

PYROMETER TESTING AND HEAT MEASUREMENTS

Department of Commerce and Labor BUREAU OF STANDARDS Washington

BUREAU CIRCULAR NO. 7
2D EDITION

February 15, 1906.

ORGANIZATION OF THE BUREAU.

By an act of Congress approved March 3, 1901, the Office of Standard Weights and Measures of the Treasury Department was, on July 1, 1901, superseded by the Bureau of Standards. The Bureau was transferred to the Department of Commerce and Labor July 1, 1903, by the act establishing that Department.

The functions of the Bureau of Standards are as follows: The custody of the standards; the comparison of the standards used in scientific investigations, engineering, manufacturing, commerce, and educational institutions, with the standards adopted or recognized by the Government; the construction, when necessary, of standards, their multiples and subdivisions; the testing and calibration of standard measuring apparatus; the solution of problems which arise in connection with standards; the determination of physical constants and the properties of materials. The Bureau will also furnish such information concerning standards, methods of measurement, physical constants, and the properties of materials as may be at its disposal, and is authorized to exercise its functions for the Government of the United States, for State or municipal governments within the United States, for scientific societies, educational institutions, firms, corporations, or individuals engaged in manufacturing or other pursuits requiring the use of standards or standard measuring instruments.

For all comparisons, calibrations, tests, or investigations, except those performed for the Government of the United States or State governments, reasonable fees will be charged.

REGULATIONS.

APPLICATION FOR TEST.—The request for verification of any instrument should state explicitly the points at which test is to be made and the temperature or any other conditions, if any, which it is desired should be observed. Whenever possible, the request should be accompanied by the fee as shown in the appended schedules.

IDENTIFICATION MARKS.—Instruments and the packages in which they are shipped should both be plainly marked to facilitate identification, preferably with the name of the manufacturer or shipper, and a special reference number given to the article.

SHIPPING DIRECTIONS.—Instruments should be securely packed in cases or packages which may be used in returning them to the owner. Tops of cases should be screwed down whenever possible. Transportation charges are payable by the party desiring the test, and should be prepaid. Unless otherwise arranged, articles will be returned by express "collect."

ADDRESS.—Articles should be addressed simply, "Bureau of Standards, Department of Commerce and Labor, Washington, D. C." Delays incident to other forms of address will thus be avoided.

Articles delivered in person or by messenger should be left at the office of the Bureau and should be accompanied by a written request for the verification.

REMITTANCES.—Fees should be sent with the request for test in accordance with the schedules of fees following, and may be remitted by money order or check drawn to the order of the "Bureau of Standards."

Delays in forwarding fees will involve corresponding delay in the completion of tests, as the articles are not returned until all fees due thereon have been received.

GENERAL INSTRUCTIONS.

When pyrometers are submitted for test, it is highly desirable that the request for test be accompanied by a statement giving as far as possible the conditions under which the pyrometer is used (e. g., method of mounting pyrometer, depth of immersion, kind of bath or medium whose temperature is to be measured, how the pyrometer is protected, at what temperature it is used, and whether continuously exposed to these temperatures, etc.). A sketch showing method of use of instrument is often very useful. It is only when accompanied by such information that it is possible to realize approximately the same conditions in the test as in the actual use of the pyrometer and to make a statement as to the order of accuracy that may be attained. It also enables suggestions to be made as to desirable modifications in the use of the instrument that may lead to more satisfactory results.

I.—THERMOCOUPLES.

In pyrometers of this type temperatures are measured by the magnitude of the electromotive forces set up between wires of different materials when one junction is exposed to the temperature to be measured and the other junction (or junctions) is kept at some known temperature.

Experience has shown that the most satisfactory couples for the measurement of temperatures throughout the range 300° C (570° F) to 1600° C. ($2,900^{\circ}$ F) are those made of an iridium or rhodium alloy of platinum fused to pure platinum, of which the most common type, known as the Le Chatelier pyrometer, consists of a 10 per cent rhodium alloy joined to pure platinum. It is essential that the metals be pure and the alloy homogeneous.

For work in the interval 600° C to the temperature of liquid air or lower, copper-constantan (or iron-constantan) couples are available.

