DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

S. W. STRATTON, DIRECTOR

No. 51

MEASUREMENT OF TIME AND TESTS OF TIMEPIECES

[1st Edition]
Issued December 1, 1914

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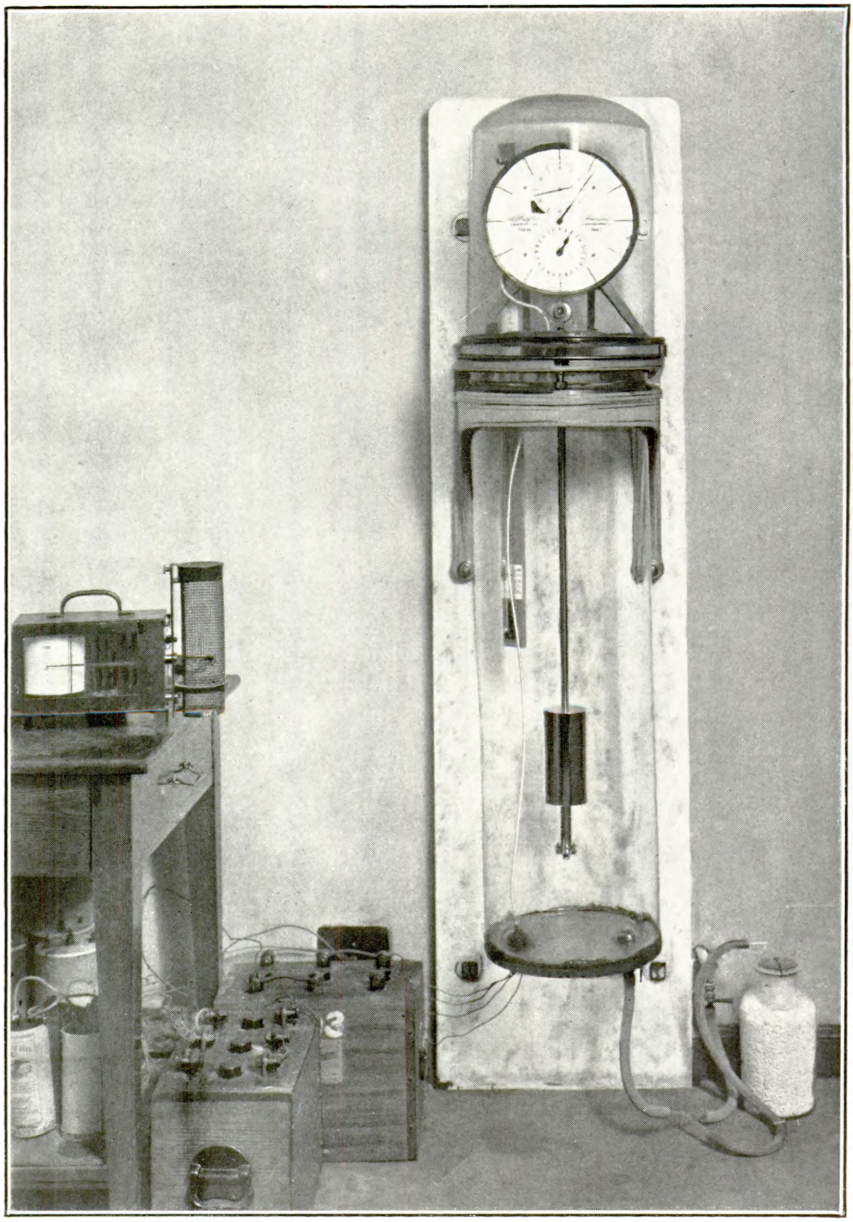

FIG. 1.—*Precision mean time clock (Riefler type) used as a standard in the testing of timepieces at the Bureau of Standards*

MEASUREMENT OF TIME AND TESTS OF TIMEPIECES

CONTENTS

I. INTRODUCTION

The functions of the Bureau of Standards include the testing and comparison with standards of various kinds of measuring apparatus, and the certification of the accuracy of such instruments. The principal object of this standardization is to bring about better agreement with the standards of the United States of all measuring apparatus used in the comparison of physical quantities, and to increase the accuracy of measurement of the physical and chemical properties of matter. This service is performed for the public, as well as for the various departments of the National and State Governments.

Included in such measuring apparatus are timepieces of various kinds, and this is the first circular announcement of the beginning of the testing and certification of watches by the Bureau. This Circular gives the regulations under which such tests will be conducted, the procedure of the tests, the criteria that will be applied to the results of the tests, and the tolerances that will be allowed in the performance of a watch for which a certificate is granted. Later, the Bureau will take up the testing of other timepieces, such as chronometers, clocks, chronometer watches, chronographs, and stop watches, and devices for the measurement of short intervals of time. Announcement of the beginning of such tests and of the methods to be employed will be made in a subsequent edition of this Circular.

II. THE METHODS OF TEST OF WATCHES

The tests of high-grade watches will consist of the determination of their daily rates[1] under the various conditions for which they are adjusted. To the results will be applied several criteria to determine whether the performance of the watch is such as might be expected from a properly adjusted timepiece, and certificates will be granted if the rates are within certain limits. The daily readings of the watches are made by the use of a telescope, which can be sighted on the watches through the glass front of the testing room, and are recorded on a chronograph, connected to the electric seconds contact of the Bureau's mean-time clock, by tapping a telegraph key when the second hand reaches the fifty-eighth, sixtieth, and second second-hand marks on the dial. It is easily possible in this way to obtain the correction of the watch each day within 0.1 second. As the readings are

[1] Throughout this circular the term "rate of a watch" will be used as meaning the amount of time more, or less, than 24 hours which the watch indicates in 24 hours, or the amount the watch "gains" or "loses" in a day, as the words are ordinarily used when applied to timepieces. For a full definition of the term "rate" as here used see p. 15.

made at the same point on the second-hand dial each day any error in graduation of the dial or eccentricity of the position of the second hand is avoided. Furthermore, the comparisons being made at the same time each day, within a few minutes, the 24-hour rate is obtained at once without further correction, other than for the small variation in the correction of the comparison clock, which is checked daily. The watches are wound at the same time at which they are read, so that the variations from isochronism are not introduced into the regular daily readings.

1. POSITION TEST

The better grade of watches are usually adjusted for three or five positions, to isochronism, and for temperature variations. While a few adjusted watches made in this country are adjusted to two, four, or six positions, the three and five position adjusted watches are by far the most common. Accordingly, two classes of tests have been adopted, for the five-position and three-position watch, respectively. The five positions for which adjustments are made are with the watch vertical and the stem or pendant up, with the pendant 90° to the right and 90° to the left of the first position, and with the watch horizontal with dial up and with dial down. The pendant right and left positions are omitted in the three-position adjustment.

The test of position adjustment, therefore, consists in running the watches for several days in each of the five or three positions. This test is made at as constant a temperature as possible in order to eliminate from this position test as much as possible any irregularities due to temperature variations. The rates for several days in each position are taken in order to ascertain the degree of uniformity of the rate on successive days, one of the best tests of a well-made watch. This quality is most simply expressed by the deviations of the rates of the various days in any one position from the mean of those rates, and to this deviation of the rates is applied a tolerance, as the first criterion by which the watch is judged.

Inasmuch as it has been found, both in tests made at the Bureau of Standards and abroad, that nearly all watches have a steady progressive change in rate, usually a slowing up of the rate, it is desirable, in the position-adjustment tests, to eliminate this progressive change of rate, so far as possible, in order to determine the true precision of position adjustment, or to separate the one from the other. This is done by repeating the series of position tests in the reverse order. The mean of the two sets of rates,

thus determined in each position, is then taken as the rate of that position. The differences between the mean rates of the two periods in the same position will give the progressive change in rate for the period covered by the time intervening between the middle of each of the two periods. Allowing 3 days to each position period, this gives 6 days in which the watch is run in each position; or 30 days for the five-position watch and 18 days for the three-position watch are devoted to the test of the position adjustment and of the uniformity of and progressive change in the daily rate.

The accuracy of the position adjustment is judged primarily by the deviations of each of the means of the two sets of rates for each position, from the average of all five of these mean rates. As a further limitation upon the allowable variations of rates with changes of position, certain tolerances are applied to the largest difference of rate of any two positions, and smaller tolerances are allowed for the differences of the three most important positions—the vertical, pendant up, the horizontal, dial up, and the horizontal, dial down positions.

The progressive change in rate, shown in the differences between the rates of the first and the second periods, when the watch was in the same position, will be, therefore (in the five-position test), the change occurring in 27 days for the vertical, pendant up position; that in the vertical, pendant right position will be the change in 21 days; that for the vertical, pendant left will be the change in 15 days; while the change in the horizontal, dial up and horizontal, dial down positions will be that for 9 and 3 days, respectively; or the mean of the differences for the five positions will, on the average, represent the change of rate in 15 days.

2. ISOCHRONISM TEST

The test of the adjustment of a watch for isochronism, or the uniformity of rate throughout the day, is made by taking readings of the watch at three-hour intervals or less until the watch runs down. This test is carried out in the vertical, pendant up position, as it is the position in which the watch is carried, and, therefore, the position in which the question of isochronism is of most interest, although a nearer approach to true isochronism can usually be obtained for the watch in horizontal positions. The results of this test will be shown graphically in the form of a curve accompanying the certificate, and may be used to ascertain the total amount that the watch has gained or lost at any time after winding. In this test the watch will be allowed to run down (except in the case of watches running

over 2 days on one winding), although the first 24 hours is the only period for which the adjuster may be expected to attempt to secure isochronism, as any attempt to obtain isochronism for a longer period would usually be at a loss of isochronism in the first 24 hours. The objects of carrying this test out for a longer period than that for which the adjustment is made are to show more vividly the value of the isochronism adjustment in the first 24 hours, to make the user of the watch realize the importance of regular winding, and to indicate what deviations he may expect in the rate of the watch if it is not wound regularly. The character of these deviations of rate after the first 24 hours varies considerably, depending upon the methods employed to secure isochronism. Sometimes a sharp reversal of the rate will take place within a few hours of the twenty-fourth after winding, while in other watches the rate will continue in the same direction as for the first 24 hours, but will be greatly changed. The hourly rate often increases as much as five or ten times the earlier rate ("rate" here being understood as the amount by which the indicated time differs from the true elapsed time).

