THE TESTING OF CLINICAL THERMOMETERS.

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Soon after the organization of the Bureau of Standards work preparatory to the testing of clinical thermometers was taken up.^a At the same time all of the prominent manufacturers of clinical thermometers were requested to submit samples of their product in order that the Bureau could determine what accuracy might be expected and what defects were most common.

The design and construction of the apparatus required for this purpose was undertaken with two main objects in view: first, that the highest accuracy should be obtained, and second, that the tests could be made so rapidly that the fees for testing would be reduced to a minimum. The apparatus finally adopted has been in use for some time, and the methods of testing have been subjected to exhaustive trials. As both the apparatus and methods used by the Bureau have been the subject of numerous inquiries, it is deemed advisable to publish a full description for the use of those interested and also an account of the experiments upon which the regulations finally adopted are based.

The first tests made showed that many of the clinical thermometers had errors as large as 0.5° or 0.6° F., and in some cases even larger errors were found. Moreover, a study of groups of thermometers suggested that the standards used were in error. The manufacturers were accordingly requested to submit their standards to the Bureau for examination. Without exception this request was complied with, and, as suspected, the conclusion that the standards were in error was confirmed.

^aThe work was begun in the section of weights and measures under the direction of Mr. Fischer, and was subsequently transferred to the section of thermometry, upon its organization, under the direction of Dr. Waidner.

CLINICAL STANDARD THERMOMETERS.

Some of the standards submitted were found to be radically defective in construction. Some were so constructed that when used in the water bath for the pointing of ordinary clinical thermometers the stems projected above the surface of the bath by amounts corresponding to 60° F. and even more. Since changes of 20° F. or more occur in the temperature of rooms where clinical thermometers are graduated, and since the temperature of the exposed portion of the stem is largely controlled by the temperature of the room, there is here presented a possible source of error of about 0.1° F. Another defect common to most of the clinical standards submitted was the absence of the ice point (32° F.) from the scale. The presence of this point is important, since it enables one immediately to detect any change in the indications of a thermometer by determining the ice point in a mixture of finely crushed pure ice and distilled water. If any change is detected in this point the reading of the thermometer may then be corrected. It is true that most of the standards used by manufacturers are quite old, and hence changes in these thermometers would probably be small. Nevertheless changes might occur on account of the development of minute air bubbles or other causes, which, as before stated, would be readily detected by a determination of the ice point.

A form of clinical standard well adapted for the pointing or testing of clinical thermometers is shown in fig. 1.

Immediately above the ice point is an enlargement of the bore, which makes it possible to obtain on a short stem the ice point and also the range of temperature required in clinical thermometry. Above the enlargement there are graduations corresponding to $0^{\circ}.1$ and covering the range 90° to 110° F. In ordinary use these standard thermometers are immersed in the water bath to about the 93° mark, so that not more than 17° is emergent from the bath, and hence the variations in the temperature of the room may be neglected. The corrections to these thermometers are carefully determined by comparing them with the primary standards of the Bureau.

These latter are made of the usual thermometric glasses, namely, French hard glass or Jena 16^{III} normal glass, and are artificially aged, before final filling, by exposing them to a temperature of about 850° F. for at least 60 hours, after which they are allowed to cool slowly. When treated in this manner subsequent time changes are extremely small. The graduations on these thermometers are very fine, whereas some of the standards submitted to the Bureau for examination were only graduated into $0^{\circ}.2$ F., and the graduation lines were nearly as wide

FIG. 1. CLINICAL STANDARDS.

as half an interval. Under such conditions it is easily possible to make an error of several hundredths of a degree in reading the thermometer. It might seem at first sight that errors of this magnitude are negligible in clinical thermometry, but they are sufficient to make the corrections to large numbers of clinical thermometers $0^{\circ}.1$, while if the correct temperature of the bath had been known when the clinical thermometers were pointed the corrections resulting from the tests of the Bureau would have been given as $0^{\circ}.0$. To illustrate, if the observed correction is $0^{\circ}.05$ or less it is given as $0^{\circ}.0$, while if $0^{\circ}.06$ had been observed the correction would have been given as $0^{\circ}.1$.

