DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 5

TESTING OF CLINICAL THERMOMETERS

[3d Edition]
Issued July 16, 1917

PRICE, 5 CENTS
Sold only by the Superintendent of Documents, Government Printing Office
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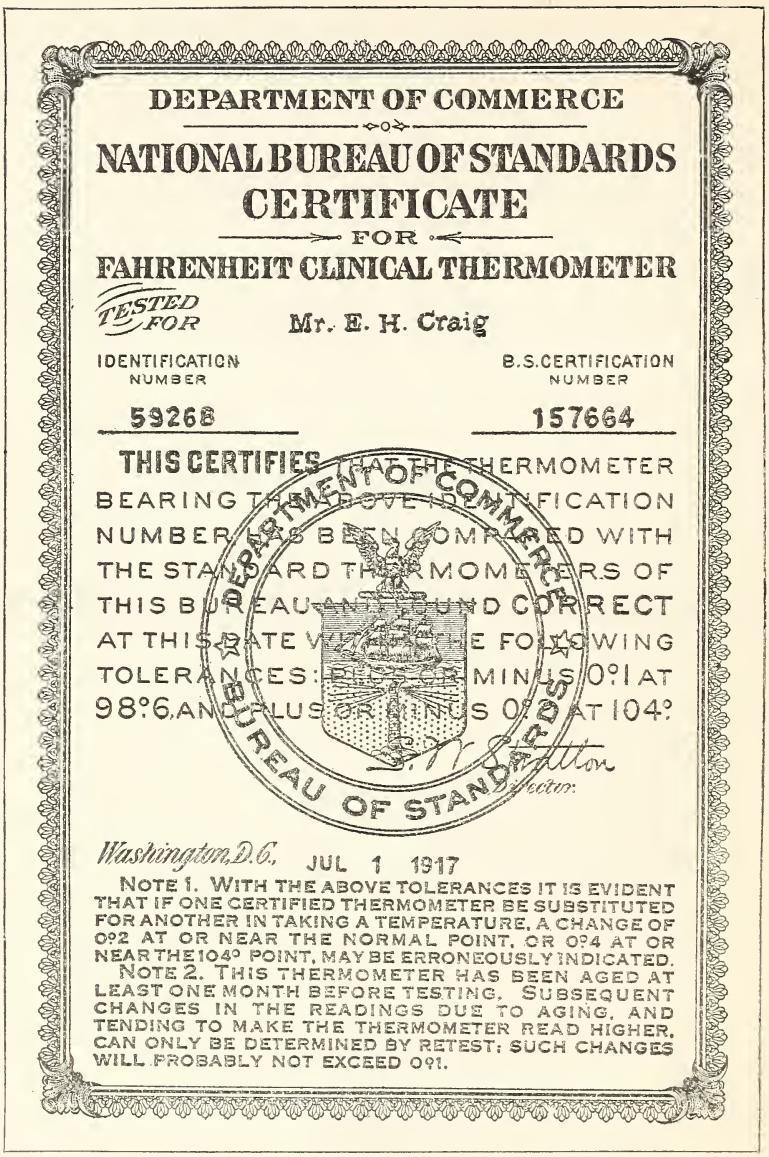

DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

CERTIFICATE

FOR

FAHRENHEIT CLINICAL THERMOMETER

TESTED FOR Mr. E. H. Craig

IDENTIFICATION NUMBER 59268

B.S.CERTIFICATION NUMBER 157664

THIS CERTIFIES THAT THE THERMOMETER BEARING THE ABOVE IDENTIFICATION NUMBER HAS BEEN COMPARED WITH THE STANDARD THERMOMETERS OF THIS BUREAU AND FOUND CORRECT AT THIS DATE WITHIN THE FOLLOWING TOLERANCES: [illegible] MINUS 0°.1 AT 98°.6, AND PLUS OR MINUS 0°.2 AT 104°.

DEPARTMENT OF COMMERCE ★ BUREAU OF STANDARDS ★

S. W. Stratton
Director.

Washington, D. C. JUL 1 1917

NOTE 1. WITH THE ABOVE TOLERANCES IT IS EVIDENT THAT IF ONE CERTIFIED THERMOMETER BE SUBSTITUTED FOR ANOTHER IN TAKING A TEMPERATURE, A CHANGE OF 0°.2 AT OR NEAR THE NORMAL POINT, OR 0°.4 AT OR NEAR THE 104° POINT, MAY BE ERRONEOUSLY INDICATED.

NOTE 2. THIS THERMOMETER HAS BEEN AGED AT LEAST ONE MONTH BEFORE TESTING. SUBSEQUENT CHANGES IN THE READINGS DUE TO AGING, AND TENDING TO MAKE THE THERMOMETER READ HIGHER, CAN ONLY BE DETERMINED BY RETEST; SUCH CHANGES WILL PROBABLY NOT EXCEED 0°.1.