In figs. 2 and 3 are given typical examples of isochronism curves of watches, well adjusted for isochronism during the first 24 hours after winding, but showing marked changes in rate shortly after the 24-hour point. The amount in seconds gained or lost since winding is shown by the vertical ordinates of these curves, while the time in hours since winding is plotted horizontally. A straight line has been drawn through the 0 and 24 hour points of the curve, and represents what true isochronism for the observed 24-hour rate would have been. The vertical differences between this straight line and the curve are a measure of the isochronism error. In figs. 4 and 5 are shown isochronism curves of watches having relatively poor isochronal adjustment for the first 24 hours (outside the tolerance set for the class A test; see p. 32), and showing irregularities of rate after the 24-hour point.

3. TEMPERATURE TEST

The position and isochronism tests are carried out with the watches, kept at a temperature between 28° and 30° C (82° to 86° F), in a constant-temperature room controlled by a thermostat. This temperature is assumed to approximately represent the temperature of the watch in a man's pocket, and is nearly the temperature at which the position adjustments were made at the factory. For the tests of the temperature adjustment the watch is run for five days each at the temperatures of 5°, 20°,

and 35° C (41°, 68°, and 95° F). These tests are likewise made in a room under thermostatic control.

In the interpretation of the results of the test of the temperature compensation it should be kept in mind that it is practically impossible,

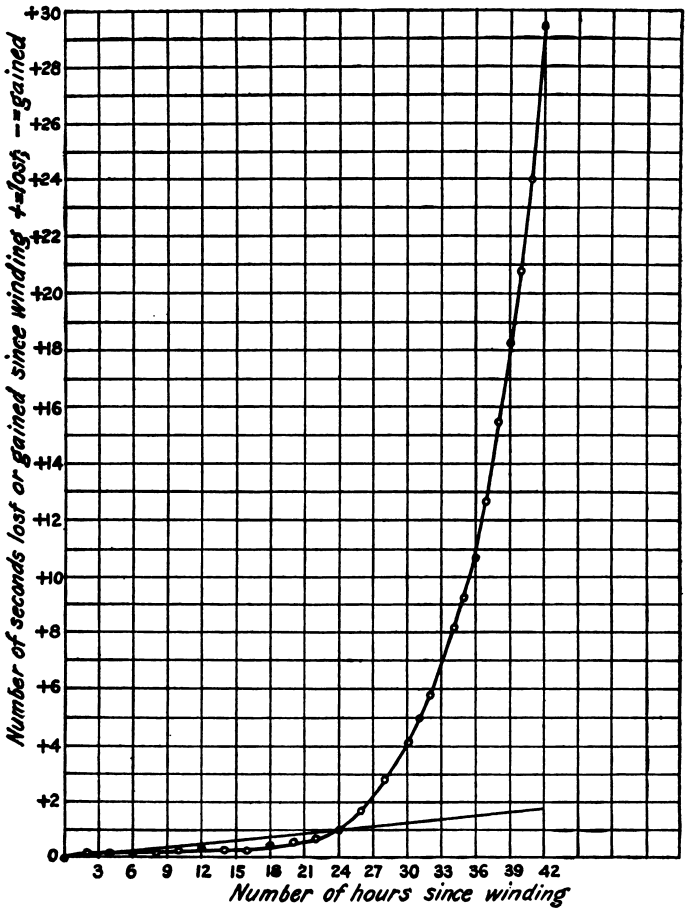

FIG. 2.—*Example of isochronism curve of a watch well adjusted for isochronism for the first 24 hours after winding (isochronism error +0.2 sec.) but showing a marked decrease in rate after 24 hours*

at least with the usual steel and brass balance wheel and steel hairspring, to reduce the variation of rate with temperature to a uniform, linear function, and at the same time keep the change of rate small. The variations that take place usually follow approximately the form of a parabola, and

it is the aim of the watchmaker to so adjust the timepiece as to bring the point of maximum rate, or the "temperature of compensation" of the parabola, at about the ordinary temperature at which the watch will be used, and to make the rates at lower and higher temperatures, while neces-

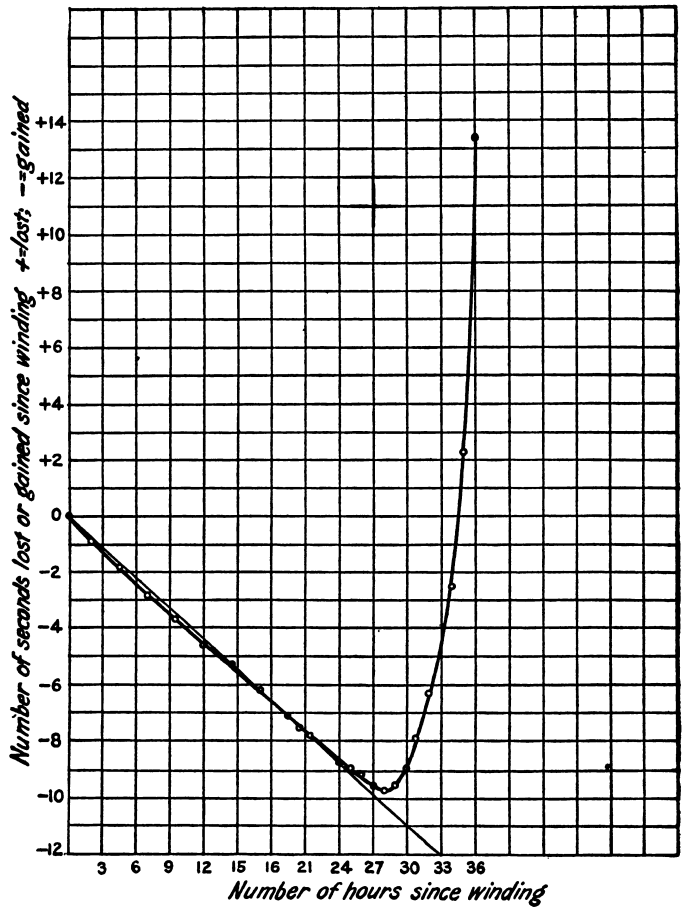

FIG. 3.—*Example of isochronism curve of a watch well adjusted for isochronism for the first 24 or 28 hours after winding (isochronism error +0.5 sec.) but showing a marked reversal of rate after the 28-hour point*

sarily somewhat slower than at the medium temperature, as nearly alike as practicable. The consequence is that, with a given balance wheel and hairspring, practically all the adjuster can hope to accomplish is to make the rate at the high temperature (usually 90° or 95° F) the same as at the low

(generally about freezing temperature or a few degrees above), and let the rate at the medium temperature be what it may. The watchmaker, accordingly, is chiefly interested in the difference of the rates at the low and high temperatures, and in the general slope and flatness of the curve representing

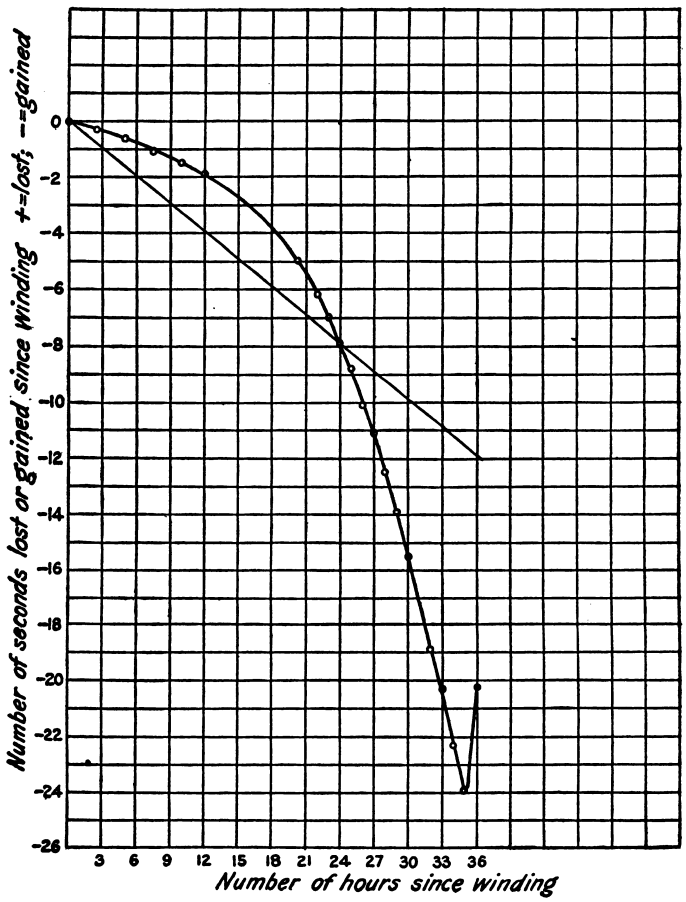

FIG. 4.—*Example of isochronism curve of a watch poorly adjusted for isochronism (isochronism error −4.1 sec.) and exhibiting a steady increase in rate after the 24-hour point except for a reversal of rate in the last hour before the watch stopped*

the variations of rate, while the user of a watch, on the other hand, is chiefly concerned in knowing what the watch's rate is at the various temperatures, or the slope of the curve from the low to the medium temperature and from the medium to the high temperature.