To facilitate the use of standards of proper construction and of a uniform scale of temperature the Bureau has loaned a few of these specially constructed standards to a number of manufacturers for brief periods. The Bureau has also pointed a number of standards made and submitted by the manufacturers for this purpose. The result of this work has been greatly to reduce the errors of clinical thermometers, those now submitted for test having, on the average, errors less than one-half as great as those first submitted.

SCALE OF TEMPERATURE.

The advantages resulting from the universal use of one and the same scale of temperature are almost self-evident, but notwithstanding this fact a number of slightly different scales were found in use by manufacturers, all of whom supposed their standards to be correct. Since frequent inquiries are made as to the scale of temperature used by the Bureau, the question will be briefly considered here.

The interval covering the ordinary range of temperature is fixed by the temperature of melting ice and by the temperature of steam under normal pressure.^a These two temperatures are universally used to determine the so-called fixed points of thermometers of various kinds.

It is well known that the indications of mercury thermometers constructed of different kinds of glass may differ very materially from one another, after making all necessary corrections to their readings for errors in the fixed points, and for nonuniformity in the caliber of the tubes. These differences, due to the fact that different glasses have different coefficients of expansion, may amount to more than $0^{\circ}.2$ F. Thermometers made up from the same pot of glass, or even from the same piece of tubing that have been worked differently in the blast flame, will often show very appreciable differences in their temperature scales. For these reasons mercury in glass thermometers are not suited for establishing a standard scale of temperature.

^aThe pressure of 760 mm of mercury at 0° C. and at sea level and latitude 45° .

The scale that has now come into almost universal use in all accurate scientific and technical work is what is known as the International Hydrogen Scale, based upon the researches of Chappuis carried out at the International Bureau of Weights and Measures. This scale is defined as follows in a resolution of the International Committee on Weights and Measures adopted October 15, 1887:

The International Committee on Weights and Measures adopts as the standard thermometric scale for the International Service of Weights and Measures the centigrade scale of the hydrogen thermometer, having as fixed points the temperature of melting ice (0°), and of the vapor of distilled water boiling (100°) at standard atmospheric pressure; the hydrogen being taken at an initial manometric pressure of 1 m of mercury; that is to say, $\frac{1000}{760} = 1.3158$ times the standard atmospheric pressure.

On this scale of temperature, therefore, 1° is measured by $\frac{1}{100}$ of the change of pressure, between the two fixed points, of a confined mass of hydrogen gas whose volume is kept constant, and whose initial pressure (at 0° C.) is equivalent to 1 meter of mercury (at 0° C., and at sea level, lat. 45°).

TYPES OF CLINICAL THERMOMETERS.

Clinical thermometers are made of many different forms. By way of illustration it is only necessary to describe a few of the leading 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, is shown in (*a*), fig. 2.

It 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 skilfully 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. This operation introduces strains in the glass, which sometimes cause small slivers of glass to break off in the vicinity of the contraction, often after long

FIG. 2.

TYPES OF CLINICAL THERMOMETERS.

FIG. 3.

TYPES OF ASEPTIC THERMOMETERS.

intervals of time, frequently rendering the thermometer untrustworthy. These defects are 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.

In some of the larger forms of clinical thermometers widely used in Europe other devices are employed. The device shown in (*b*) fig. 2 is quite common. It consists of 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 is bent in 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 form of thermometer shown in (*a*), fig. 2, 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 form of thermometer shown in (*b*), fig. 2, known as 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, as shown in (*b*), fig. 2.

It is claimed by some that the graduations of thermometers of type (*a*), fig. 2, 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 (*b*), fig. 2, 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 bacteriologist.

Two other types of aseptic thermometers, shown in (*a*) and (*b*), fig. 3, are also found on the market.

In type (*a*), fig. 3, the outside of the stem of the thermometer is

perfectly smooth; the scale, graduated on mica, is sealed in the rectangular slot in the stem, immediately behind the capillary bore. In the type (*b*), fig. 3, a thermometer of the form shown in (*a*), fig. 2, is inclosed in a neatly fitting glass envelope, displacement being prevented by the rubber ring *R*.