Thermocouples are well adapted to many requirements of technical operations, since they are durable, act quickly, and being usually direct reading are simple to operate.

The essential precautions to be observed in the use of thermocouples are: Protection of the wires from the action of hot furnace gases, silicon, metallic vapors, etc.; the cold junctions should be so placed that their fluctuations of temperature are negligible; the electrical resistance of the pyrometer-galvanometer should be so high that the errors resulting from the resistance of the leads and the variation of the resistance of the couple may be entirely neglected. A great many of the reported failures of thermocouples to fulfill the practical requirements of technical applications have been traced to neglect of one or the other of these precautions.

It is desirable, when a thermocouple is submitted for test, that it be accompanied by the galvanometer with which it is used. The protecting sheaths should not be sent in.

The complete test of a thermocouple consists in a thorough annealing at white heat, determination of the electromotive force of the couple at three or more known temperatures in terms of the standard scale of temperature of this Bureau, and the measurement of the resistance of the couple (when cold), with accompanying tables of corresponding electromotive forces and temperatures, and when the pyrometer-galvanometer is submitted a table will be furnished giving temperatures directly in terms of the readings of the galvanometer joined to the couple.

The test of the pyrometer-galvanometer consists in a determination of the corrections at five points of the scale, and its resistance at one temperature.

FEES—SCHEDULE 36—(THERMOCOUPLES).

The following schedule of fees has been established for the testing of thermocouples (the platinum, etc., couples for high temperatures and the constantan, etc., couples for low temperatures) and the pyrometer-galvanometers used with the couples:

(a) Complete test of thermocouple.....	\$3.00
(b) Same as above, in lots of three or more, each.....	2.00
(c) Examination of homogeneity of wires of couple.....	1.00
(d) Test of pyrometer-galvanometer at 5 points.....	1.50
(e) Test of pyrometer-galvanometer, each additional point10
(f) The standardization of potentiometers used in connection with thermocouples will be carried out in accordance with the requirements and schedules governing the testing of resistances (Bureau Circular No. 6, Schedule 72).	

II.—ELECTRICAL RESISTANCE THERMOMETERS.

These thermometers are based on the variation of the electrical resistance of a metal (preferably platinum) with the temperature. When properly constructed and due precautions are taken in its use, the platinum thermometer is an instrument of great accuracy for the measurement of temperature from the lowest attainable up to about 1000° C (1,800° F).

The complete standardization of a platinum thermometer includes a determination of its constants from measurements of its electrical resistance at three known temperatures—melting ice, steam, and sulphur vapor. Where the platinum thermometer is to be used for measurements of temperatures below -100° C (-150° F), the boiling point of liquid oxygen will be used instead of the sulphur point.

The fees are given in the schedule below.

FEES—SCHEDULE 37—(ELECTRICAL RESISTANCE THERMOMETERS).

(a) Complete standardization of a platinum resistance thermometer for precision work.....	\$7.50
(b) The standardization of platinum or other resistance thermometers used in the industries, not requiring the highest precision.....	3.50
(c) The standardization of the resistance boxes or potentiometers used in connection with resistance thermometers will be carried out in accordance with the requirements and schedules governing the testing of resistances (Bureau Circular No. 6).	

III.—OPTICAL PYROMETERS.

Any type of instrument for the measurement of temperature in terms of the intensity of light or radiation from an incandescent object may be classed, for the purpose of testing, under the head of optical pyrometers.

This method may be made very sensitive, as the light intensity increases much more rapidly than the temperature. The measurable range is from that of dull red (600° C.) to indefinitely high temperatures. Such a pyrometer is completely separated from the object or furnace whose temperature is to be determined, and this is of great advantage in many processes and essential to others.

Such pyrometers are therefore particularly adapted to the measurement of temperatures of inaccessible and moving luminous objects, and to the study of uniformity of heating as in a furnace or over any considerable area, and are the only instruments available for the satisfactory estimation of very high temperatures.

The accuracy attainable in optical pyrometry varies greatly with the instrument, the temperature, the experience of the observer, and the care exercised by him.

The various optical pyrometers on the market have been investigated experimentally at the Bureau, and in Bulletin No. 2, Vol. 1, pp. 189-254, are published in detail the results of this work.