To meet these two requirements the report of the temperature test will give, first, the change of rate per degree centigrade from 5° to 35° C (41° to 95° F) to show the degree of success of the adjustment for temperature, and

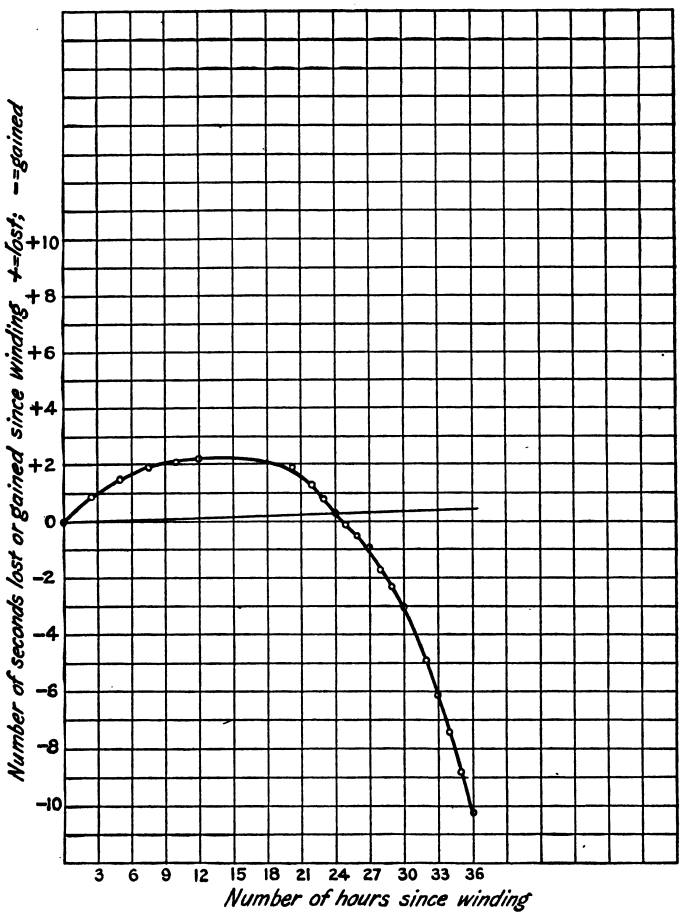

FIG. 5.—*Example of isochronism curve of a watch poorly adjusted for isochronism (isochronism error −4.1 sec.). The daily rate is only +0.3 sec. but during the first 24 hours it is in error by more than 2 seconds and in the 12 hours after the 24th it gains 10.5 seconds*

then will also give the change of rate per degree from 5° to 20° C (41° to 68° F) and from 20° to 35° C (68° to 95° F), to show the variations of rate which the user may expect in the watch with temperature changes. The first slope (from 5° to 35°) and the difference between this and the second

slope, from 5° to 20° C, as measuring the general slope of the curve and its flatness, respectively, will be used as criteria by which to judge the performance of the watch for its accuracy of temperature compensation.

In Fig. 6 are shown parabolic curves in solid line, illustrating the limiting variations allowable under the class A tolerances given on page 32 for the change of rate with change of temperature; that is, when the rate at 35° C is 6 seconds faster, and 6 seconds slower, than that at 5° C or 0.20 second

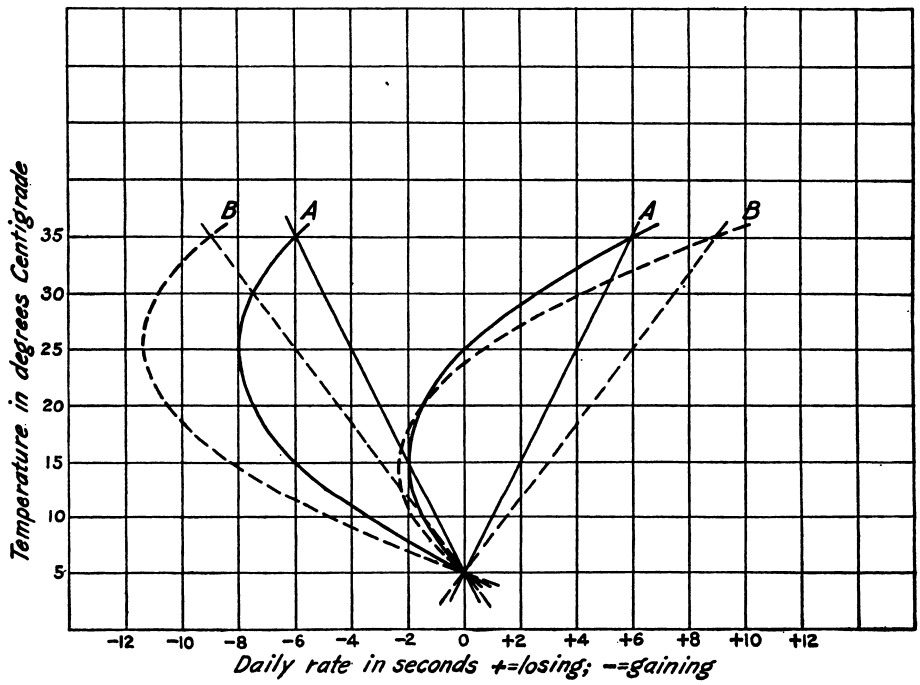

FIG. 6.—*Curves showing the limiting variations of rate with temperature allowable under the Bureau of Standards tolerances for a watch to receive a class A or class B certificate (indicated by curves A and B, respectively)*

per 1° C, and for the rate at 20° C, 7.5 seconds faster and 1.5 seconds faster, respectively, than that at 5°, which are the limiting rates for an excess of the change of rate per 1° from 5° to 20° over that from 5° to 35° of 0.30 second per degree. In these curves temperatures are plotted vertically and daily rates in seconds horizontally. In broken lines are shown the corresponding limiting positions under the class B tolerances. (See p. 35.) In these curves the rate at medium temperature is faster than at low and high temperatures—the usual case. A watch, however, would not be

rejected which gave the reverse performance if it was within the tolerances set. In Fig. 7 is shown the curve (I) of an exceptionally well-compensated watch having a brass and steel balance wheel, and in II the curve of a watch giving an average performance within the class A tolerances.

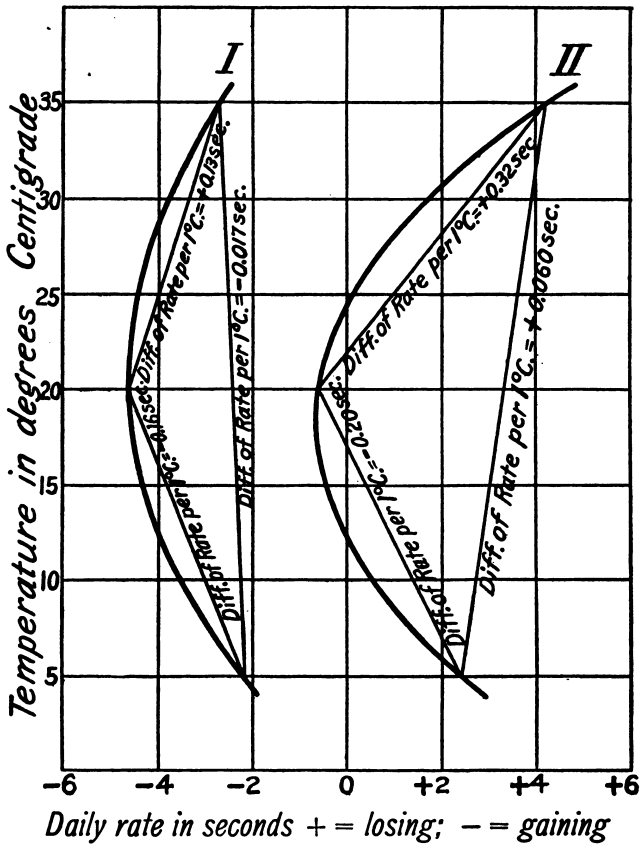

FIG. 7.—*Temperature curves of watches. Curve I is that of an exceptionally well compensated watch with a brass-steel balance wheel; curve II shows an average performance of a watch meeting the requirements as to temperature compensation for a Bureau of Standards class A certificate*

III. THE USE AND VALUE OF TESTS OF WATCHES

In deciding upon the form of test given in this Circular, the Bureau has had in mind chiefly the value of the test to the purchaser or user of a watch. It is a well-known fact that it is impossible to secure a perfect adjustment of a watch, that is, to eliminate all variations in the watch's rate. It is, in fact, impossible to secure perfection of rate in any respect,

owing to the interrelation of the various adjustments and to certain factors which prevent the securing of the ideal uniformity of rates. For example, the isochronism of the rate of a watch, or its uniformity of rate as the arcs of vibration of the balance decrease as the watch runs down, is so dependent upon the poise of the balance and other factors that an adjustment made for it in one position will be materially affected by the change of the watch to another position, so that the best the adjuster can do is to attempt to secure only approximate isochronism in one position and make its error of such a sign that when the watch is changed to another position the change in rate shall be such as to reverse, or tend to reverse, the sign of the error rather than to increase the error.

Because of such difficulties, therefore, the best the manufacturer or adjuster of a watch can do is to reduce the various errors within certain limits. If upon the first or second trial the error is not brought within a given limit, further adjustments are made until the error is reduced to the limit set in the practice of that factory. These limits vary in the different factories and with the different grades and models. Such a test as the Bureau will give a watch will, therefore, show the owner of a watch what degree of success was attained by the manufacturer in reducing the errors of his watch, and will furnish data for a comparison of the watch with the average product. It will enable the purchaser to see whether the watch is what is claimed for it in the matter of adjustment, and whether it gives a reasonable performance for a high-grade watch.

The data given in the certificate may also be used to advantage in securing a better pocket performance on the part of the watch; for the positions and temperatures for which the watch has the poorest rates may be avoided, and in the winding and general care of the timepiece one may be guided to obtain the most uniform results.

A third item of value in the certification of a watch is the assurance to the purchaser that at the time of the test the watch was in good condition and free from any defects or injury likely to affect the rate to which so delicate a mechanism as a watch is so subject; for if at the time of test such defects existed, they would almost certainly be evident at some point in the test in the form of marked irregularities of the rate or in the stopping of the watch. To make this feature of the greatest value it is highly desirable that the watches submitted for test be delivered to the Bureau in person, and that they be called for at the end of the test, in order that they may be delivered to the owner without the necessity of shipment by the ordinary means of transportation.

The tests of watches will also be of value to the manufacturers and adjusters of watches, and to the trade in general, in furnishing information as to the relative performance of various grades and makes of timepieces and particularly as to the value of any special features or improvements that may from time to time be introduced in their manufacture. To make the results of the most service in this respect the Bureau plans to publish from time to time, probably yearly, as is done by other testing laboratories and observatories, the data respecting the performance of the watches tested, together with such descriptive matter as will be of interest in this connection. To this end it is very desirable that all persons submitting watches for test should give all the information called for on the blank of application for test. Individuals submitting watches for test who are unable to give this information are requested to secure the information, so far as possible, by consulting a reliable jeweler or by communication with the maker of the watch.

IV. DEFINITIONS OF CORRECTION TO A WATCH, RATE, ETC.

In the rating of watches a *correction to a watch* will be taken to mean the amount of time to be added algebraically to the reading of a watch at any instant to give the true time. In the usual case of watches giving mean solar time, this correction shall be such as to give the true standard time for the standard time belt in which the watch is used. Accordingly, if a watch is slow, its correction will be plus; if it is fast, its correction will be minus in sign.