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.

All of the types illustrated 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.

TIME REQUIRED TO ATTAIN THE PROPER TEMPERATURE.

The question of the so-called "time of action" of clinical thermometers frequently gives rise to misunderstandings between the manufacturer and user. The time required by a thermometer to attain its final temperature depends largely upon how it is used, and hence to say that a thermometer is a half, one, or two minute thermometer means nothing definite. Owing to the demand for a short "time of action" the manufacturers have been compelled to use extremely thin wall tubing for the bulbs, and also to reduce to a minimum the amount of mercury used in the thermometers. Owing to the latter they have also been compelled to use for the stem very fine capillary bore tubing. The general effect has been to produce somewhat frail thermometers, inconvenient to use because of the difficulty of throwing back the index; hence it seems probable that the effort in this direction has been carried too far. To increase the exposed surface of the bulb the latter is sometimes made double and are then called "twin bulb" thermometers.

To get the best results the thermometer should be kept under and in good contact with the tongue, and care should also be taken by the user not to inhale air through the mouth. The time may be slightly reduced

by taking care not to press the thermometer against the tongue hard enough to impede circulation. When properly used, thermometers of type (a), fig. 2, require from less than a half minute to two minutes. In a water bath thermometers of this type will generally take up the temperature of the bath in five seconds or less. The larger clinical thermometers of type (b), fig. 2, or the form illustrated in (b), fig. 3, necessarily have a longer time of action.

AGING OF CLINICAL THERMOMETERS.

One of the important and most difficult questions that had to be settled before regulations concerning the certification could be adopted was that of aging. 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 $0^{\circ}.6$ F. or more. To protect the certificate of the Bureau and at the same time meet the requirements of all those interested, several courses were open, each of which was both favored and criticised when submitted to the interested parties for their opinion.

One suggestion was that the thermometers be deposited with the Bureau for at least four months. They could then be withdrawn by the maker for final inscription and returned to the Bureau for test. The Bureau would then be satisfied that the thermometer had been duly aged for a period that would probably render any subsequent time changes negligible. This procedure is open to objections, chief among which are the uncertainty of the demand, the necessity for double transportation, and the twofold process of engraving.

Another suggestion was to test them as soon as possible, hold them for a period of from four to six weeks, and again test them. Since a considerable part of the time change in green thermometers occurs within the first month or two, the two tests would determine whether the thermometers had been sufficiently aged. The principal objection to this procedure is the necessity of two tests, with consequent increase in the cost of testing.

In order to determine 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:

Glass.	Average increase in reading of clinical thermometers.		
	At the end of 1 month.	At the end of 2 months.	At the end of 14 months.
Jena 16 ^{III} glass.....	0°.04 F.	0°.06 F.	0°.11 F.
Soft glass		0°.30 F.	0°.68 F.

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 are used, such as Jena normal or French hard glass, the total change in fourteen months is only about 0°.1 F., and about one-half of this total change takes place in the first two months. Other experiments have shown that time changes after fourteen 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 negligible.

When glass is heated to a certain temperature it expands quite rapidly to the volume corresponding to that temperature. If cooled again to its initial temperature it contracts rather quickly to nearly, but not quite, its original volume. To completely recover takes days, and with some kinds of glass weeks and months. Consequently the strains due to working the glass in the high temperature of the blowpipe disappear slowly, the disappearance being made manifest by a rise in the indications of the thermometers as the glass contracts. If the thermometer is made by making the bulb out of glass tubing, by closing one end and fusing the other end to the stem, the strains, and consequently the time changes, are less than if the bulb is blown on the stem.

The common practice in the United States is to make the bulbs of the hard thermometer glasses, and the stems of softer enamel back and lens front tubing. As the volume of the mercury in the bulb is many times greater than that in the stem, the changes in the stem are negligible, and hence thermometers constructed in this manner are just as satisfactory as those made entirely of hard glass.

In view of these circumstances and of the foregoing experiments the Bureau decided to waive all requirements as to aging, at least for the present, and instead the statement is made in the certificate furnished by the Bureau that the indications are liable to change unless the thermometer has been suitably aged.

