inevitable, and also that the

indications of thermometers are subject to variations due to the inherent properties of the glass. The tolerances must be sufficiently rigid to insure to the user a satisfactory high-grade thermometer and at the same time must not be so rigid as to cause undue manufacturing difficulties.

The tolerances in the tables may appear somewhat large, but it has been the experience of the Bureau that some manufacturers are meeting with considerable difficulty in complying with them. It is hoped ultimately that conditions will be such as to permit reducing these tolerances.

By comparing the tables of tolerances for total and for partial immersion thermometers, it will be seen that somewhat larger tolerances are permissible in the latter type and also that the certified corrections, resulting from an ordinary routine test, are reliable to a lower order of accuracy. The reader should not interpret the above facts to mean that the user of a standardized total immersion thermometer will necessarily get higher accuracy than he would by using a standardized partial immersion thermometer. The reasons for the differences in the tables has been fully explained elsewhere.[3]

The fourth columns of the respective tables indicate, in general, the order of accuracy to which corrections obtained as the result of an ordinary routine test may be depended upon. The figures given mean that for the conditions stated in the certificate or report the application of the corrections to the observed indications of the thermometer will give results, expressed on the standard scale of temperature, which are accurate within the limits stated in this column for the various thermometers and temperature ranges specified. In general, it is preferable to give the corrections as found, rather than to give "rounded-off" figures, although this often involves giving corrections to a somewhat higher order of accuracy than can be attained with certainty in such tests. This practice seems justified in view of the fact that the result actually obtained is the best which can be deduced from any given test, and that any considerable rounding off necessarily introduces an additional uncertainty. The fifth columns of the respective tables show to what extent the certified corrections are, in general, rounded off.

[3] Journal of Ind. and Eng. Chemistry, p. 237, March, 1921; also Thermometry, loc. cit.

TABLE 1.—Tolerances for Centigrade Mercurial Total Immersion Laboratory Thermometers

THERMOMETERS FOR LOW TEMPERATURES

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
—35 to 0	1 or 0.5	0.5	0.1 –0.2	0.1
—35 to 0	.2	.4	.02– .05	.02
THERMOMETERS NOT GRADUATED ABOVE 150°				
0 up to 150	1 or 0.5	0.5	0.1 –0.2	0.1
0 up to 150	.2	.4	.02– .05	.02
0 up to 100	.1	.3	.01– .03	.01
THERMOMETERS NOT GRADUATED ABOVE 300°				
0 up to 100	1 or 0.5	0.5	0.1 –0.2	0.1
Above 100 up to 300		1.0	.2 – .3	.1
0 up to 100	.2	.4	.02– .05	.02
Above 100 up to 200		.5	.05– .1	.02
THERMOMETERS GRADUATED ABOVE 300°				
0 up to 300	2	2	0.2–0.5	0.2
Above 300 up to 500		4	.5–1.0	.2
0 up to 300	1 or 0.5	2	.1– .5	.1
Above 300 up to 500		4	.2– .5	.1

TABLE 2.—Tolerances for Fahrenheit Mercurial Total Immersion Laboratory Thermometers

THERMOMETERS FOR LOW TEMPERATURES

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
—35 to 32	1 or 0.5	1	0.1–0.2	0.1
—35 to 32	.2	.5	.05	.02
THERMOMETERS NOT GRADUATED ABOVE 300°				
32 up to 300	2	1	0.2 –0.5	0.2
32 up to 300	1 or 0.5	1	.1 – .2	.1
32 up to 212	.2 or 0.1	.5	.02– .05	.02
THERMOMETERS NOT GRADUATED ABOVE 600°				
32 up to 212	2 or 1	1	0.2–0.5	0.2
Above 212 up to 600		2	.5	.2
THERMOMETERS GRADUATED ABOVE 600°				
32 up to 600	5	4	0.5–1.0	0.5
Above 600 up to 950		7	1 –2	.5
32 up to 600	2 or 1	3	.2–1.0	.2
Above 600 up to 950		6	.5–1.0	.2

TABLE 3.—Tolerances for Centigrade Mercurial Partial Immersion Laboratory Thermometers

THERMOMETERS FOR LOW TEMPERATURES

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
−35 to 0	1 or 0.5	0.5	0.2–0.3	0.1
THERMOMETERS NOT GRADUATED ABOVE 150°				
0 up to 150	1 or 0.5	1.0	0.1–0.5	0.1
THERMOMETERS NOT GRADUATED ABOVE 300°				
0 up to 100	1	1.0	0.1–0.3	0.1
Above 100 up to 300	1	1.5	.5–1.0	.2
THERMOMETERS GRADUATED ABOVE 300°				
0 up to 300	2 or 1	2.5	0.5–1	0.5
Above 300 up to 500		5	1 –2	.5