The daily rate of a watch will be taken to mean the difference between 24 hours and the interval of time the watch indicates in that period. In other words, it will be the correction of a watch at the end of a 24-hour period minus the correction at the beginning of the same period. If a watch indicates in 24 hours the passage of more time than 24 hours, it will be said to have a gaining rate, or to gain. If it indicates the passage of less than 24 hours in the same period, it will be said to have a losing rate, or to lose. A gaining rate, or the amount a watch gains in a day, being the algebraic difference of the correction at the end of 24 hours minus that at the beginning, where the former is larger negatively than the latter, will have a minus sign. Where the correction at the end of 24 hours is larger positively than at the beginning, the watch will have a losing rate and the rate a plus sign.

The amount gained or lost in any period of time will be taken as the difference between the true elapsed time and the elapsed time indicated by the

timepiece. Its sign will therefore have the same significance as that for daily rate. If the watch had been correct in its reading at the beginning of the period, its correction at the end of the period would be the same in quantity and sign as the amount gained or lost in that period.

All differences between rates of any period, day or series of days and any other similar interval of time, shall be taken as the rate of the later period or day minus that of the earlier period or day, so that a minus difference shall indicate a faster rate in the later period than in the earlier, and a difference having a plus sign shall indicate a slower rate in the later period than in the earlier.

If the difference of rate is to be used for determining *difference of rate per degree difference of temperature*, the rate at the lower temperature shall be subtracted from that at the higher temperature and this shall be divided by the difference of the temperatures; accordingly, a negative difference of rate per degree of temperature will mean that the timepiece runs faster the higher the temperature, and a difference of rate per degree of temperature having a plus sign will indicate that the rate is slower at the higher temperature than at the lower.

V. BY WHOM WATCHES MAY BE SUBMITTED FOR TEST

Watches may be submitted for test by manufacturers, jobbers, wholesale or retail jewelers, importers, or by the owners of individual watches. There is no restriction placed upon those who may submit watches for test as to the country in which the watch is made or the method of deposit of the watch for test, except that an application blank shall be filled out for each watch submitted. The blank when returned to the Bureau should be accompanied by a remittance to cover the cost of the test, as the watch can not be returned or the certificate or report furnished under the regulations until all fees are paid. In case the watch should be withdrawn or should stop before the close of the test, the proper refund on the fee will be promptly made.

Watches may be submitted by one person with the request that the certificate be made out in another person's name; or purchasers of watches in placing an order for one, may direct that the watch be sent to this Bureau for test before being forwarded to them. In such instances, however, the request for the test should distinctly state whether the watch, in case of failure to pass the test and receive a certificate, should be returned to the person from whom the watch was purchased or be forwarded to the purchaser.

VI. SIZES OF WATCH MOVEMENTS

In indicating the size of watch movements in the application for a test, the following table of sizes should be followed. The size numbers are based on the number of thirtieths of an inch by which the diameter of the movement exceeds 1 5/30 inch.

Size	Diameter—		
	In fractions of an inch	In decimals of an inch	In millimeters
18	$1\frac{23}{30}$	1.767	44.87
16	$1\frac{21}{30}$	1.700	43.18
14	$1\frac{19}{30}$	1.633	41.49
12	$1\frac{17}{30}$	1.567	39.79
10	$1\frac{15}{30}$	1.500	38.10
8	$1\frac{13}{30}$	1.433	36.41
6	$1\frac{11}{30}$	1.367	34.71
4	$1\frac{9}{30}$	1.300	33.02
2	$1\frac{7}{30}$	1.233	31.33
0	$1\frac{5}{30}$	1.167	29.63
00	$1\frac{4}{30}$	1.133	28.79
000	$1\frac{2}{30}$	1.100	27.94
0000	$1\frac{3}{30}$	1.067	27.09
00000	$1\frac{1}{30}$	1.033	26.25
000000	1	1.000	25.40

VII. THE USE AND CARE OF A WATCH

The importance of the careful handling of a fine watch, of regularity in winding it, and of frequent checking of its correction with some source of accurate time in order to obtain the best results is so well known as scarcely to need emphasis. However, with the thought of calling the reader's attention to some important precautions heretofore overlooked, the following suggestions on the handling, winding, and carrying of a watch are included here, together with some additional information on the sources of accurate time measurement with which one may frequently compare his watch.

1. THE HANDLING OF A WATCH

It is well known that a fall or severe jar is liable to injure the mechanism, especially in the bending of a pivot or the breaking of a jewel. It is, perhaps, not so well known that the mere fall of a watch to the end of its chain, or the jar it may receive when the article of clothing containing the watch is thrown down or dropped may cause as serious an injury to some part of the movement. Even the sudden motions or jar of jumping off

or on a car may injure it seriously. Because of the small size of the pivots necessary in accurate watches all sudden motions of the watch, even when in the hand, should be avoided.

Likewise care should be taken to keep the watch from being magnetized by proximity to electrical apparatus, although the trouble from this cause is being reduced by the present type of construction of dynamos and motors.

Unless the watch has a thoroughly dust-proof case care should be taken to keep the pocket free from dirt and lint, and it is desirable to have a watch pocket of such material that there will be as little accumulation of lint in the pocket as possible. The watchcase should be opened as seldom as possible and only in places where there is little chance of dust gathering on the movement while it is exposed. A broken watch crystal should be replaced promptly, even if the watch has a hunting case, to prevent dirt getting into the mechanism.

2. THE WINDING OF A WATCH

The importance of the regular winding of a watch will be quickly realized when one sees the isochronism curve of a given watch. Even the delay of an hour in the time of winding may cause considerable variation in the rate in some instances. Often it will materially improve the uniformity of rate of a watch throughout the 24 hours to wind the watch twice a day, but it is desirable that this plan should not be followed unless it is carried out every day, as a watch having comparatively poor adjustment for isochronism would exhibit larger variations of rate when semidaily windings are occasionally omitted than if it were wound only once a day. Such semidaily winding should be done as regularly as the daily winding, and the practice of winding up the watch a little at a time, often absent-mindedly, whenever one takes it from his pocket, is not productive of uniformity of rate. The winding should not be done jerkily but steadily and not too rapidly, and its conclusion should be approached carefully to avoid injury to the spring or winding mechanism.

If one winds the watch only once a day, it is generally regarded as slightly better to wind it in the morning than at night, as the large variations of the balance under the tight spring will perhaps give more uniform results with the movements and jar of the watch during the day than if the balance wheel were subject to the lesser tension 12 hours after winding. The difference is, however, not so important as the *regular* winding of the watch, and if circumstances are such that one is more apt to forget to wind it in the

morning than in the evening, the latter time of winding should be adopted. If one has an opportunity to compare his watch daily at a certain time with some source of standard time, as with the time as sent out by telegraph or by radio (wireless) signals or the dropping of a time ball, or by the regular comparison with some accurate clock as one daily passes a jeweler's store, for instance, it would be well to establish the habit of winding the watch at that time, as it is better to have such daily comparisons made at the time the watch is wound, and more regular winding will usually ensue.

3. THE CARRYING OF A WATCH

The pocket in which one carries his watch, the size of the pocket, and the kind of watch chain or fob used have a more important effect on the uniformity of a watch's rate than is generally realized. The temperature of the watch in different pockets will vary considerably and the amount of motion and jar to which the watch would be subject would differ. For instance, a watch carried in the upper coat pocket would generally be at a lower temperature and would be more frequently disturbed, as well as being held in various positions more irregularly, than in other pockets. In a large pocket the watch is apt to turn to the right or left by various amounts, giving irregular rates unless one adopts some method to hold it upright. Perhaps the best method to prevent a watch turning in this way (other than actually pinning it in place) is to keep the watch in a chamois or kid watch bag, such as may be obtained from jewelers in correct size to fit one's watch. The watch can not turn in this if of the proper size, and the friction of the bag in the pocket prevents its turning. The bag also protects the watch and keeps it cleaner. Most watch chains and many watch fobs are not effective in holding the watch upright. A fob of the type which hangs over the top of the pocket sometimes holds the watch upright quite well, but with such a fob one is somewhat more likely to drop the watch.

At night, or when the watch is not in use, it is desirable to leave the watch in the same position as during the day, and preferably in some place where it will not be subject to any great temperature change. If it is desirable to leave the watch in a horizontal position during the night for the sake of compensating any considerable gaining or losing of the watch in the pendant-up position during the day, the same precaution to avoid marked temperature changes should be observed, and the regularity with which such a change of position is carried out may be as important as regularity of winding.

VIII. THE COMPARISONS OF A WATCH WITH SOME RELIABLE SOURCE OF STANDARD TIME

The regular daily comparison of one's watch with a reliable regulator, chronometer, or some kind of authoritative time signal will be found very valuable for several reasons. When one's watch is running well such a daily comparison will give him an idea of what is a reasonable performance of his watch as no other fact could; and having such a definite idea of what is the watch's regular rate, any marked departure from such a rate will usually indicate that some accident has happened to the mechanism, which it is always desirable should be repaired promptly before further damage or wear takes place from the friction of any bent or broken parts. When a watch of high grade and in good condition is running well, differences of successive daily rates of not more than 2 to 4 seconds may be expected, if the precautions suggested above are observed, especially those in regard to the constancy of position and temperature of the watch day and night. If these precautions are not observed, much larger variations of rate may result. The record, therefore, of a watch which shows a difference of correction at the beginning and end of a month of "only 1 second," or 2, or some other similarly small difference over a long interval of time, as are occasionally reported, is of little if any value or importance in indicating the quality of the watch unless the corrections on the intervening days are known and show a consistent regularity of performance. A watch may be so regulated that the total variation in a month may be small but the daily variations may be very large.

Such a regular comparison of a watch will also be useful in determining whether the watch needs cleaning and fresh oiling. When the variations of daily rate gradually become larger and the progressive change in rate, which has been mentioned before, becomes more pronounced, it is a very reliable indication that the watch should be cleaned. The frequency with which a watch should be cleaned varies greatly and depends largely upon the usage it has received and the exposure to air, to contamination of dirt, fumes, and moisture, and upon the temperature changes to which it has been subjected. A watch which under one man's usage may require cleaning every year may, under the care of another man, give as accurate or better results for five years without being touched by a watchmaker. When a watch does require cleaning or repairing it is always important that the work should be done by an experienced and reliable watchmaker or jeweler.