FIG. 4. HOLDERS FOR THERMOMETERS.

FIG. 5. WHIRLING MACHINE.

REQUIREMENTS FOR CERTIFICATION.

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. If this test is passed the thermometer is then compared with two standard thermometers of the Bureau at the four test points, 96° , 100° , 104° , and 108° , two independent comparisons being made at each point. If the two tests at any point differ by more than $0^{\circ}.15$ F., or if the mean of the two tests give a correction in excess of $0^{\circ}.3$ F., the thermometer is rejected. Furthermore, errors in the intervals between test points must not exceed $0^{\circ}.3$ F.^a

Thermometers submitted for test must have a clear space of at least 2 cm. ($\frac{3}{4}$ inch) near the stop of the stem for etching thereon the identification marks of the Bureau.

METHOD OF TESTING.

. PRELIMINARY TEST.

Those thermometers which successfully pass the examination for such defects as are evident on careful inspection are mounted in lots of 24 in the small holders shown in fig. 4. The thermometers are held in position in the holders by the pressure of springs made of phosphor bronze.

The holders have identification numbers, and to each holder is assigned a record sheet similar to that shown in fig. 9. The sheets are numbered to correspond with the holders, and the thermometers are entered on this sheet in the same order that they are mounted in the holder, the manufacturer's number being entered in the second column.

The next step is to test the registering device. Where 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 conveniently and rapidly made by means of the "whirling machine" shown in fig. 5.

Two of the holders loaded with thermometers are mounted in this machine, by pulling back the lock spring S_2 , raising the shaft P , and slipping on the holder, as shown in the figure, and then dropping the

^a For example, if the correction at 96° is $+0^{\circ}.3$ and at 100° $-0^{\circ}.1$, the error in the interval would be $0^{\circ}.4$ F., and the thermometer would be rejected.

shaft back into a horizontal position where it is held by the lock spring. By whirling the thermometers the mercury index is driven back into the bulb. The machine is operated by turning the handle H , which acts through bevel gears on the shaft S , on top of which is a glass tube filled with oil or glycerin. When the shaft S is rotated the surface of the liquid assumes a parabolic form, the center being depressed by an amount dependent upon the speed of rotation. This is therefore a very simple and convenient speed indicator.

The speed of rotation has been determined corresponding to what is considered the maximum muscular effort that should be required to throw back the index. The test then simply consists in whirling the machine until this limiting speed has been reached. The thermometers are then rapidly examined in succession by turning the holders on the shaft P . Such as have failed to fall below 95° F. are removed from the holder and placed among those rejected. This completes the preliminary test.

DETERMINATIONS OF CORRECTIONS.

The thermometers that have fulfilled the preliminary test are next compared at 96° , 100° , 104° , 108° F., or, if centigrade thermometers, at 35° , 37° , 39° , 42° C. in a well-stirred water bath with two standard thermometers similar to those already described.

COMPARISON TANK.

The tank shown in fig. 6 is a double-wall vessel made of seamless brass tubing. The water in the inner tank is thoroughly stirred by a small propeller K which is driven at a high speed by the small direct-connected electric motor M . This propeller forces the water downward through the central tube and upward in the space between the inner and outer tube, as indicated by the arrows. The stirring is so thorough that the temperature of the bath is constant throughout to within $0^{\circ}.01$. The inner tank is covered with a very fine layer of sheet mica, on which are wound two heating coils, C_1 and C_2 , of cotton-covered constantan wire shellaced in place. Each coil has a resistance of about 80 ohms, and its terminals are connected to binding posts on the bottom of the tank. The coils are connected to a 110-volt circuit through the rheostat R , which serves to regulate the current in the heating coils. If rapid heating is desired, as when raising the temperature of the bath up to the first test point, or from one test point to another, the two coils are put in parallel by throwing the double-pole double-throw switch S_2 to the side marked "Fast." When a constant temperature or a slowly-rising one is desired, the

FIG. 6. COMPARISON TANK.

two coils are placed in series by throwing the switch to the side marked "Slow." A Weston wattmeter W^1 serves to measure the electrical energy required in heating the coils. When the switch is thrown to the side marked "Fast" the wattmeter and rheostat are cut out.