FIG. 1.—*Facsimile, except that the seal is printed in red, of Fahrenheit clinical thermometer certificate as issued by the Bureau of Standards after July 1, 1917*

(A similar certificate with seal in blue is issued for centigrade thermometers)

CAUTION.—Many manufacturers and dealers issue certificates for thermometers sold by them, and while the Bureau does not in any sense condemn such practice, it nevertheless desires to call the attention of the public to certificates that are made to resemble the Bureau of Standards certificate and which often contain the words "Bureau of Standards, Washington, D. C.," in boldface type so that the casual observer is deceived into believing that the certificate in question was issued by the Bureau of Standards. Such practice is most strongly to be condemned, and the purchaser of a clinical thermometer is therefore cautioned to read the certificate carefully to assure himself or herself on this point. The above figure is an exact facsimile except as to color of the seal of the certificate issued under the testing regulations effective July 1, 1917. The certificates bear the seal of the Bureau of Standards.

TESTING OF CLINICAL THERMOMETERS

CONTENTS

1. INTRODUCTION

Shortly after the organization of the Bureau of Standards in 1901, numerous inquiries were received from manufacturers and users of clinical thermometers concerning the certification of such thermometers by the Bureau. Before undertaking this work an exhaustive study was made of the magnitude of the errors and the most common defects in such thermometers as were then found on the market. A large number of clinical thermometers of various types and manufacture were carefully investigated as to magnitude of errors, retreating of index, difficulty of throwing back index, time of action, effect of aging, effect of using different kinds of glass, difference in reading when warm and when cold, etc.

These experiments soon disclosed the fact that there was a marked discrepancy in the temperatures indicated by thermometers sent in by different makers, showing a great lack of uniformity in the standards commonly in use in this country. The scale of temperature most commonly used was about 0°.2 F high, and accordingly some of the leading manufacturers of clinical thermometers were requested to submit their standards for verification. The tests of these standards confirmed the conclusions drawn from the tests of the clinical thermometers.

2. UNIFORM SCALE OF TEMPERATURE

The readiness with which manufacturers complied with our request, and the interest they have shown in our work, have been of great assistance to us in this important work of introducing a *uniform scale of temperature.* The standard scale of temperature now in world-wide use is the so-called "international hydrogen scale" or its equivalent as defined by the platinum-resistance thermometer. The adoption of this scale of temperature by the manufacturers and users of clinical thermometers, besides offering the advantages resulting from a uniform scale in this country, can not fail to be of service where our thermometers are sent abroad and come into competition with those certified by foreign testing bureaus. The satisfactory conclusion to which this work has led is evidenced by the fact that the corrections found for the clinical thermometers that are now sent in by manufacturers who have certified standards are very much smaller than the corrections of those submitted at the beginning of these investigations.

Specially designed and carefully calibrated clinical standards have for several years past been loaned by the Bureau to manufacturers with a view to facilitating the use of standard thermometers of proper construction and the adoption of a uniform scale of temperature.

3. SPECIFICATIONS FOR CLINICAL STANDARDS

A clinical standard is an ordinary thermometer, i. e., not self-registering, adapted to the pointing and testing of clinical thermometers, and which has a scale including the ordinary range required in clinical thermometry.

One of the important features of a clinical standard is the presence of the ice point on the scale, as it enables the user to determine whether the thermometer has undergone any changes since it was last tested. The Bureau has had a number of satisfactory clinical standards made under the following specifications, which apply for centigrade thermometers on crossing out the lower bracketed figures and for Fahrenheit thermometers on crossing out the upper ones.

Description.—The thermometer is to be graduated in 0°.1 intervals from $\begin{cases} -1^\circ \text{ to } +1^\circ \text{ C} \\ 31^\circ \text{ to } 33^\circ \text{ F} \end{cases}$ and from $\begin{cases} 31^\circ.8 \text{ to } 45^\circ.2 \text{ C} \\ 89^\circ.5 \text{ to } 112^\circ.5 \text{ F} \end{cases}$ with an auxiliary reservoir between the $\begin{cases} +1^\circ \text{ and } 31^\circ.8 \\ 33^\circ \text{ and } 89^\circ.5 \end{cases}$ marks and a pear-

shaped reservoir above the $\left\{\begin{matrix}45°.2\\112°.5\end{matrix}\right\}$ mark. The upper end of the stem is to have a small glass ring not larger than the diameter of the stem.

General.—All material and workmanship are to be first class in every respect.