In keeping a careful record of the rate of a watch, it is very desirable that the time with which it is compared should be reliable. The best generally available authority of accurate time for comparison is the time signal as transmitted over the telegraph wires from the United States Naval Observatory, the observatory at the Mare Island Navy Yard in California, and from two or three other observatories in this country. This time as sent from the United States Naval Observatory and Mare Island is transmitted twice a day only (notwithstanding certain misleading notices in the large cities of "U. S. Observatory time received hourly"). These two periods are the five minutes preceeding noon and 10 p. m., eastern (seventy-fifth meridian) standard time from the United States Naval Observatory and at the same hours, mountain (one hundred and twentieth meridian) time from Mare Island. The signals are sent at one-second intervals for a period of five minutes, except that the twenty-ninth, and fifty-fifth, fifty-sixth, fifty-seventh, fifty-eighth, and fifty-ninth seconds of each minute are omitted. In the last minute before noon and 10 p. m. the last 10 seconds are omitted instead of the last five, and on the following sixtieth second—the last signal—the key is held down or the contact is continued for a whole second instead of the small part of a second which the other signals last. Time balls in several cities are dropped automatically by this long contact of the last signal and furnish a somewhat less satisfactory means of comparison of a watch.

These time signals, if received directly and automatically, are very seldom in error by as much as 0.20 second, while the average error is generally less than 0.05 second. The same signals are also transmitted by wireless telegraphy from the radio station at Arlington, Va., and from a few other radio stations, and can be received with a suitable installation at a distance of 1000 miles or more across the land. A list of these stations, and the wave length used, is given below:

Radio (Wireless) Transmission of Time Signals

Station	Wave length	When sent
	Meters	
Arlington, Va.	2500	Daily from 11.55 a. m. to noon and 9.55 to 10.00 p. m. standard time, seventy-fifth meridian.
Key West, Fla.	1000	Daily from 11.55 a. m. to noon standard time, seventy-fifth meridian.
New Orleans, La.	1000	Do.
North Head, Cal.	2000	Daily except Sundays and holidays from 11.55 a. m. to noon, standard time, one hundred and twentieth meridian.
Eureka, Cal.	1400	Do.
San Diego, Cal.	2000	Do.
Mare Island, Cal.	2500	Daily from 11.55 a. m. to noon and 9.55 to 10 p. m., standard time, one hundred and twentieth meridian.

If for any reason the Arlington station is out of commission, the time signal will be sent daily, except Sundays and holidays, from 11.55 a. m. to noon from the naval radio stations at Newport, R. I., New York, N. Y., Norfolk, Va., and Charleston, S. C., with a wave length of 1000 meters.

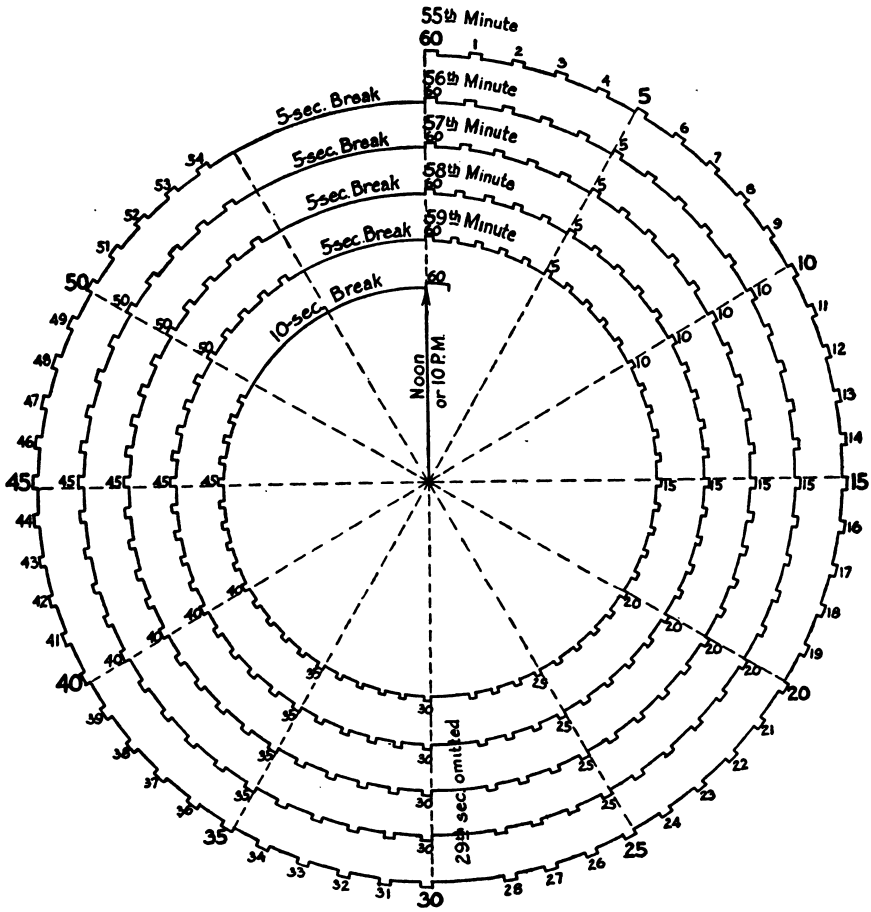

FIG. 8.—*Illustrating the time signals as sent out by telegraph and radio (wireless) for five minutes preceding noon and 10 p. m. from the United States Naval Observatory, Washington, and the Mare Island Observatory, Cal., for 75th and 120th meridian standard time*

The time is sent from the Naval Observatory, Washington, for the Atlantic coast and from the observatory at the Mare Island Navy Yard for the Pacific coast. The series of signals sent out are illustrated in the diagram of fig. 8.

In many of the larger cities there is located a master clock in the telegraph office, which is synchronized daily by means of the signal from the United States Naval Observatory, and a service is furnished to subscribers of synchronization of other clocks in the city hourly by means of this master clock. If the master clock receives proper attention and is regulated so that its daily rate is small—only a few seconds a day—and, if the subsidiary clocks are in good condition so that they are regularly synchronized, this system is very satisfactory and furnishes a comparatively automatic and direct means of establishing the correct time. The subsidiary clocks, or jewelers' regulators corrected by them, may, therefore, serve as a suitable standard for the comparison of a watch. It is desirable, however, on account of the possible large rate of the master clock in the telegraph office, to make watch comparisons with such clocks within an hour or two after the time of the Naval Observatory or other telegraphic signal by which the master clock is synchronized, and not immediately before it, as thus the effect of the daily rate of the master clock is minimized. Many jewelers, however, have regulators or chronometers which have a very small rate, and, if such timepieces are frequently set correctly by comparison, either with a telegraphic time signal or with a synchronized clock immediately after the receipt of the time signal, they will generally serve as an accurate source of time at any period of the day.

The actual comparison of a watch with any of these sources of time can readily be made to within a half or a quarter of a second, with a little practice. If the comparison is made with a signal beating seconds or with a clock ticking seconds where one can hear the beats, the best method is to count the seconds one hears and while looking at his watch note with the eye the second and fraction of a second on the watch when the signal to which one is listening reaches the sixtieth second, or some integral ten-second point, or else, keeping the count of the second beats, one notes the number of the second and fraction heard by the ear when the second hand of the watch reaches the sixtieth second or some integral ten-second point. If the beat of the comparison clock can not be heard on account of other noises, it will be necessary to get the count of the seconds on the regulator or chronometer by watching the beats of the pendulum or the unlocking of the second hand, and when one has the time intervals of the clock well in mind look down at his watch while continuing the count and note the time by either process outlined above and then without stopping the count of the

seconds of the clock look back at the clock again and check up his carrying of the count. If in looking at the watch the count has been slightly accelerated or retarded, it may be necessary to repeat the trial to obtain accurate results.

Whether the watch is fast or slow must be determined by a separate rough comparison or, in the case of a time signal, by waiting until the end of the signal, if one has not kept sufficient account of his watch's error to know its approximate correction. If the daily comparisons of a watch are not made at the same time each day, it is of course necessary to interpolate between them to determine the true 24-hour rate of the watch.

IX. STANDARD TIME AND THE STANDARD TIME SECTIONS

The use of standard time in sections differing by integral hour differences of longitude from Greenwich instead of local mean time has now become nearly universal throughout the civilized world. Practically all the nations of Europe have abandoned their local meridian time in favor of this important change to the use of a common meridian of reference. The use of standard time in this country is so universal and so well understood that it scarcely needs any explanation here, but as an introduction to the table of the boundary points of the different time sections in the United States it may be well to explain briefly what the difference is between standard time and mean local time and how the country is divided up into different time sections.

The mean local time of any place is the time in mean solar days reckoned from the mean time of the sun's passage across the meridian through that place as the point of reference for the time. The mean solar day is the average, throughout the year, of the time between two successive passages of the sun across any given meridian of the earth. The actual time of transit of the sun across the meridian varies from mean noon throughout the year, due to the elliptical shape of the earth's orbit, the total variation being about 32 minutes. Therefore, in order that the days measured by the sun's transits may not be of varying duration, the instant of transit of a "mean sun" or imaginary sun is taken as the zero, and the intervals between such assumed transits of a "mean sun" are designated as mean solar days.

Standard time is mean solar time, so far as its duration or unit of measurement is concerned; the difference between it and mean local time lies in the point of reference from which it is measured. In order to avoid the troubles arising from each place using its own local time reckoned from

the transit of the "mean sun" across the local meridian, the country is divided into standard time sections of approximately 15° of longitude in width and each place in the time section uses, instead of its own local time, the time counted from the transit of the "mean sun" across the seventy-fifth meridian west of Greenwich, or of the ninetieth, one hundred and fifth, or one hundred and twentieth meridian, depending upon the time section in which the place is located. These seventy-fifth, ninetieth, one hundred and fifth, and one hundred and twentieth meridians are nominally the centers of the time sections and the boundaries would consequently be, theoretically, the meridians of 67° 30′ and 82° 30′ west of Greenwich for the seventy-fifth meridian section, or the eastern time section as it is called, and, similarly, 82° 30′ and 97° 30′ for the ninetieth meridian, or central time section, and 97° 30′ and 112° 30′ for the one hundred and fifth or Mountain time section, and 112° 30′ and 127° 30′ for the one hundred and twentieth, or Pacific time section.

The question of changing from the time of one time section to that of another arises in practice almost exclusively in the operation of railroads, however, and because of the inconvenience of changing the time by the necessary amount of one hour at every point where a railroad crosses one of these boundary meridians the more convenient practice has been followed of making the change usually at some terminal or division point on the road, or at some junction point, or at the boundary line between the United States and Canada. The result is that practically the boundaries of the time sections are defined by the lines connecting these railroad points of time change and because of the location of these railroad junctions or terminals the resulting lines are quite irregular. There is given below a table made up from data in the Official Railway Guide showing the points on the various railroads of the United States and Canada at which the time is changed in this way, and giving the time used locally in these cities.