From a series of preliminary experiments, a table has been made out giving the amount of electrical energy required to maintain constant temperatures at the several test points for different room temperatures. The amount of energy necessary is so small, never exceeding 75 watts, that its cost is trifling.

The rheostat R has two dials of 24 steps each, the step on one corresponding to nearly the entire turn on the other.

Within the tank is a small coil C of seamless copper tubing through which hot or cold water may be circulated to also control the temperature. This water is introduced through the two-way mixing cock C_3 connected to hot and cold water tanks, and the amount of each may be easily controlled by turning the knurled hard-rubber head, shown on the front of the tank. The circulation of cold water enables the temperature of the bath to be lowered and is a necessary adjunct to the electrical heating. The hot water has been added because it helps to bring the temperature quickly to the different test points. The hot and cold water circulation, with the use of a sensitive stop cock, is sufficient for all purposes, but on account of its convenience the electric current regulation is always used. From the bottom of the tank, which is made with four stiffening webs of brass, there project upward four brass pins P on which a like number of loaded holders are slipped. Hence, 96 thermometers may be immersed at one time.

Two standards, T_1 and T_2 , pass through short brass tubes in the cover of the tank. Inside of the short tubes are springs which keep the thermometers vertical and at any desired depth. On top of the tank are mounted two small reading microscopes MM , through which the thermometers are read with accuracy and ease.^a The microscope shown in the illustration, which has proven to be entirely satisfactory, is known as the Bruecke dissecting lens, and was made by the Bausch and Lomb Optical Company, of Rochester, N. Y.

A complete testing apparatus is shown in fig. 7. The whirling machine is shown at the right end of the table, the comparison tank near the center; the hot and cold water tanks, with necessary supply and overflow connections, are mounted on a cast-iron support about 75 cm in height. The hot water tank contains an electric heating coil wound in two sections inside a thin-walled copper tube. The

^a One microscope is sufficient, since it may be quickly turned from one standard to the other.

copper tube is wound in a spiral of 15 cm diameter. The two sections of this coil can be joined, by means of a simple switch, to give fast, medium, and slow heating, the latter being sufficient to keep the temperature 15 or 20° F. below the boiling point.

The supply of electrical energy for the comparison tank is controlled by the switches and rheostat handles shown on the front of the table, and by a wattmeter mounted inside of and read through a small plate glass window in the top of the table. On top of the table is shown a reading stand, in which the holders are placed and the thermometers read through a small microscope. There is also shown a tray with holders to illustrate the method of carrying them around. The scales of the two standard thermometers in the tank are illuminated by the incandescent lamp mounted on the flexible stand in the rear. The large drawer on the left of the table is used to store thermometers undergoing test, while the door on the right is a switchboard on which are mounted the necessary switches and the rheostat. The door is hinged and opens outward, thus rendering all the connections accessible. The above testing outfit was exhibited at the Louisiana Purchase Exposition at St. Louis, Mo.

To return to the process of testing, the temperature of the bath is quickly brought up to within a fraction of a degree of the temperature of the lowest test point (96° F.) by the hot water circulation, and then by means of the rheostat *R* and the wattmeter *W* the current is regulated to maintain the temperature at 96° F.

Four holders are then put into the bath, and by momentarily throwing the switch to the side marked "Fast," the temperature of the bath is brought to exactly 96°.00 F. The temperature can be brought with ease to within 0°.01 F. of the test point, and it rarely happens that the readings of the two standard thermometers differ by more than this amount. The readings of the two thermometers are then entered on the test record sheet (see fig. 9). This procedure is repeated until all the holders have been dipped at the first test point.

READING OF THE CLINICAL THERMOMETERS.

After all the thermometers have been dipped, the holders are mounted one at a time in the reading stand shown in fig. 8.