Material.—The bulbs shall be made of Jena 16^{III} normal, Corning normal, or other approved glass that has been found equally satisfactory for thermometric purposes. The bulbs shall be approximately cylindrical, having a maximum diameter not greater than that of the stem, and a wall thickness of about 0.5 mm. The stems shall be made of enamel-backed tubing.[1] The tubes used shall be straight, of uniform diameter, and free from defects. They shall be of circular cross section, and about 5.7 mm in diameter, but not less than 5.5 mm nor more than 6.0 mm. The capillary shall be approximately circular in cross section and about 0.12 mm in diameter, but not less than 0.10 nor more than 0.15 mm. The tubes used shall be of such uniform bore that variations in cross section will cause no error greater than 0°.04 in readings interpolated between test points 5° apart. The mercury used shall be clean and pure and the thermometer shall be filled so that the mercury will be free from entrapped gas.

Dimensions.—The length of a degree interval shall be about $\left\{\begin{matrix}9.0\\7.0\end{matrix}\right\}$ mm, but shall not be less than $\left\{\begin{matrix}8.0\\6.0\end{matrix}\right\}$ nor more than $\left\{\begin{matrix}10.0\\8.0\end{matrix}\right\}$ mm. The $\left\{\begin{matrix}-1°\\31°\end{matrix}\right\}$ mark shall be not less than 1 cm from the upper end of the bulb. The $\left\{\begin{matrix}+1°\\33°\end{matrix}\right\}$ mark shall be not less than 5 mm below the auxiliary reservoir. The upper end of the auxiliary reservoir shall be not more than 5 cm above the upper end of the bulb. The $\left\{\begin{matrix}31°.8\\89°.5\end{matrix}\right\}$ mark shall be not less than 5 mm above the auxiliary reservoir. The $\left\{\begin{matrix}45°.2\\112°.5\end{matrix}\right\}$ mark shall be not less than 5 mm below the upper pear-shaped reservoir nor more than 3 cm from the end of the thermometer. The total length of the thermometer shall not exceed $\left\{\begin{matrix}24\\27\end{matrix}\right\}$ cm.

[1] Experience has shown that stems of normal glass are more likely to develop cracks than those of some other glasses.

Graduation.—The thermometers shall be graduated to read temperatures on the scale of the international hydrogen gas thermometer. The maximum error at any point shall not exceed $\left\{\begin{matrix}0°.1\\0°.2\end{matrix}\right\}$.

Graduation marks and numbering.—The graduating should be done on a good dividing engine. The whole degree and half degree marks should be 3 mm in length, but shall not be more than 3.2 mm nor less than 2.8 mm. The remaining marks should be 1.2 mm shorter than the others, but shall not be more than 1.4 mm nor less than 1 mm shorter. The longer marks should preferably extend equally to the right and left of the shorter ones. The marks made in pointing shall not be such as to cause a widening of the graduation lines near the center. The width of the graduation marks shall be not more than one-tenth nor less than one-thirtieth of the length of a graduation interval. The marks shall be regularly spaced, of uniform width and length (for all lines of a given specified length) with clearly defined edges, and shall be straight and perpendicular to the axis of the stem. They shall be uniformly filled with a coloring matter which is not removed by hot or cold water. An imaginary line passing through the middle points of all the graduation marks shall be straight, parallel to the axis of the stem, and diametrically opposite the enamel backing. The graduations are to be numbered in full at each degree mark, the numbers being so placed as to be upright when the thermometer is vertical. The numbers shall be not less than 1.5 mm nor more than 2 mm in height, shall be clear and easily legible, and so placed as to indicate definitely to which mark they belong.

Annealing.—The thermometers shall be thoroughly annealed before the final filling, being heated for not less than 48 hours at a temperature between 410° and 450° C (depending on the glass used for the stem), with subsequent slow cooling. (See Bureau of Standards Scientific Paper[2] No. 32 and Circular No. 8 for particulars.)

Identification.—The maker's name and a serial number shall be engraved on the thermometer.

Case.—The thermometer shall be provided with a well-made, felt-lined brass case.

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[2] Bulletin, Bureau of Standards, 2, p. 189.

4. METHODS OF TESTING

In view of the fact that clinical thermometers are submitted in large numbers for test and certification, it has been necessary to develop methods of testing that will involve a minimum of time and expense, without in any way sacrificing the desired accuracy. As these methods may be of some service to manufacturers in the construction and testing of thermometers, full details of the apparatus and methods of testing used and the results of some of the investigations referred to above have been published in a special bulletin on The Testing of Clinical Thermometers (Bureau of Standards Scientific Paper[3] No. 13). The only significant change that has been introduced in the apparatus for testing clinical thermometers described in Scientific Paper No. 13 is a new type of "whirling machine" in which the thermometer holders are mounted in buckets pivoted slightly above the center so that they hang vertically when the machine is at rest and assume a nearly horizontal position when the machine is rotated rapidly. Much of the apparatus and many of the essential details of these methods have since been adopted by a number of manufacturers of clinical thermometers.