As stated before, the difference of standard time between two adjacent time sections is just one hour, inasmuch as the equivalent of the difference of 15° of longitude between the reference meridians amounts to one hour in time. Hence, when it is noon at any point in the eastern time section it is 11 a. m. at all places in the central time section, 10 a. m. in the mountain time section, and 9 a. m. in the Pacific time section. In traveling westward, therefore, from one time section to another, one must set his watch back one hour, while in traveling eastward the watch should be set ahead one hour whenever he passes from one time section to another.

DIVIDING POINTS OF THE STANDARD TIME SECTIONS OF THE UNITED STATES AND CANADA

Showing the Boundary Points of the Different Sections, the Time Used Locally in the City, and the Time Used by the Railroads Running Out of the City. (The Cities Are Arranged in General in their Order from North to South)

BETWEEN ATLANTIC OR INTERCOLONIAL AND EASTERN TIME SECTIONS

City	Time used locally	Railroads and time used	
		EASTERN TIME	ATLANTIC TIME
Campbellton, New Brunswick, Canada	Atlantic	Intercolonial (westward)	Intercolonial (eastward).
Fredericton, New Brunswick, Canada.	do	Canadian Pacific	Intercolonial.
St. John, New Brunswick, Canada.	do	do	Do.

BETWEEN EASTERN AND CENTRAL TIME SECTIONS

		CENTRAL TIME	EASTERN TIME
Fort William, Ontario, Canada.	Central	Canadian Pacific (westward)	Canadian Pacific (eastward).
		Grand Trunk	
Sault Ste. Marie, Ontario, Canada.	Eastern	Duluth, So. Shore and Atlantic	Algona, Central & Hudson Bay.
		Minneapolis, St. Paul & S. Ste. Marie.	Canadian Pacific.
Sault Ste. Marie, Mich.	Central	Duluth, So. Shore & Atlantic	Algona, Central & Hudson Bay.
		Minneapolis, St. Paul & S. Ste. Marie.	Canadian Pacific.
Port Huron, Mich.	do	Grand Trunk (in Michigan)	Grand Trunk (in Canada).
		Pere Marquette (in Michigan)	Pere Marquette (in Canada).
Detroit, Mich.	do	Grand Trunk (in Michigan)	Canadian Pacific.
		Lake Shore & Michigan Southern	Grand Trunk (in Canada).
		Michigan Central (westward)	Michigan Central (eastward).
		Pere Marquette (in Michigan)	Pere Marquette (in Canada).
		Wabash (in Michigan)	Wabash (in Canada).
Buffalo, N. Y.	Eastern	Lake Shore & Michigan Southern.	Buffalo, Rochester & Pittsburgh.
		New York, Chicago & St. Louis	Delaware, Lackawanna & Western.
			Erie.
			Grand Trunk.
			Lehigh Valley.
			Michigan Central.
			New York Central & Hudson River.
			Pennsylvania.
			Wabash.
			West Shore.
Dunkirk, N. Y.	do	Dunkirk, Allegheny Valley & Pittsburgh.	Erie.
			Pennsylvania.
		Lake Shore & Michigan Southern	
		New York, Chicago & St. Louis	

DIVIDING POINTS OF THE STANDARD TIME SECTIONS OF THE UNITED STATES AND CANADA—Continued

BETWEEN EASTERN AND CENTRAL TIME SECTIONS—Continued

City	Time used locally	Railroads and time used	
		CENTRAL TIME—Continued.	EASTERN TIME—Continued.
Westfield, N.Y.	Eastern	Lake Shore & Michigan Southern..	Jamestown, Chautauqua & Lake Erie.
		New York, Chicago & St. Louis....	
Salamanca, N. Y.	do	Erie (westward)	Buffalo, Rochester & Pittsburgh.
			Erie (eastward).
			Pennsylvania.
Jamestown, N. Y.	do	Erie (main line)	Erie (B. & S. W. div.).
			Jamestown, Chautauqua & Lake Erie.
Erie, Pa.	do	Pennsylvania Co	Pennsylvania (Erie div.).
		Lake Shore & Michigan Southern..	Bessemer & Lake Erie.
		New York, Chicago & St. Louis....	
Conneaut, Ohio	do	Lake Shore & Michigan Southern..	Bessemer & Lake Erie.
		New York, Chicago & St. Louis....	
Union City, Pa.	do	Erie	Pennsylvania.
Corry, Pa.	do	Erie	Do.
Titusville, Pa.	do	Dunkirk, Allegheny Valley & Pittsburgh.	Do.
Oil City, Pa.	do	Erie	Do.
		Lake Shore & Michigan Southern..	
Franklin, Pa.	do	Erie	Pennsylvania.
		Lake Shore & Michigan Southern..	
Sutton, Pa.		Lake Shore & Michigan Southern (westward).	Lake Shore & Michigan Southern. (eastward).
			Pennsylvania (southward).
New Castle Junction, Pa.		Baltimore & Ohio (westward)	Baltimore & Ohio (eastward).
Pittsburgh Pa.	Eastern	Pennsylvania Co	Baltimore & Ohio.
		Pittsburgh & Lake Erie	Buffalo, Rochester & Pittsburgh.
		Pittsburgh, Cincinnati, Chicago & St. Louis.	Pennsylvania.
		Wabash-Pittsburgh Terminal	Pittsburgh Railways.
Washington, Pa.	do	Pittsburgh, Cincinnati, Chicago & St. Louis.	Baltimore & Ohio.
		Waynesburg & Washington	
Wheeling, W. Va.	do	Pittsburgh, Cincinnati, Chicago & St. Louis.	Baltimore & Ohio (main line).
		Wheeling & Lake Erie	Baltimore & Ohio (Cleveland, Lorain & Wheeling).
Holloway, Ohio	do	Baltimore & Ohio (Cleveland, Lorain & Wheeling, westward).	Baltimore & Ohio (Cleveland, Lorain & Wheeling, eastward).
Benwood, W. Va.	do	Baltimore & Ohio (westward)	Baltimore & Ohio (eastward).
Parkersburg, W. Va.	do	Baltimore & Ohio Southwestern	Baltimore & Ohio.
Huntington, W. Va.	do	Chesapeake & Ohio (westward)	Do.
			Chesapeake & Ohio (eastward).
Kenova, W. Va.	Central	Chesapeake & Ohio	Baltimore & Ohio.
		Norfolk & Western	
Williamson, W. Va.	do	Norfolk & Western (westward)	Norfolk & Western (eastward).
Norton, Va.		Louisville & Nashville	Norfolk & Western.

DIVIDING POINTS OF THE STANDARD TIME SECTIONS OF THE UNITED STATES AND CANADA—Continued

BETWEEN EASTERN AND CENTRAL TIME SECTIONS—Continued

City	Time used locally	Railroads and time used	
		CENTRAL TIME—Continued.	EASTERN TIME—Continued.
Bristol, Tenn.	Eastern.	Southern.	Norfolk & Western. Virginia & Southwestern.
Asheville, N. C.	do.	Southern (Asheville & Morristown Line).	Southern (except Asheville & Morristown Line).
Columbia, S. C.	do.	Seaboard Air Line (southward).	Atlantic Coast Line. Columbia, Newberry & Laurens. Seaboard Air Line (northward). Southern.
Gainesville, Ga.	Mean local.	Georgia.	Southern.
Athens, Ga.	Eastern.	do.	Southern.
		Central of Georgia.	Seaboard Air Line.
Atlanta, Ga.	Central.	Atlanta & West Point.	Seaboard Air Line (eastward).
		Central of Georgia.	Southern, main line (eastward).
		Georgia.	
		Seaboard Air Line (westward).	
		Southern (westward and southward).	
		Western & Atlantic.	
Augusta, Ga.	Eastern.	Central of Georgia.	Atlantic Coast Line.
		Georgia.	Charleston & Western Carolina.
		Georgia & Florida.	Southern.
Central Junction, Ga.		Atlantic Coast Line (southward).	Atlantic Coast Line (northward).

BETWEEN CENTRAL AND MOUNTAIN TIME SECTIONS

		MOUNTAIN TIME	CENTRAL TIME
Hudson Bay Junction, Sask., Canada.	Central	Canadian Northern (westward).	Canadian Northern (eastward).
Kamsack, Sask., Canada.		do.	Do.
Ross Junction, Sask., Canada.		do.	Do.
Bredenbury, Sask., Canada.		Canadian Pacific (westward).	Canadian Pacific (eastward).
Watrous, Sask., Canada.	Mountain.	Grand Trunk Pacific (westward).	Grand Trunk Pacific (eastward).
Melville, Sask., Canada.	Central	Grand Trunk Pacific (southward).	Grand Trunk Pacific (eastward and westward).
Neudorf, Sask., Canada.		Canadian Pacific (westward).	Canadian Pacific (eastward).
Broadview, Sask., Canada.	Central.	do.	Do.
Kipling, Sask., Canada.	do	Canadian Northern (westward).	Canadian Northern (eastward).
Arcola, Sask., Canada.		Canadian Pacific (westward).	Canadian Pacific (eastward).
Portal, N. Dak.	Central.	Canadian Pacific.	Minneapolis, St. Paul & S. Ste. Marie.
Williston, N. Dak.	do.	Great Northern (westward).	Great Northern (eastward).
Mandan, N. Dak.	Mountain.	Northern Pacific (westward).	Northern Pacific (eastward).
Mobridge, S. Dak.	Central.	Chicago, Milwaukee & Puget Sound.	Chicago, Milwaukee & St. Paul.