One observer reads the thermometers as they are successively brought into the field of view of the microscope by turning the knurled head of the arbor on which the holders are slipped, while another records the readings on the test record sheet. With a little practice the thermometers may be read at the rate of 20 per minute, without sacrificing accuracy, as has been demonstrated by repeated trials. The readings,

FIG. 7. CLINICAL TESTING TABLE.

FIG. 8. READING STAND.

even when made by different observers, rarely differ by more than $0^{\circ}.03$ F.

After all the loaded holders have been read at the first test point, the bath is brought to the next test temperature, 100° F., and the clinical thermometers are again dipped and read in the manner described. This procedure is repeated for the other test points, 104° and 108° F. The holders are then mounted two at a time in the whirling machine and the mercury is made to retreat below 95° , and the entire series of observations at the four test points is repeated.

The record sheet previously referred to on page 283 is the record for one holder. The corrections at each test point as determined by the two independent tests are entered in columns 6, 10, 14, and 18, and the means of the two tests to the nearest $0^{\circ}.1$ are entered in columns 7, 11, 15, and 19. In the test record sheet shown thermometers Nos. 5 and 17 were rejected because the indices were too difficult to throw back, No. 8 failed to hold its index ("retreater"), No. 11 because the error exceeded the allowable error ($0^{\circ}.3$), and Nos. 14 and 22 because they failed to repeat their readings within $0^{\circ}.15$ F. in the two tests. The remaining thermometers fulfilled all the test requirements and were then given B. S. serial numbers, which are entered in column 3.

B. S. IDENTIFICATION MARKS.

The serial numbers just referred to, preceded by the letters B. S., are then etched on the thermometers. To accomplish this the upper parts of the stems are thoroughly cleaned and dried, and then covered with a thin coating of wax by immersion in a pot of molten wax. The extreme ends are further protected by a second dipping before engraving. The wax pot used in this work has proved so convenient that a brief description will be given. It consists of a double-wall vessel wound with two heating coils connected to a lighting circuit by an ordinary fuse-plug connector. To melt the cold wax quickly the two coils are thrown in parallel, and when the wax is all melted it is kept at a constant temperature by the two coils in series.

The letters B. S. and the serial numbers are engraved on the back of the thermometers by means of an engraving machine made by Eaton and Glover. This machine, though somewhat large for this character of work, is nevertheless quite convenient. The etching is done by immersing the end of the thermometer for a short time in a bath of hydrofluoric acid.

CERTIFICATE.

The corrections to the thermometers are then transferred from the test record to the certificates, a facsimile of which is shown in fig. 11.

RÉSUMÉ SHEET.

When a number of thermometers are submitted for a test a "résumé sheet" is returned with the certificates. This sheet gives a statement of the number of thermometers that have received certificates, the reasons why others were rejected, etc. A sample résumé sheet corresponding to the test record sheet shown on the preceding page is shown in fig. 10.

RESULTS OF THE WORK.

It is gratifying to note a marked improvement in the quality of the thermometers now being submitted, especially in the product of those firms which have freely availed themselves of the facilities of the Bureau. Not the least important result has been the introduction into the clinical-thermometer industry of a uniform scale of temperature. At the present time practically all the large manufacturers have sent their standards to the Bureau for comparisons, so that not only are the standards in accord with one another, but they are also in accord with the scale of temperature used throughout the scientific and technical world. An impartial and authoritative test is of value alike to the manufacturer, the dealer, and the user of thermometers. To the first mentioned it is a constant check on his standards and product, and to the dealer and user the certificate is a guarantee of the accuracy of the thermometer.

The allowable errors for certification have been made as liberal as is consistent with a good product and with due regard to the interests of all concerned. The present limits were fixed after extensive experiments made on clinical thermometers obtained from different sources, but as the standard of product increases it may be desirable to modify these limits.

The investigation of the methods described and testing on a small scale have been in progress for the past three years. The announcement, however, that the Bureau was prepared to test thermometers was made only about eight months ago. Since then about five thousand thermometers have been submitted for test, so that ample opportunity has been afforded to test both the apparatus and the methods.