5. TESTING REGULATIONS

As the result of a large number of experiments on clinical thermometers found on the market, certain regulations governing their test were adopted by this Bureau in 1903. These regulations are given in an appendix to this circular. They included the issuing of a certificate giving corrections at four points, 96°, 100°, 104°, and 108° F. to an accuracy of 0°.1 F (36°, 38°, 40°, and 42° C to an accuracy of 0°.1 C). This method of certification, while entirely satisfactory if the corrections given in the certificate were applied, was nevertheless open to objections. Of these objections may be mentioned, first, that 96° and 108° F are temperatures seldom met with in clinical practice, and if they were, an accuracy of 0°.1 in their determination would obviously be unnecessary; second, as the corrections were not applied in practice, and since a maximum correction of plus or minus 0°.3 was allowable, there was a possibility if one thermometer were substituted for another that the second thermometer would erroneously indicate a change of 0°.6 in a temperature which in reality had remained constant; third, thermometer dealers claimed that customers would not

[3] Bulletin, Bureau of Standards, 1, p. 275.

buy thermometers the certificates for which showed any corrections other than zero, and thus the sale of certified thermometers was discouraged.

After correspondence with physicians, thermometer manufacturers, and others interested the following revised regulations were adopted as being better suited to practical usage than the former ones. These regulations are effective July 1, 1917.

Thermometers submitted for certification will be tested at two points, the so-called normal point, 98°.6 F (37° C) (see p. 15), and 104° F (40° C). If the instrument on comparison with the standard thermometers of this Bureau is found correct within + or − 0°.1 F (0°.06 C) at the normal point, and within + or − 0°.2 F (0°.12 C) at 104° F (40° C), and repeats its readings on successive tests to within 0°.1 F (0°.06 C), a certificate will be issued stating that the thermometer is correct within these tolerances.

Before being tested for accuracy, clinical thermometers are examined for defects which can be detected by inspection, such as presence of air bubbles or moisture in the mercury or in the capillary bore, cracks in the glass, and defective graduations or numbering. The thermometer is also tested to determine whether the index is too difficult to throw back. When large numbers of thermometers have to be tested, the usual method of throwing back the index by hand is impracticable on account of the time and effort required. This test is accordingly carried out by mounting a large number of the thermometers in a centrifuge with the bulbs outward and at a definite distance from the axis, in which position they are rotated at a definite predetermined speed. All thermometers that hold their index in this test are rejected as presenting too much difficulty in throwing back the index in ordinary use.

Of the total number of thermometers submitted each year it was found that from 6 to 10 per cent were rejected for various reasons (see appendix) under the testing regulations in force prior to July 1, 1917. Under the revised regulations the percentage of thermometers rejected for exceeding the limits of allowable error will be somewhat larger, assuming that the same grade of thermometers as has been submitted in the past continues to be submitted in the future. The compensating advantages are that the dealer will not be troubled by purchasers picking over every certificate to find a thermometer with all zero corrections; that the manufacturer therefore will be relieved of the

unreasonable demand that he furnish thermometers with all zero corrections; and that the user will be provided with a thermometer the maximum error of which is smaller than was permitted under the old regulations, and since it seems to have been the universal practice to disregard corrections given in the certificate and to assume that a certified thermometer was good enough to use without applying corrections, the user therefore secures higher accuracy than under the old regulations.

For the reasons set forth under section 8, thermometers can not be certified under the regulations in force after July 1, 1917, within a period less than five weeks after they are received by the Bureau. However, in special cases, when the thermometers are very urgently needed, the Bureau may agree to furnish the corrections to the readings at the two test points in the form of a typewritten report giving "corrections at the date of test."

The fees for tests under these regulations are given in section 13 of this circular.

The form of certificate issued under these regulations is shown in Fig. 1.

Tests under Regulations in Force Prior to July 1, 1917.—When specially requested, tests will be made under the regulations set forth in the appendix.

6. TYPES OF CLINICAL THERMOMETERS

Clinical thermometers are made in many different forms. By way of illustration it is only necessary to describe a few of the more common types.

Nearly all clinical thermometers are self-registering; that is to say, they register the highest temperature to which they have been exposed. Various devices for accomplishing this object are in use, but the one almost universally used in the United States and in Great Britain, and also extensively in Europe, consists of a contraction or trap in the capillary tube of the thermometer, which permits the mercury to expand through the contraction in fine globules, but does not allow it to return unless the mercury is forced back. This contraction must be very skillfully made, for if the globules of mercury that pass are large the readings will increase by a series of large jumps and the thermometer will not register accurately. If the contraction is too large ("loose"), the thermometer will not hold its index at all. On the other hand, if the contraction is too small ("tight"), it is difficult to force the

mercury below the contraction (throw back the index) when a new reading is desired. These defects cause the rejection of a considerable number of thermometers submitted for test. The contractions are made by heating the glass tube with a blowpipe and allowing the walls to collapse.