TABLE 4.—Tolerances for Fahrenheit Mercurial Partial Immersion Laboratory Thermometers

THERMOMETERS FOR LOW TEMPERATURE

Temperature range in degrees	Graduation interval in degrees	Tolerance in degrees	Accuracy in degrees	Corrections stated to
−35 to 32	1	1	0.3–0.5	0.1
THERMOMETERS NOT GRADUATED ABOVE 300°				
32 up to 300	2 or 1	2	0.2–1.0	0.2
THERMOMETERS NOT GRADUATED ABOVE 600°				
32 up to 212	2 or 1	2	0.2–0.5	0.2
Above 212 up to 600	2 or 1	3	1 –2	.5
THERMOMETERS GRADUATED ABOVE 600°				
32 up to 600	5 or 2	5.0	1–2	1
Above 600 up to 950		10	2–3	1

In addition to the requirements shown in the above tables the error in any temperature interval must not exceed 5 per cent of the nominal value of the interval. The obvious intent of this requirement is to eliminate thermometers having large corrections of alternating signs.

Tolerances for Calorimetric and Differential Thermometers.—In calorimetric or differential thermometers the accuracy at any one temperature is of less importance than the accuracy of the temperature intervals. Table 5 gives the tolerances for the temperature intervals of some typical differential thermometers.

TABLE 5.—Tolerances for Calorimetric and Differential Thermometers

Number of degrees included on scale	Graduation interval in degrees	Allowable change in correction in degrees	Accuracy of interval in degrees	Corrections stated to
20–45° F	0.05	0.08 over a 5° interval	0.01 to 0.02	0.01
10–20° C	.02	.03 over a 2° interval	.005 to .01	.002
5–6° C (Beckmann type)	.01	.01 over a 0.5° interval for setting of 20°	.002 to .005	.001

No tolerances for scale error are given in the table although it is desirable that the scale error be small.

In the fourth column of the table is given the probable accuracy with which the thermometer can be used to measure the short interval between adjacent test points, or in the case of a Beckmann thermometer the accuracy attainable in the measurement of any interval within the limits of the scale. The fifth column indicates to what extent the certified corrections are, in general, rounded off.

6. CERTIFICATES AND REPORTS FOR LABORATORY THERMOMETERS

Thermometers which fail to meet the above-mentioned general requirements or which exceed the tolerances shown in the several tables or which are tested only within a limited portion of their scale will either be rejected or will receive a report (not a certificate) showing the results of the test. The report will also state why certification was refused.

The intent of the above regulations is to ensure that a Bureau certificate, in addition to giving information concerning the corrections applicable at the several test points, shall serve as an indication that a certified thermometer is not defective and is as nearly correct as can be reasonably expected under good manufacturing conditions.

A report of test will usually serve, if the thermometer is properly used and corrections are applied, to enable the user to secure satisfactory and reliable temperature measurements.

A certificate or report of test will contain, in addition to the results of the test, the following information: Identification mark-

ings and numbers on the instrument; the name of the person for whom the test was made; a brief description of the instrument; the test number and date of test; an explanation of the method of applying the emergent stem correction, in case of a thermometer graduated to read temperatures under conditions of total immersion, but actually used with a part of the mercury column emergent from the bath, or if the thermometer is of the calorimetric or metastatic type, the method of applying the differential stem correction, when such a thermometer is used with emergent stem; a table of setting factors, if the thermometer is of the metastatic (Beckmann) type, to enable the user to apply the results of the test if the thermometer is used with a setting other than that for which it was standardized; and such explanatory notes as will define the conditions under which the results of test are applicable and which will enable the user at all times to use the results of the test to advantage; as further evidence of its origin, the certificate or report contains finally the signature of the Director and the impressed seal of the Bureau.

7. REASONS FOR REFUSAL TO TEST OR CERTIFY

The reasons for which test of a thermometer may be refused, or for which a report rather than a certificate will be issued, have been given in preceeding sections, but for convenience these reasons are briefly summarized below.

(*a*) The thermometer is not of a type which the Bureau is prepared to test.

(*b*) The thermometer is not in condition to be tested (cracks in glass, etc.).

(*c*) Defective material or workmanship as, for example, the use of unsuitable glass for the bulb, dirty mercury, unclean capillaries, entrapped gas in the mercury, insufficient annealing, omission of gas filling where needed, improper or defective graduation or numbering, or graduation in unsuitable intervals, such as 1/4°.

(*d*) Omission where required of the ice (or steam) point.

(*e*) Omission of required markings on partial immersion thermometers.

(*f*) The scale error at one or more points exceeds tolerance.