DIVIDING POINTS OF THE STANDARD TIME SECTIONS OF THE UNITED STATES AND CANADA—Continued

BETWEEN CENTRAL AND MOUNTAIN TIME SECTIONS—Continued

City	Time used locally	Railroads and time used	
		MOUNTAIN TIME	CENTRAL TIME
Pierre, S. Dak.	Central	Pierre, Rapid City & Northwestern (westward).	Chicago & North Western (eastward).
Rapid City, S. Dak.	Mountain	Chicago & North Western Rapid City, Black Hills & Western.	Chicago, Milwaukee & St. Paul.
Long Pine, Nebr.	Central	Chicago & North Western (westward).	Chicago & North Western (eastward).
Alliance, Nebr.	Mountain	Chicago, Burlington & Quincy lines west of the Missouri River (westward).	Chicago, Burlington & Quincy lines west of the Missouri River (eastward).
North Platte, Nebr.	Central	Union Pacific (westward)	Union Pacific (eastward).
Sterling, Colo.	do	Chicago, Burlington & Quincy lines west of the Missouri River (westward).	Chicago, Burlington & Quincy lines west of the Missouri River (eastward).
McCook, Nebr.	do	do	Do.
Phillipsburg, Kans.	do	Chicago, Rock Island & Pacific (westward).	Chicago, Rock Island & Pacific (eastward).
Plainville, Kans.		Union Pacific, Oakley branch (westward).	Union Pacific, Oakley branch (eastward).
Ellis, Kans.	do	Union Pacific, Colorado division (westward).	Union Pacific, Kansas division (eastward).
Hoisington, Kans.	do	Missouri Pacific (westward)	Missouri Pacific (eastward).
Dodge City, Kans.	do	Atchison, Topeka & Santa Fe (westward).	Atchison, Topeka & Santa Fe (eastward). Chicago, Rock Island & Pacific.
Sirela, Tex.		Colorado & Southern	Fort Worth & Denver City.
Tucumcari, N. Mex.	Mountain	El Paso & Southwestern	Chicago, Rock Island & Pacific.
Clovis, N. Mex.	do	Santa Fe route (westward and southward).	Santa Fe route (eastward).
El Paso, Tex.	do	Atchison, Topeka & Santa Fe	Galveston, Harrisburg & San Antonio.
		El Paso & Northeastern	Texas & Pacific.
		Galveston, Harrisburg & San Antonio (El Paso to Rio Grande).	

BETWEEN MOUNTAIN AND PACIFIC TIME SECTIONS

		PACIFIC TIME	MOUNTAIN TIME
Field, B. C., Canada	Pacific	Canadian Pacific (westward)	Canadian Pacific (eastward).
Kingsgate, B. C., Canada	Mountain	Spokane International	Canadian Pacific.
Eastport, Idaho	Pacific	do	Do.
Troy, Mont.	Mountain	Great Northern (westward)	Great Northern (eastward).
Paradise, Mont.	Pacific	Northern Pacific (westward)	Northern Pacific (eastward).
Avery, Idaho	Mountain	Chicago, Milwaukee & Puget Sound (westward).	Chicago, Milwaukee & Puget Sound (eastward).
Huntington, Oreg.	Pacific	Oregon-Washington Railroad & Navigation Co.	Oregon Short Line.

DIVIDING POINTS OF THE STANDARD TIME SECTIONS OF THE UNITED STATES AND CANADA—Continued

BETWEEN MOUNTAIN AND PACIFIC TIME SECTIONS—Continued

City.	Time used locally	Railroads and time used	
		PACIFIC TIME—Continued.	MOUNTAIN TIME—Continued.
Ogden, Utah	Mountain	Southern Pacific	Denver & Rio Grande. Oregon Short Line. Salt Lake & Ogden. Union Pacific.
Salt Lake City, Utah	do	Western Pacific	Denver & Rio Grande. Oregon Short Line. San Pedro, Los Angeles & Salt Lake. Salt Lake & Los Angeles. Salt Lake & Ogden.
Caliente, Nev	do	San Pedro, Los Angeles & Salt Lake (westward).	San Pedro, Los Angeles & Salt Lake (eastward).
Seligman, Ariz	do	Santa Fe Route (westward)	Santa Fe Route (eastward).
Parker, Ariz	do	Atchison, Topeka & Santa Fe Coast Lines (westward).	Santa Fe, Prescott & Phoenix (northward).
Yuma, Ariz	Pacific	Southern Pacific (westward)	Southern Pacific (eastward).

X. REGULATIONS GOVERNING THE TESTING OF WATCHES

GENERAL

1. **Classes of Test.**—Pocket watches will be received for rating under two classes of tests, designated as class A and class B. Class A is intended for watches of the better grades which come under the designation "Adjusted for five positions, temperature and isochronism." Class B is intended for watches which are designated as "Adjusted for three positions and temperature." Watches of either class may be submitted for rating in the other class of test than that under which they are designated, if desired. A watch which has been submitted for test under class A will be awarded a class B certificate, if the party submitting it so desires, in case its performance does not meet the requirements of class A but does conform to those of class B. The request for a class B certificate under such circumstances must be made, however, when application for the test is made. In such cases the full fee for a class A test must be paid. In addition to the class B certificate a report will be rendered showing wherein the watch failed to conform to the class A requirements.

2. **Time of Tests.**—The test under class A will require 54 days; that under class B will require 40 days. Tests will be held four times a year, the class A tests beginning on the second Tuesday in January, April, August, and October, while the class B tests will begin 14 days later in each case.

3. **Cases or Mountings.**—The watch movements may be mounted in regular cases of either open face or hunting style, or they may be submitted in exhibition or "skeleton" cases if fitted with dust-proof covers and provided with a stem for winding the watch. If watches are submitted mounted in regular cases, the name of the maker and maker's number of the case will be given on the certificate, unless request is made to the contrary.

4. **Application for Test.**—Application for the test of a watch must be made in advance of the beginning of the test. The application should be made on a blank which may be obtained from the Bureau upon request. A separate blank must be made out for each watch submitted, and all the information requested concerning each watch must be furnished so far as available.

5. **Winding Before Test.**—Watches delivered personally or by messenger considerably in advance of the beginning of the tests will be kept wound regularly until the trial begins. Watches shipped to the Bureau, upon being unpacked, will be wound and set. All watches will be kept in the vertical, pendant up position until the beginning of the trial.

CLASS A

6. **Method of Test.**—Watches submitted for test under class A will be run for 54 days in a series of periods in the positions and at approximately the temperatures given below, each period being of the duration indicated:

Period number	Duration in days	Position	Temperature
1	3	Vertical, pendant up	28°–30° C (82°–86° F).
2	3	Vertical, pendant right	Do.
3	3	Vertical, pendant left	Do.
4	3	Horizontal, dial up	Do.
5	3	Horizontal, dial down	Do.
6	3	.....do	Do.
7	3	Horizontal, dial up	Do.
8	3	Vertical, pendant left	Do.
9	3	Vertical, pendant right	Do.
10	3	Vertical, pendant up	Do.
*11	3	.....do	Do.
12	5	Horizontal, dial up	5° C (41° F).
		One intermediate day.	
13	5	.....do	20° C (68° F).
		One intermediate day.	
14	5	.....do	35° C (95° F).
		One intermediate day.	
15	3	Vertical, pendant up	28°–30° C (82°–86° F).

*This period to be an isochronism test, readings being made at intervals of a few hours from the time of winding the watches at the beginning of the period until they run down.

7. **Tolerances.**—Certificates will be granted to watches which in the above test give results within the following tolerances:

(1) The *mean deviation of daily rate* not to exceed 0.75 second.

(2) The *mean deviation for change of position* not to exceed 3.00 seconds.

(3) The *difference between the mean rates of any two positions* not to exceed 10.0 seconds.

(4) The *difference between the mean rates in the vertical, pendant up and the horizontal, dial up positions* not to exceed 5.0 seconds.

(5) The *difference between the mean rates in the horizontal, dial up and the horizontal, dial down positions* not to exceed 4.0 seconds.

(6) The *progressive change in rate in periods 1 to 10* do not exceed 3.00 seconds.

(7) The *recovery of rate* (period 15 minus period 1) not to exceed 6.0 seconds.

(8) The *isochronism error* not to exceed 3.0 seconds.

(9) The *difference of rate per degree centigrade between 5° and 35°* not to exceed 0.20 second.

(10) The *difference of rate per degree centigrade between 5° and 20°* not to differ algebraically from *that between 5° and 35°* by more than 0.30 second.

(11) The *mean daily rate of any of the 15 periods* (except period 11) not to exceed 10.0 seconds.

8. **Application of Tolerances.**—In determining whether a watch's performance is within the above tolerances the various quantities shall be computed as follows:

(1) To obtain the *mean deviation of daily rate* the difference between each day's rate and the mean daily rate of the period in which it occurs shall be taken for all periods except the eleventh, and the arithmetrical mean of the 48 differences thus obtained shall be taken as the mean deviation of daily rate.

(2) To obtain the *mean deviation for change of position*, the algebraic average shall be taken of the mean daily rates of periods 1 and 10, 2 and 9, 3 and 8, 4 and 7, and 5 and 6, and from the algebraic mean of the five values corresponding to the five positions obtained in this way each of the five shall be subtracted. The arithmetical mean of these five differences shall be taken at the *mean deviation for change of position*.

(3) The five mean rates thus obtained for the five positions shall be used in applying the third, fourth, and fifth tolerances, the differences being taken algebraically.

(4) To obtain the *progressive change in rate in periods 1 to 10*, the difference between the mean rates of periods 1 and 10, 2 and 9, 3 and 8, 4 and 7, and 5 and 6 shall be taken and the algebraical mean of the five values so obtained shall be taken as the mean recovery of rate in periods 1 to 10 and will represent the average change in rate of the watch in 15 days. The differences shall be so taken that a plus sign shall indicate that the watch ran slower at the end of 15 days than at the beginning; a minus sign that it ran faster.

(5) The *recovery of rate*, period 15 minus period 1, shall be taken with the same meaning of plus and minus signs as above.

(6) To obtain the *isochronism error*, twice the amount gained or lost in the first 12 hours of the isochronism test of period 11 shall be subtracted algebraically from the amount gained or lost in the first 24 hours of this test. This algebraic difference shall be taken as the *isochronism error*, and a minus sign will indicate that the watch ran at a faster rate in the first 24 hours after winding than in the first 12 hours, a plus sign that it ran slower.

(7) The *difference of rate per degree centigrade* shall be obtained from the results of the three temperature periods by the solution of the three equations of the form $r = r_{20} + a\ (t-20) + b\ (t-20)^2$ where r is the observed rate at $t°$ C, and r_{20} is the rate at 20° C (to be determined) and a and b are two constants to be determined. From these results the rates at 5° and 35° are also found (if not already observed) and the algebraic differences of the rates at 5°, 20°, and 35° C are divided by the differences of temperature to obtain the *difference of rate per degree centigrade.*

9. **Certificates.**—The certificate granted under regulation 7 will show the mean daily rate of the watch in each of the 15 periods, except period 11, and the mean temperature at which the watch ran in each period. It will also show the various quantities computed for the different criteria of regulation 7, together with the tolerances for the same. The results of the isochronism test will be given in the form of a curve accompanying the certificate and showing the amounts gained or lost after winding. The certificate will also give the maker of the watch, if known, and the maker's number of the watch, together with such additional details of description

as may seem desirable. The name of the person by whom or for whom the watch was submitted for test will be given. The certificate will be dated according to the last day of the test. The certificate will bear the signature of the Director of the Bureau of Standards (or of the Acting Director of the Bureau in case of absence of the Director) and will be stamped with the seal of the Bureau of Standards. The certificate will also give a number to indicate the relative performance of the watch based on a scale from 0 to 100, as provided in regulation 10, in which 0 indicates a watch that has just met the limits of tolerances 1, 2, 7, 9, and 10, and 100 indicates a watch whose performance would be perfect with respect to these factors.