In some of the larger forms of clinical thermometers widely used in Europe other devices are sometimes employed—e. g., a small air bubble in the column of mercury, which pushes before it a short column (index) of mercury when the temperature is raised, but which leaves the index in position when the highest temperature has been reached. The capillary stem, which is inclosed within a protecting glass tube, is bent into a loop to prevent the air bubble from receding into the bulb when the index is thrown back. Another device frequently used is a small glass rod attached to the bottom of the bulb, which runs through the center of the bulb and terminates in the bottom of the capillary stem. As the mercury expands it forces its way through the narrow annular opening between the rod and the capillary; but when the mercury contracts the mercury above the trap can not retreat, and hence the highest temperature is recorded.

The "stem" type of thermometer usually has the graduations on the outside of the glass tube, and is made with what is called a magnifying lens front and a white enamel back. The fine thread of mercury is thus seen greatly magnified against the white background. In the "einschluss" or inclosed scale type, the scale is ruled on a strip of milk glass, which is placed directly back of the fine capillary stem of the thermometer, both being inclosed in a glass tube. The outer glass tube is always fused to the bulb or the capillary tube, but different methods are used to fasten the scale in position. In some the scales are fastened with sealing wax in a groove cut in a cork that closes the top of the outer glass tube. In the better forms the scale is fused to the top of the outer glass tube.

It is claimed by some that the graduations of thermometers of the stem type, which are, in part, filled with some black coloring matter, will retain disease germs, which can not be as readily removed as in the case of the inclosed scale type when the thermometer is placed in the antiseptic liquid. The latter are, therefore, sometimes called "aseptic" thermometers. Whether this criticism is valid would have to be determined by the bacteri-

ologist. Another advantage claimed for the "aseptic" type of thermometers is that the black coloring matter in the graduations is not exposed to the action of the antiseptic fluid, so that its scale always remains legible. It should be added that if there is any advantage in the aseptic form of thermometer, from a bacteriological standpoint, it is often lost by the addition of metallic caps to the thermometers, which must be far more dangerous germ traps than outside graduations, because the metal caps are seldom exposed to the antiseptic fluid. Thermometers of the stem type are occasionally made in the aseptic form by ruling the scale on a thin strip of mica, which is then inclosed in a small rectangular slot within the glass stem and immediately back of the capillary bore.

All of the types here referred to are sometimes modified to adapt them to special purposes. Thus, the bulb is sometimes made in the form of a flat spiral for determining local surface temperatures, and in others it has a special form to suit the organ whose temperature is to be measured—as, for example, the eye.

7. READING CLINICAL THERMOMETERS

Clinical thermometers are usually graduated into subdivisions of 0°.1 C or 0°.2 F. In the ordinary use of these thermometers, readings to one-half of the finest subdivision are sufficiently accurate. The most important source of error to be avoided in reading is that arising from parallax. This is readily avoided in stem thermometers by so holding the thermometer before the eye that the graduation marks near the end of the mercury index, where the reading is to be made, are superimposed upon the reflected images of the corresponding graduation marks seen in the mercury index; in inclosed scale (einschluss) thermometers, by so placing the eye that the portions of the graduations seen through the capillary glass stem immediately above the mercury index, where the reading is to be made, are in the same straight line with the corresponding parts of the same graduations seen on either side of the fine capillary stem.

The readings are most conveniently made by taking hold of the thermometer near the top and holding it in a horizontal position.

Reading a large number of thermometers rapidly and with high accuracy, as is required in the work of testing, is best accomplished by mounting the thermometers in a suitable holder that

can be placed in a reading stand, provided with a simple microscope, as explained in Bureau of Standards Scientific Paper No. 13. In this way an experienced observer, with the aid of an assistant to record his readings, can readily read 20 thermometers per minute with a precision of 0.1 or 0.2 of a graduation interval.

8. EFFECT OF AGING

The strains set up in glass in the process of working in the blowpipe are only relieved after a long period of time, extending over many months and even years. The disappearance of these strains makes itself manifest by a slow contraction of the glass and a consequent rise in the reading of the thermometer. Hence, thermometers not aged or "green," as they are called, might pass the most rigid test requirements, and yet if made of certain kinds of glass they might, in the course of two or three months, develop errors of 0°.6 F or more. In order to determine more definitely the magnitude of the errors that might result from time changes, a series of experiments were undertaken with a large number of green clinical thermometers made of different kinds of glass and by different manufacturers. The results of these experiments, based on many hundreds of observations, are given in the following table for different periods from the date the thermometers were made:

Average increase in Reading of Clinical Thermometers

Glass	At end of 1 month	At end of 2 months	At end of 14 months
	° F	° F	° F
Jena 16^{III} glass	0.04	0.06	0.11
Soft glass		.30	.68

These experiments show that if soft glass is used the time changes are by no means negligible. On the other hand, when the better grades of thermometer glass, such as Jena normal, Corning normal, or French hard glass are used, the total change in 14 months is only about 0°.1 F, and about one-half of this total change takes place in the first two months. Further experiments have shown that time changes after 14 months are insignificant. It is therefore evident that if clinical thermometers are made of the proper glass, three or four months are sufficient to age them, so that subsequent changes will be entirely negligible.