(*g*) The change of correction over a given interval exceeds tolerance.

(*h*) Thermometers which are submitted for test for only a limited portion of their scale will receive a report and not a certificate.

8. NOTES ON THE BEHAVIOR OF THERMOMETERS

The following brief notes on the characteristic behavior of mercury in glass thermometers are added to aid the user in understanding the behavior of such thermometers and in a better utilization of the information that is contained in the Bureau's certificates or reports of tests.

Secular Changes in Glass.—There is a slow secular change in the volume of the bulb which goes on for years. This manifests itself by a slow rise in the ice-point reading. With the better grades of thermometric glasses this change will not exceed 0.1° C in many years provided the thermometer has not been heated to high temperatures (300° C or thereabouts). The allowance for this change can readily be made by determining the ice-point reading from time to time, since if the ice-point reading is found to be higher (or lower) than at the time of test, all other readings will be higher (or lower) to the same extent.

Temporary Changes in Volume of Bulb.—When a thermometer which has been for a long time at room temperature is heated to a higher temperature, the glass quickly expands to its final equilibrium condition corresponding to the higher temperature. When the thermometer is again cooled down to its original temperature the glass does not completely return to its original volume for a long time (months or even years) although the original volume will be recovered within the equivalent of 0.01 or 0.02° in about three days. Obviously this phenomenon has an important bearing on the precision attainable with mercurial thermometers and must be taken into consideration in precision thermometry, especially in the interval 0 to 100° C. Thus if a thermometer is used to measure a given temperature, it will read lower than it otherwise would if it has a short time previously been exposed to a higher temperature. With the better grades of thermometric glasses the error resulting from this imperfect thermal property of the glass will not exceed (in the interval 0 to 100° C), 0.01° C for each 10° difference between the temperature being measured and the higher temperature to which the thermometer has recently been exposed, and with the best glasses only a few thousandths of a degree. The errors due to the cause referred to become somewhat erratic at temperatures much above 100° C. It is for the reasons above briefly set forth that it is customary, in thermometry of the highest precision, to determine the ice point immediately after each temperature measurement.

Changes in Volume of Bulb Due to Annealing.—Another change to which the indications of thermometers are subject is the so-called annealing change at high temperatures. If the glass has not been properly annealed, it will slowly and progressively contract when exposed to high temperatures (above about 300° C), thus causing the indications of the thermometer to rise progressively. These annealing changes may amount to 30 or 40° C, and hence thorough annealing of a high-temperature thermometer is very important. While no amount of annealing will make the ice-point reading of a thermometer absolutely constant if the thermometer is exposed for a long period of time to the highest temperatures (450° C or thereabouts), for well-annealed thermometers such changes will be quite small and can be readily allowed for by occasional determinations of the ice-point reading and application of the necessary additional corrections to take account of the changes found to have occurred since the thermometer was standardized. In the use of high-temperature thermometers care must be taken not to overheat them. When the glass becomes "soft" the high internal gas pressure enlarges the bulb and thus causes a lowering in the indications of the thermometer.

9. BREAKAGE OF THERMOMETERS

A not inconsiderable number of thermometers are received broken, due either to improper packing or to rough treatment in transportation, or both. A smaller number are broken in return shipment. A small percentage of thermometers (about 2 per cent) are broken in the various testing operations in the laboratory. These breakages are of two kinds: One which may be reasonably classed as accidental and unavoidable, and the other as due either to momentary carelessness, to defects that have developed in the testing apparatus, or to the fact that some steps in the testing operations must necessarily be intrusted to those who have not yet served a long apprenticeship in thermometer testing. Certain operations in testing, such as detaching a mercury thread of the required length for subcalibration of the scale between test points, etc., are liable to result in breakage and no amount of care can totally eliminate such breakage. The only possible way to avoid such breakage would be not to test the thermometers. The second class of breakages referred to above are those for which the Bureau feels more directly responsible and it is a matter of regret that there is no legal way in which it can make reimbursement for

breakages of that kind. It is therefore a matter of necessity, and not of choice, that the Bureau must make those who send apparatus for test assume all the risks involved. Damages to apparatus, even in cases where the Bureau would be pleased to assume them, can not be made good out of fees received for testing since such fees are not expendable by the Bureau but are converted directly into the Treasury. Under the circumstances, all that the Bureau can do is to make every effort to reduce such breakage to the absolute minimum under the conditions under which the work has to be done.

10. GENERAL INSTRUCTIONS TO APPLICANTS FOR TESTS

Application for Test.—The request for test should be made in writing, addressed to "Bureau of Standards, Washington, D. C.," and should enumerate the articles submitted for test, giving sufficient information to identify each article or group of similar articles.