This Bureau is prepared to test optical or radiation pyrometers of the usual types used in scientific and technical work, such as the Mesuré-Notel pyrometric telescope, the Morse Thermo-Gage, the Holborn-Kurlbaum, the Le Chatelier, and the Wanner optical pyrometers, the Féry thermoelectric telescope and absorption pyrometer, etc.

The test consists in determining the readings of the instrument at three or more known temperatures in terms of the standard scale of this Bureau, together with a statement of directions and necessary precautions that should be observed in the use of the pyrometer. A table is also furnished giving temperatures in terms of readings of the instrument.

FEES—SCHEDULE 38 (OPTICAL PYROMETERS).

The following schedule of fees for testing optical pyrometers has been established:

(a) For a pyrometer test at three temperatures.....	\$7.50
(b) For test at each additional temperature.....	1.00

IV.—EXPANSION AND OTHER PYROMETERS.

Mercury thermometers reading to about 550° C (1,000° F) are obtainable, in which the stem above the mercury column is filled with an inert gas under great pressure. To avoid troublesome changes of zero, the thermometer bulbs should be made of very hard glass and the instrument thoroughly annealed.

For the measurement of temperatures to about 1,400° F, pyrometers based on the relative expansion of metals, or of a metal and graphite, are widely used. These instruments should be tested from time to time to correct for changes in zero.

This Bureau will also receive for test other types of pyrometer, such as the various kinds of recording instruments, specific heat, expansion, transpiration, and viscosity pyrometers, etc.

FEES—SCHEDULE 33 (MERCURY THERMOMETERS).

(c) Determination of the corrections in the interval 100° C (212° F) to 550° C (1,000° F) for each point tested.....	\$0.25
(d) Same as above in lots of 6 or over, for each point tested20
(c) The annealing of thermometers.....	1.00

For pyrometers not specified in the previous schedules, the amount of fee will depend upon the construction of the pyrometer submitted, difficulty of test, the temperatures at which tests are to be made, and the order of accuracy desired.

V.—HEAT MEASUREMENTS.

Testing of various kinds of calorimetric apparatus and thermal properties of fuels, oils, and other substances is undertaken by this Bureau. In cases of scientific or technical interest, special investigations in heat measurements and allied subjects will be carried out, such as the determination of coefficients of expansion at high temperature, specific heats, boiling points, melting points of metals, alloys, minerals, etc.

FEES—SCHEDULE 39.

- | | | |
|----|---|--------|
| a) | Standardization of combustion calorimeters of type of Mahler, Berthelot, Junkers, etc., including a determination of the water equivalent and the corrections to mercury thermometers, with accompanying certificates..... | \$7.50 |
| b) | Determination of the calorific values of fuels, including proximate analysis (for departments of the National Government, State, county, and municipal governments, and in special cases for corporations and individuals)..... | 10.00 |
| c) | For other heat measurements, the amount of fee charged will depend upon the nature of the test. | |

FORM OF CERTIFICATE.

The certificate furnished by the Bureau of Standards will contain the following data:

- (a) Description or identification marks of article or instrument.
- (b) Bureau of Standards test number.
- (c) Name of party for whom instrument is compared.
- (d) Temperature and other conditions of the test.
- (e) Table of corrected values or of desired corrections.
- (f) Date of certification.
- (g) Seal of the Bureau and signature of the Director.
- (h) Special remarks where necessary.

It is the desire of the Bureau to cooperate with manufacturers, scientists, and others in bringing about more satisfactory conditions relative to weights, measures, measuring instruments, and thermal constants, and to place at the disposal of those interested such information relative to these subjects as may be in its possession.

It is also desired to aid in the solution of specific scientific problems arising in technical or scientific work, coming within the scope of the Bureau, and to this end correspondence is invited.

Persons interested in pyrometric problems are welcome to visit the laboratories of the Bureau, where many of the leading types of pyrometers may be seen in operation.

All communications should be addressed "Bureau of Standards, Department of Commerce and Labor, Washington, D. C."

S. W. STRATTON,
Director.

Approved:

V. H. METCALF,
Secretary.