As already explained, for the purposes of clinical thermometry, the changes in the indications of a thermometer with time are very small—quite negligible indeed, after a month or two—if the bulb of the thermometer is made of any of the suitable thermometric glasses. However, if the bulbs are made of some of the unsuitable soft glasses, the total time change may amount to a large fraction of a degree, and the time changes that may take place, even some months after manufacture, may by no means be negligible. Hence, it will be obvious that if such thermometers are tested and certified soon after their manufacture the subsequent changes may be sufficient to render the certificates almost useless.

It obviously would be very desirable if the testing laboratory could add a statement on the certificate which would assure the user that the thermometer in question was made of a suitable thermometric glass and that its subsequent time changes would therefore be negligible. Unfortunately, there is no practicable test which can be made on a clinical thermometer to determine definitely whether the glass in the bulb is a suitable thermometric glass. The only way in which the testing laboratory could make the above positive statement would be by testing the thermometer when it is received, let it age for several months, and then retest it to determine the magnitude of the change in its indications. After a careful investigation of this question it hardly seems feasible to hold thermometers for so long a period in the testing laboratory. However, as several weeks usually elapse before the Bureau can complete its tests, the following plan has been adopted, which seems to be the best compromise that is possible. Immediately on receipt of a lot of thermometers a number are selected from the lot and tested. If when these thermometers are again tested four weeks later, together with the whole lot of thermometers, they do not show significant changes, it may be fairly assumed that the bulbs of these thermometers are not made of the inferior grades of soft glass and that the subsequent changes will not be very great, very probably not exceeding 0°.1 F. This test is the basis of the statement "such changes will probably not exceed 0°.1" found on the certificate. If the user desires to assure himself that his thermometer has not changed and that the certificate corrections are absolutely dependable, two courses of procedure are possible. He should either assure himself that the thermometer is suitably

aged before submitting it for test—e. g., by aging it himself for about one year—or he should have it retested some months after the first test.

The strains introduced in making the contraction or "trap" in the capillary stem of the thermometer, by which device the thermometer holds its highest reading until the mercury index is again thrown back, sometimes cause small slivers of glass to break off after long intervals of time, frequently rendering the thermometer untrustworthy. This defect is referred to because of the prevailing belief that if a thermometer has once been tested and has received a certificate it will always remain reliable as long as it continues to register.

9. TIME OF ACTION

The so-called "time of action" of clinical thermometers, which frequently gives rise to misunderstandings between the manufacturer and the user, depends largely on how the thermometer is used. Owing to the demand for short time of action, the manufacturers have been compelled to use very small and thin-walled bulbs and very fine capillaries, resulting in a very frail thermometer and making it difficult to throw back the index. To get the best results in use the thermometer should be placed under the tongue, and care should be taken not to inhale air through the mouth. The time of action varies from one-half minute to three minutes, or more, for some of the larger types commonly used abroad. Many thermometers found on the market, marked "half-minute," require a much longer time to register within 0°.1 of their final reading. In a water bath, only three to five seconds are required for the thermometer to take up the temperature of the bath.

Dr. Edwin Franck[4] concludes that the axilla (armpit) method of taking clinical temperature observations no longer meets the requirements of diagnosis, on account of possible inaccuracies and the time required. He regards rectal measurements as the quickest and most accurate means. Prof. Wiebe,[5] of the Physikalisch-Technische Reichsanstalt, has investigated the time of action of clinical thermometers sold as "one-half minute" and as "minute" thermometers. Both the stem type, commonly used in this country and in England, and the inclosed-scale (einschluss) type commonly used in Germany were tested, when used by the mouth method and the axilla method. Wiebe found that many

[4] Therapeutischen Monatshefte; Mai 1910.

[5] Zeitschrift für ärztliche Fortbildung; No. 7, 1909.

of these thermometers of the stem type, when properly used in the mouth, would register within 0°.1 C (0°.2 F) of the true temperature of the body within 1 minute, and some even within 35 or 40 seconds. The time of action of the so-called 1-minute thermometers of the inclosed scale type was considerably longer, about 2 minutes or more, on the average. Clinical thermometers of the stem type have, in general, smaller bulbs with thinner glass walls than the inclosed-scale thermometers. The wall thickness of the bulbs of the thermometers used in these experiments was about 0.10 mm and 0.25 mm, respectively, for these two types. On account of the larger bulbs, the inclosed-scale thermometers, have, in general, the more open scale.