10. **Relative Performance.**—On each watch certificate under class A will be given its relative performance on a scale from 0 to 100, computed according to the following formula:

$$\text{Relative performance} = 30\left(1-\frac{a}{0.75}\right)+30\left(1-\frac{b}{3.00}\right)+30\left(1-\frac{c}{0.25}\right)+10\left(1-\frac{d}{6.0}\right).$$

Where a = the observed *mean deviation of daily rate.*

b = the observed *mean deviation for change of position.*

c = the arithmetical mean of the *difference of rate per degree centigrade between 5° and 35°* and the amount by which the *difference of rate per degree centigrade between 5° and 20°* differs algebraically from the *difference of rate per degree centigrade between 5° and 35°.*

d = the *recovery of rate* (period 15 minus period 1).

When a watch receives a relative performance of 75 or more it will be noted on the certificate as "very satisfactory."

11. **Reports on Rejected Watches.**—The test of a watch which fails to meet the requirements of class A at any point in the test will be continued to the end (except in case of the accidental stopping of the watch or its withdrawal from test by the person submitting it), and a report will be made showing the results of the test and giving the items under which it was rejected. If the watch has stopped during the test from accidental or unexpected causes, or if it is withdrawn from test before the completion of the test, a report will be made of the rates of the watch for as much of the test as it underwent. A watch may be withdrawn from test at any time during the test by the person submitting it or may be withdrawn before

period 11 by request made in the application for the test in case the watch fails to meet the requirements of tolerances 2, 3, 4, 5, 6, and 11 (the latter as applied to periods 1 to 10 only). In case a watch stops from accidental or unexpected causes or is withdrawn from test before the eleventh period, only half the fee for a complete test will be charged.

CLASS B

12. **Method of Test.**—Watches submitted for test under class B will be run for 40 days in a series of periods in the positions and approximately at the temperatures given below, each period being of the duration indicated.

Period number	Duration in days	Position	Temperature
1	3	Vertical, pendant up	28°–30° C (82°–86° F).
2	3	Horizontal, dial up	Do.
3	3	Horizontal, dial down	Do.
4	3	do	Do.
5	3	Horizontal, dial up	Do.
6	3	Vertical, pendant up	Do.
		One intermediate day.	
7	5	Horizontal, dial up	5° C (41° F).
		One intermediate day.	
8	5	do	20° C (68° F).
		One intermediate day.	
9	5	do	35° C (95° F).
		One intermediate day.	
10	3	Vertical, pendant up	28°–30° C (82°–86° F).

13. **Tolerances.**—A class B certificate will be granted to watches which in the above trial give results within the following tolerances:

(1) The *mean deviation of daily rate* not to exceed 1.00 second.

(2) The *difference between the mean rates in the vertical, pendant up and the horizontal, dial up positions* not to exceed 6.0 seconds.

(3) The *difference between the mean rates in the horizontal, dial up and the horizontal, dial down positions* not to exceed 5.0 seconds.

(4) The *recovery of rate*, period 10 minus period 1, not to exceed 8.0 seconds.

(5) The *difference of rate per degree centigrade between 5° and 35°* C not to exceed 0.30 second.

(6) The *difference of rate per degree centigrade between 5° and 20°* C not to differ algebraically from *that between 5° and 35°* by more than 0.40 second.

(7) The *mean daily rate of any of the 10 periods* not to exceed 10.0 seconds.

14. **Application of Tolerances.**—In determining whether a watch's performance is within the above tolerances the various quantities shall be computed as follows:

(1) To obtain the *mean deviation of daily rate* the difference between each day's rate and the mean daily rate of the period in which it occurs shall be taken for all periods, and the arithmetical mean of the 36 differences thus obtained shall be taken as the mean deviation of daily rate.

(2) In applying the second and third tolerances the algebraic averages of the mean daily rates of periods 1 and 6, 2 and 5, and 3 and 4, shall be taken and used as the mean rates of the vertical, pendant up, the horizontal, dial up, and the horizontal, dial down positions respectively, the differences being taken algebraically.

(3) The *recovery of rate*, period 10 minus period 1, is so taken that a plus sign shall indicate that the watch ran slower in period 10 than in period 1; a minus sign that it ran faster.

(4) The *differences of rate per degree centigrade* shall be obtained as in class A; that is, from the results of the three temperature periods by the solution of the three equations of the form $r = r_{20} + a\,(t-20) + b\,(t-20)^2$, where r is the observed rate at $t°$ C, r_{20} is the rate at 20° C (to be determined) and a and b are two constants to be determined. From these results the rates at 5° and 35° are also found (if not directly observed), and the algebraic differences of the rates at 5°, 20°, and 35° C are divided by the differences of temperature to obtain the *difference of rate per degree centigrade.*

15. **Certificates.**—The certificate granted under regulation 13 will show the mean daily rate of the watch in each of the 10 periods and the mean temperature at which the watch ran in each period. It will also show the various quantities computed for the different criteria of regulation 13, together with the tolerances for the same. The description of the watch, the name of the person submitting the watch, the date, signature, and seal of the certificate will be as given in a class A certificate. There will be no relative performance computed for class B watches.

16. **Reports on Rejected Watches.**—The test of a watch which fails to meet the requirements of class B at any point in the trial will be continued to the end (except in the case of accidental stopping of the watch or its withdrawal from test by the person submitting it), and a report will be made

showing the results of the test and giving the items under which it was rejected. If the watch has stopped during the test from accidental or unexpected causes, or if it is withdrawn from test before the completion of the test, a report will be made of the rates of the watch for as much of the test as it underwent. A watch may be withdrawn from test at any time during the test by the person submitting it, or it may be withdrawn before period 7 by request made in the application for the test in case the watch fails to meet the requirements of tolerances 2, 3, 4, and 7 (the latter as applied to periods 1 to 6 only). If the watch stops during the trial from accidental or unexpected causes or is withdrawn from test before the seventh period, only half the fee for a complete test will be charged.

MISCELLANEOUS

17. **Replacement of Certificates.**—If the certificate of a watch is damaged or if the person submitting the watch wishes the certificate issued in another person's name than that of the original certificate, a new certificate will be issued upon the payment of a fee of 50 cents and the return of the old certificate, which will be destroyed, providing such a request is made within three years of the test of the watch. The new certificate will be identical with the old in every respect including the date, except for the possible change of name of the person to whom it is issued.

18. **Detailed Reports of Tests.**—In addition to the certificate of a watch a full report, if desired, will be furnished which will show the rate of the watch for each day during the test and the mean temperature for each day, together with such computations as were made in the application of the criteria. The charge for such an additional report will be $1.

19. **Retest of Watches.**—In case a watch which has received a certificate from the Bureau of Standards is submitted for test a second time, the previous certificate must be submitted with it and is destroyed if the watch is submitted for test in the same class as before. If it is submitted for test in a higher class, the certificate is held until the close of the test and is destroyed or returned according as the watch does or does not obtain a certificate in the higher class.

20. **Publication of Results.**—The Bureau reserves the right to publish any or all of the results of the tests of watches together with such descriptive matter concerning the different movements as may be useful or of interest in the improvement of the manufacture and adjustment of timepieces.

XI. SHIPPING DIRECTIONS, REMITTANCES, ETC.

Shipping Directions.—When timepieces are not delivered at the Bureau personally they should be securely packed in cases or packages which will not be broken in transportation and which may be used in returning them to the owner. The shipment in both directions is at the applicant's risk. It is recommended that shipment be made by express. Great care should be taken in packing. Each instrument should be wrapped in strong paper or other covering to prevent dust from getting into it. The tops of large boxes should be put on with screws, as the jar due to nailing and the subsequent opening is liable to cause damage. All packages should be plainly marked with the shipper's name and address. The tops of the shipping boxes should have the return or forwarding address on the underside. Transportation charges are payable by the person requesting the test. The charges for shipment to the Bureau must be prepaid, and, unless otherwise arranged, articles will be returned or forwarded by express "collect."

When timepieces are submitted by one person with instructions to test and forward to another, directions should be given for the disposition of such as may be rejected by the Bureau. If such instructions are not given at the time the test is requested, much unnecessary delay results.

Breakage.—No risk of breakage will be assumed by the Bureau. All possible care will be taken in handling the apparatus submitted for test, but breakage is sometimes unavoidable and must be borne by the owner.

Address.—Articles should be addressed "Bureau of Standards, Washington, D. C."; delays incident to other forms of addresses will thus be avoided. Articles delivered in person or by messenger should be accompanied by the application for test properly filled out. The receipt of the application for test will be acknowledged by the Bureau and a test number will be assigned to it which should be used in any future correspondence relative to the test.

Remittances.—Fees should be remitted by money order or check drawn to the order of the "Secretary of Commerce," and should be sent with the request for test whenever practicable. Delays in forwarding fees involve corresponding delays in the return of articles tested, as the articles are held until the fees due thereon have been paid.

All communications should be addressed simply "Bureau of Standards, Washington, D. C."

XII. SCHEDULE OF FEES

SCHEDULE 153.—Pocket Watches

(*a*) Test and certification or report of a watch under class A	$5.00
(*b*) Partial test of a watch under class A which stops running before the completion of the test or is withdrawn from test before the end of the trial, as provided in regulation 11	2.50
(*c*) Test under class A and certification under class B of a watch which fails to meet the requirements of class A but does meet those of class B	5.00
(*d*) Test and certification or report of a watch under class B	3.00
(*e*) Partial test of a watch under class B which stops running before the completion of the test or is withdrawn from test before the end of the trial, as provided in regulation 16	1.50
(*f*) Replacement of a damaged certificate or the reissue of a certificate under a different name	.50
(*g*) Detailed report of performance of a watch, as provided in regulation 18	1.00

S. W. STRATTON,
Director.

Approved:
WILLIAM C. REDFIELD,
Secretary.