When apparatus is sent simply for test, without definite instructions, the Bureau will decide upon the nature of the test. Any special information which may be of value in deciding upon the nature of the test, such as the use for which the thermometers are intended, should be clearly stated in the request for test.

All packages should bear the shipper's name and address and, when convenient, a list of the contents. Each separate article or group of articles should be plainly marked to facilitate identification.

Packing and Shipping.—Thermometers are liable to be broken in packing and shipment in three ways:

(*a*) Thermometers often break from sliding or shaking in their individual cases. This can be avoided by wrapping each thermometer carefully in soft paper before placing it in its case, and having sufficient soft packing, as paper or cotton wool, at each end of the case so that the thermometer can not slip endwise.

(*b*) Thermometers are sometimes broken by the bending of the individual cases due to uneven packing outside of them. This can be avoided by using metal or wooden cases in place of paper cases, and even with paper cases, by care in distributing the packing material.

(*c*) Thermometers are often broken by jars and blows on the outside of the packing case, due to careless handling. The danger of such breakage can be minimized by surrounding the individual

thermometer case or cases with a sufficient amount, say 2 or 3 inches, of excelsior or similar elastic material on all sides and at the ends, within a strong but light wooden box. The marking on the outside of this box should call attention to the necessity for careful handling.

Proper packing is emphasized because an unduly large percentage of the thermometers shipped to the Bureau for test are broken when received.

Apparatus should be securely packed in cases or packages which will not be broken in transportation. The shipment in both directions is at the applicant's risk. Transportation charges on apparatus forwarded to the Bureau for test must be prepaid. Unless otherwise arranged articles will be returned or forwarded by express "collect."

Apparatus submitted for test, as well as all correspondence, should be addressed simply "Bureau of Standards, Washington, D. C." Apparatus delivered in person or by messenger must be accompanied by a written request for test.

Remittances.—As soon as the test has progressed sufficiently to determine the fee, the bill will be sent out. Payment should be made promptly, as certificates or reports are not issued nor is apparatus returned until the fees due thereon have been received. Remittances may be made by money order or check drawn to the order of the "Bureau of Standards."

11. SCHEDULES OF FEES

These schedules will go into effect on October 1, 1921, and will apply to all tests received on and after that date.

FEE SCHEDULE 32.—LABORATORY AND SPECIAL THERMOMETERS

(Applicable to types of thermometers listed in Tables 1, 2, 3, and 4.)

(*a*) Determination of corrections in the interval 0 to 100° C (32 to 212° F) for thermometers divided in 0.5° or larger intervals, for each point tested....	$0.20
(*b*) Determination of corrections in the interval 0 to 100° C (32 to 212° F) for thermometers divided in 0.2° or smaller intervals, for each point tested...	.30
(*c*) Determination of corrections in the interval above 100° and up to 300° C (212 to 600° F) for each point tested.....	.40
(*d*) Determination of corrections in the interval above 300° and up to 500° C (600 to 930° F) for each point tested.....	.50
(*e*) Determination of corrections in the interval below 0° and down to −50° C (32 to −60° F) for each point tested.....	.40
(*f*) Determination of corrections for alcohol, toluene or pentane thermometers, below −50° C (−60° F) for each point tested.....	.75

SCHEDULE 34.—CALORIMETRIC AND BECKMANN THERMOMETERS

(Applicable to types of thermometers listed in Table 5)

(*a*) Determination of corrections at a number of test points by comparison with standard mercury in glass thermometers, for each point tested..... $0.30

(*b*) Standardization of a calorimetric thermometer by comparison at 2° C intervals with a platinum resistance thermometer..... 5.00

(*c*) Complete standardization of a calorimetric thermometer divided in 0.01 or 0.02° C intervals, by comparison with a platinum resistance thermometer and subcalibration with a 1° thread..... 8.00

(*d*) Complete standardization of a Beckmann thermometer with the highest accuracy warranted by the construction and action of the thermometer..... 8.00

SCHEDULE 36.—THERMOCOUPLES

Thermocouples for use at high temperatures are tested by the pyrometer laboratories in accordance with fee schedule No. 36 published in B. S. Circular No. 7. Thermocouples within the thermometric range of temperatures (−200 to 550° C) are not scheduled as routine tests but are sometimes accepted as special tests, the fee depending on temperature range and required accuracy.

SCHEDULE 37.—PLATINUM RESISTANCE THERMOMETERS

(*a*) Standardization of a platinum resistance thermometer at the ice, steam, and sulphur-boiling points..... 10.00

(*c*) Standardization of a calorimetric platinum resistance thermometer.... 10.00

S. W. STRATTON,
Director.

Approved:
HERBERT HOOVER,
Secretary of Commerce.