The time required for a thermometer to attain within 0°.1 C (0°.2 F) of its final reading was very much longer when inserted in the axilla than when properly used in the mouth, the time required varying from 3 to 15 minutes for the former method. The final temperature attained was, however, the same whether the thermometer was used in the mouth or in the axilla. The longer time required in the axilla is due to the fact that it takes some time for the surface of the skin, which has been previously somewhat exposed, to take up the temperature of the blood. A similar effect was observed by Callendar,[6] who found that it required a longer time for a clinical thermometer to attain its final reading if the mouth had not been kept closed some minutes before inserting the thermometer. The time also depends on the intimacy of the contact between the skin and the bulb of the thermometer. Wiebe recommends the mouth method of taking the temperature over the axilla method, so widely used in Germany.

10. NORMAL TEMPERATURE OF THE HUMAN BODY

The so-called "normal temperature" is by no means a definite temperature, even for any one individual in normal health. It may vary by 2° F at different times of the day, being usually, under normal conditions of living, lowest in the morning (6 to 7 a. m.) and highest in the afternoon (5 to 7 p. m.). The temperature of the body also depends upon many other factors, among which are age, sex, food, temperament, occupation, etc. The temperatures very generally taken as normal are 98°.6 F (37° C) or 98°.4 F, 98°.6 being the more generally accepted value. It

[6] Phil. Mag. (VI), **19**, p. 550; 1910.

might be added that much of the work on which these values are based was carried out at a time when due attention was not given to the accuracy of the clinical thermometers used in the investigations. In view of the fact also that at that time, before the general introduction of the better thermometer glasses, inferior glasses were used in the construction of clinical thermometers, there is a reasonable probability that the thermometers read high a short time after they were made up, assuming that they were correct when pointed by the maker. There is also a probability that the standards by which the clinical thermometers were pointed read somewhat high, in view of the fact that the mercury-in-glass scale of temperature (of most glasses except English crystal), used before the general introduction of the gas scale, read somewhat higher than the latter scale. In view of these facts, it would not be surprising if systematic experiments, carried out on a large scale, with carefully standardized clinical thermometers, would lead to a somewhat lower value for the so-called "average normal temperature."

11. ACCURACY REQUIRED IN CLINICAL THERMOMETRY

Some years ago and again quite recently the Bureau addressed inquiries to a number of physicians in hospitals and members of medical faculties as to the accuracy required in clinical thermometry. The opinion was quite unanimous that 0°.1 F was entirely negligible, and that 0°.2 F rarely, if ever, was of significance in diagnosis. In this connection it should be stated that it is the practice of the Physikalisch-Technische Reichsanstalt in Berlin and its allied testing branches to engrave on a thermometer the word "fehlerfrei" (free from error) if the corrections are found not to exceed 0°.06 C. (0°.1 F). A certain accuracy of 0°.2 F. would undoubtedly meet nearly every requirement of the medical practitioner, yet errors of 0°.2 F, if not known, might be of importance in cases where a thermometer reading, say, 0°.2 F too high, had been used by a physician and was replaced by one reading 0°.2 F low. This would produce an apparent change of 0°.4 F, which might vary readily be of significance in the conclusions to be drawn. for readings of temperatures near the normal point. It may be fairly stated that a clinical thermometer having corrections no greater than 0°.1 F is sufficiently accurate to meet the most exacting requirements of the practitioner, and for all practical purposes, aside from a natural

predisposition in favor of perfection whether it means anything or not, is as good, or at least serves its purpose as well, as one having all zero corrections. At temperatures somewhat removed from the normal point, say below 96° and above 104° F, an accuracy of 0°.3 or 0°.4 F is probably sufficient. The demand on the manufacturer, therefore, that every thermometer in a large lot shall have zero corrections, is rather a severe one and to some extent unfair. The certificates issued under the new regulations obviate this difficulty and yet assure to the user of the thermometer an accuracy sufficient for practically every clinical requirement.

12. GENERAL INSTRUCTIONS CONCERNING REQUESTS FOR TESTS

Application for Test.—The request for test should be made in writing, addressed to "Bureau of Standards, Washington, D. C."

Identification Marks.—All packages should bear the shipper's name and address, and, when convenient, a statement of the contents.

Packing.—Methods of packing depend upon the number of thermometers to be shipped, but the main object of packing should be the protection of the bulb, which is the part most liable to breakage.

When from one to a dozen thermometers only are to be shipped, they can best be packed in individual hard-rubber or metal cases with sufficient cotton or paper wrapping to prevent *any motion* of the thermometers *within the case.* The individual cases can then be packed in cotton or excelsior in wooden or strong paper boxes and, when thus packed, can be shipped by parcel post (insured).