On account of the desire among users of clinical thermometers to have instruments with zero corrections the demand on the manufacturer has been unreasonably severe. As a matter of fact, a thermometer having corrections of $0^{\circ}.1$ F. is practically as good as one with zero correction, since this order of accuracy is all that is essential. A thermometer with corrections as high as $0^{\circ}.2$ F. may ordinarily be

Department of Commerce and Labor
BUREAU OF STANDARDS
Washington

B. S. TEST No. 938 of 24 CLINICAL THERMOMETERS

Submitted by Clinical Mfg. Co. Marked The E. J. H. Drug Co.

Observers: H. D. and F. W.

Computed by F. W.

Checked by H.D. Holder No. 10 Date 4/23/04.

Badin Therm.		96.04	96.05			100.04	100.05			104.04	104.05			108.00	108.00			REMARKS.				
No. 15936		-.05	-.05			-.04	-.04			-.02	-.02			.00	.00							
Green Therm		95.99	95.99			100.00	100.00			104.01	104.02			108.04	108.05							
No 1539		+0.1	+0.1			.00	-.00			-.02	-.02			-.05	-.05							
COR. TEMP.		96.00	96.00			100.00	100.00			104.00	104.00			108.00	108.00							
1	29105	3725	96.08	96.20	-.08	-.02	-.1	100.00	100.06	.00	.00	.0	104.04	104.08	-.04	.0	108.06	108.12	-.04	-.1		
2	100	24	.02	.00	-.02	.00	.0	.00	.00	.00	.0	.02	.04	-.02	.0	.00	.00	.00	.01	.0		
3	110	27	.03	.05	-.03	-.05	.0	.04	.04	-.04	-.04	.0	.00	.00	.00	.0	.06	.06	-.06	-.1		
4	101	28	.04	.06	-.04	-.06	.0	.00	.00	.00	.00	.0	.00	103.96	.00	.0	107.90	107.92	+1.00	+1		
5	108	X																		W		
6	107	29	.10	.05	-.10	-.05	-.1	.10	.10	-.10	-.10	-.1	.06	104.08	-.06	-.08	-.1	108.14	108.15	-.14	-.1	
7	103	37.30	.08	.14	-.08	-.14	-.1	.10	.08	-.10	-.08	-.1	.07	.00	-.07	.00	.0	.03	.00	-.03	.0	
8	109	X	.00	.10				99.80	99.88				103.70	103.60			107.10	106.50			r	
9	130	31	.10	.04	-.10	-.04	-.1	100.00	100.00	.00	.00	.0	104.00	104.05	-.00	.0	.90	107.86	+1.00	+1		
10	121	32	95.95	.00	+0.04	.00	.0	99.94	.00	+0.06	.00	.0	.00	.00	.00	.0	108.00	108.04	.00	.0		
11	118	X	.98	.00				100.18	.20			.25	.32				.40	.46			>	
12	114	33	96.01	.08	-.01	-.08	.0	.00	.05	-.00	.00	.0	.06	.02	-.04	-.02	.0	107.86	.00	+1.00	+1	
13	117	34	95.80	95.77	+0.20	+0.23	+2	99.97	99.84	+0.03	+1.16	+1	103.86	103.90	+1.14	+1.10	.83	107.82	+1.17	+1.18	+2	
14	135	X	96.05	.80				.90	.90				104.00	.80			.80	.84			a	
15	137	35	.04	96.02	-.04	-.02	.0	100.03	100.00	-.03	.00	.0	.00	104.14	.00	-.14	-.1	.90	.95	+0.00	+1	
16	139	36	.00	.04	-.04	-.00	.0	.00	.00	.00	.00	.0	.03	.00	-.03	.00	.0	108.00	108.05	.00	.0	
17	116	X																		W		
18	113	37	.02	.04	-.12	-.04	-.1	.00	.04	-.00	-.04	.0	.08	.05	-.08	-.05	-.1	107.92	.00	+0.00	.0	
19	119	38	.00	.00	.00	.00	.0	.00	.00	.00	.00	.0	.04	.16	-.04	-.16	-.1	108.22	.20	-.22	-.20	-.2
20	124	39	.10	.08	-.10	-.08	-.1	.06	.03	-.06	-.03	.0	.07	.02	-.07	-.02	.0	.00	.02	-.02	.0	
21	132	37.40	.05	.10	-.05	-.10	-.1	.07	.06	-.07	-.06	-.1	.00	.02	-.00	-.02	.0	.00	.04	-.00	.0	
22	141	X	95.80	.00				99.80	99.82				103.75	103.76			.00	.27			a	
23	102	41	.85	95.84	+1.15	+1.16	+2	.82	.80	+1.18	+1.20	+2	.84	.92	+1.16	+1.18	+2	107.83	107.85	+1.17	+1.15	+2
24	106	42	96.00	96.04	-.04	-.00	.0	100.00	100.00	.00	.00	.0	104.00	104.00	.00	.00	.0	108.00	108.04	-.04	.0	

FIG. 9. TEST RECORD SHEET.

Department of Commerce and Labor

BUREAU OF STANDARDS

RÉSUMÉ OF B. S. TEST NO. 938.

OF
24 CLINICAL THERMOMETERS

SUBMITTED BY

Clinical Mfg. Co.

REASON FOR FAILURE TO RECEIVE CERTIFICATE	IDENTIFICATION MARK ON THERMOMETER	TOTAL NO. THERMS.
Defects in construction: e. g. Presence of air bubbles in bulb, cracks in glass, defects in grad- uation, failure to hold index in every part of scale, etc.	29135 29141	2
Too difficult to throw back index below 95°.	29108 29116	2
Broken when received for test.		0
Broken during process of test- ing.		0
		4
Exceed limits of allowable error for certification.	29118 29109	2

For thermometers that failed to pass the preliminary test, for reasons specified in the first four sections of this table, a rebate is allowed at the pro rata rate corresponding to the number of thermometers submitted for test.

No. of thermometers submitted for test = 24
" " failed to pass preliminary test = 4
" " included in test = 20 @ per doz. =

DIRECTOR

Department of Commerce and Labor
BUREAU OF STANDARDS

CERTIFICATE OF EXAMINATION
 OF
REGISTERING CLINICAL THERMOMETER

Submitted by **Clinical Mfg. Co.**

Marked "N. B. S.

No. **3731.**"

This certifies that the above thermometer was found to have the following corrections at this date, compared with the official standards of this Bureau:

THERMOMETER READING	CORRECTIONS
96° F.	+ 0.1
100°	.0
104°	- .1
108°	- .2

NOTE.—When the correction is + it should be added to and when — subtracted from the reading.

Unless this thermometer has been suitably aged before testing, its indications are liable to change with time.

Washington, D. C.

4-23-04

Test No. 938.

S. W. Stratton

Director.

Form 35. (Ed. 4, Jan. 2, 1904—3,000.)

11-592

FIG. 11. CERTIFICATE.

used without regard to the corrections, and in cases where the accurate temperature is desired the corrections may be applied.

Of the clinical thermometers tested during the year ending July 1, 1904, 88.2 per cent satisfied all the requirements and received certificates, 8.5 per cent were rejected because their errors exceeded the allowable error, 1.6 per cent because the mercury index was too difficult to throw back, and 1.5 per cent for other causes, such as defects in construction, moisture, or air bubbles in mercury, etc.; 0.67 per cent were broken when received and 0.50 per cent were broken during test.

In conclusion, the authors wish to acknowledge their obligations to Dr. S. W. Stratton, Director of the Bureau of Standards, for many valuable suggestions in the design of the apparatus; to Dr. Chree, of the Kew Observatory, where clinical thermometers have been tested for many years, and to Dr. Wiebe and Dr. Hebe, of the Physikalisch-Technische Reichsanstalt, where such work is done on the largest scale, who gave the authors every facility to inspect the apparatus and methods in use at these institutions; to Mr. L. G. Hoxton and Mr. H. C. Dickinson, who were actively associated with the authors in the work. We are also pleased to acknowledge our indebtedness to the manufacturers for placing at our disposal for investigation considerable numbers of clinical thermometers, and also for much valuable advice and many suggestions. All the testing apparatus described was constructed in the instrument shop of the Bureau.

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