Where more than a dozen thermometers are to be shipped together, a better method than packing in individual cases is to bundle the thermometers, without cases, in bundles containing preferably from two dozen to four dozen, held firmly together by rubber bands. These bundles should then be wrapped preferably in corrugated paper at least an inch longer than the thermometers. The ends of these bundles should be filled in with loose cotton and the bundles should be packed in light, strong wooden boxes, laying all the bundles together. The box should be large enough to allow for 1 to 3 inches of excelsior on all sides between the bundles and the box, the thickness of packing being greater for larger numbers of thermometers.

Thermometers having projections interfering with proper handling should be wrapped individually.

Clinical thermometers should never be left exposed to bright sunlight, whether packed or not, as the temperature reached may be high enough to break the thermometer.

Shipping Directions.—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. To facilitate packing and shipping, the tops of the cases should have the return or forwarding address on the underside, and should be put on with screws. Transportation charges are payable by the party desiring the test and must be prepaid. Articles will be returned or forwarded by parcel post or by express "collect."

Address.—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.—Fees should be sent promptly upon receipt of bill, which will be sent when test has progressed to such an extent that the fee can be determined. Certificates are not given nor is the 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."

13. FEES

The following schedule of fees for testing clinical thermometers is effective July 1, 1917:

Schedule 35. Clinical Thermometers

(*a*) to (*e*) Items superseded except for special test (see appendix).	
(*f*) One thermometer	$0.25
(*g*) From 2 to 8, 25 cents for first thermometer and 10 cents for each additional one.	
(*h*) Any number from 9 to 12, total fee	1.00
(*i*) One dozen or more, rate per dozen	1.00

S. W. Stratton,
Director.

Approved:
William C. Redfield,
Secretary.

APPENDIX

Testing regulations adopted in 1903 and in force until July 1, 1917:

As a result of a large number of experiments on clinical thermometers found on the market, the following regulations governing their test were adopted by the Bureau.

Before being tested for accuracy, clinical thermometers are examined for defects of construction, such as presence of air bubbles or moisture in the mercury or in the capillary bore, cracks in the glass, and defective graduations; the operation of the registering device ("index") is also tested to see that the index is neither too easy nor too difficult to throw back. When large numbers of thermometers have to be tested the usual method of throwing back the index by hand is impracticable, on account of the time and effort required. This test is accordingly carried out by mounting a large number of the thermometers in a centrifuge, with the bulbs outward and at a definite distance from the axis, in which position they are rotated at a definite predetermined speed; all thermometers that hold their index in this test are rejected as presenting too much difficulty in throwing back the index in ordinary use. If this test is passed, the thermometers are then compared in an electrically heated and motor-stirred water bath with two standard thermometers of the Bureau at the four test points, 36°, 38°, 40°, and 42° C, or 96°, 100°, 104°, and 108° F, two independent comparisons being made at each point. If the two tests at any point differ by more than 0°.08 C or 0°.15 F, or if the mean of the two tests gives a correction in excess of 0°.2 C, or 0°.3 F, the thermometer is rejected. Furthermore, errors in the value of an interval between test points must not exceed 0°.2 C or 0°.3 F. For example, if the correction for a particular thermometer at the 96° F point were +0°.3 and at the 100° F point −0°.1, the error in the value of the temperature interval would be 0°.4, and the thermometer would fail to receive a certificate.

In this connection the following statistics relating to the testing of clinical thermometers, and covering a period of five years (1905–1910), may be of interest in showing the causes of failure of clinical thermometers to receive certificates. Of the total number of thermometers submitted for test about 0.3 per cent were received broken (i. e., about 1 in 300) and about 0.2 per cent were broken in the various operations of testing. Of the remaining thermometers that were put through the various tests about 0.8 per cent failed on account of defects of construction, about 0.6 per cent because of difficulty in throwing back the index, and about 4.9 per cent because the errors exceeded the limits above specified. This includes both those whose corrections are larger than 0°.2 C or 0°.3 F and those which fail to repeat their readings at the same point to within 0°.08 C or 0°.15 F. Of the total number tested, therefore, about 93.7 per cent were certified.

When specifically requested tests will be made under the above regulations and certificates will be issued giving the corrections at the four test points specified above. The fees for tests under these regulations are given in the following schedule

Schedule 35 [in part]. Clinical Thermometers[7]

(*a*) In lots up to 8, each	$0. 25
(*b*) Any number between 8 and 12, total fee	2. 00
(*c*) In lots of 1 dozen or over, and less than 4½ dozen, per dozen	2. 00
(*d*) Any number between 4½ and 6 dozen, total fee	9. 00
(*e*) In lots of 6 dozen or over, per dozen	1. 50

[7] For full schedule, see Schedule 35, p. 18.