

VERIFICATION OF ELECTRICAL STANDARDS AND MEASURING INSTRUMENTS

Department of Commerce and Labor

BUREAU OF STANDARDS

Washington

BUREAU CIRCULAR NO. 6  
2D EDITION\*

February 20, 1906.

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approved March 3, 1901, the Office of Standard Weights and Measures of the Treasury Department was, on July 1, 1901, superseded by the Bureau of Standards, the functions of which may be briefly stated as follows: The custody of the standards; the comparison of the standards used in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, a reasonable fee will be charged.

RANGE OF ELECTRICAL TESTING.

Verification of resistance standards of the following values: 1, 10, 100, 1,000, 10,000, 100,000 ohms; and the decimal subdivisions 0.1, 0.01, 0.001, 0.0001, 0.00001.

Determination of temperature coefficients for the same.

Verification of resistance boxes, potentiometers, ratio coils, and other resistance apparatus.

Verification of resistance standards for current measurement of 0.00001 ohm and above and current-carrying capacity of 1,000 amperes or less.

Determination of electrical properties of materials, conductivity, temperature coefficients, thermoelectric power.

Verification of standards of electromotive force—Clark, Weston, or other standard cells.

Verification of direct and alternating current measuring apparatus—millivoltmeters, voltmeters up to 2,000 volts; ammeters up to 5,000 amperes; wattmeters and watthour meters up to 1,000 volts and 1,000 amperes.

Testing of condensers—measuring capacities and testing for absorption, insulation, and power factor.

Verification of inductance standards and measuring the inductances of instruments.

Photometry—verification of incandescent photometric standards.

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,

\* This edition supersedes the first issue of this circular, dated February 15, 1904.

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.

## I.—STANDARDS OF RESISTANCE AND ELECTROMOTIVE FORCE.

INCLUDING WHEATSTONE BRIDGES, POTENTIOMETERS, PRECISION RHEOSTATS, ETC.

All resistance measurements will, for the present, be referred to the mean value of five 1-ohm manganin coils, of the Reichsanstalt type, as determined by reverification from time to time at the Physikalisch-Technische Reichsanstalt, Berlin, Germany.

The accuracy attainable depends upon the magnitude of the temperature coefficient, and the thermoelectric power of the resistance material employed, as well as upon the design and construction, which latter determine the accuracy with which the actual temperature of the resistance material can be ascertained (coils of the B. A. type are particularly defective in this respect). The thermoelectric properties are of relatively less importance in the case of standards of 1 ohm and above, but may lead to very large errors in the case of low resistance standards, such as are employed for current measurement, ammeter shunts, etc.

The standards of electromotive force of the Bureau consist of a number of Clark standard cells, together with a number of Weston cells, with saturated cadmium sulphate solution. The results are expressed in terms of the volt derived from the present legal relation: The electromotive force of Clark cell at  $15^{\circ}\text{C}$  = 1.434 international volts.

## FEES.

The following schedules of fees have been established:

### SCHEDULE 71.

#### RESISTANCE STANDARDS OF PRECISION.

Standards of approved design, adjusted to within 0.1 per cent of their nominal values, will be received for verification as precision standards.

For calibration at three temperatures, approximately 15°, 20°, and 25° C, corrections given to 0.001 per cent, with an uncertainty of 0.002–0.005 per cent, depending upon the denomination, design, resistance material, etc.:

|   |        |
|---|--------|
| (a) Units .....   | \$3.00 |
| (b) Multiples of the unit .....   | 3.50   |
| (c) Tenth and hundredth ohm standards* .....  | 3.50   |
| (d) Thousandth and ten-thousandth ohm standards* .....  | 4.00   |
| (e) Hundred-thousandth ohm standards* .....   | 5.00   |
| (f) Standards adjusted in B. A. units or legal ohms, extra fee .....  | .50    |
| (g) Standards previously verified at the Bureau, or by the Physikalisch-Technische Reichsanstalt, the English National Physical Laboratory, or the B. A. Committee on Electrical Standards will be reverified, at one temperature, approximately 20° C, for one-half the above fees if accompanied by the original certificate. |        |

## SCHEDULE 72.

RESISTANCE BOXES, WHEATSTONE BRIDGES, POTENTIOMETERS, RATIO COILS, AND OTHER RESISTANCE APPARATUS.

## GRADE A.

Only apparatus of approved design and construction will be received for verification to the highest degree of precision. The corrections will in such cases be given to 0.001 per cent, except for coils of 1 ohm or less. To permit the most accurate comparisons, all resistance apparatus should, where possible, be so constructed that potential leads may be directly applied to each coil, thus eliminating from the corrections all errors due to variable contact resistances.

For calibration at one temperature, approximately 20° C:

|   |        |
|---|--------|
| (a) First coil .....  | \$1.00 |
| (b) Each additional coil .....  | .20    |
| (c) For each additional temperature the charge will be 50 per cent of the above fees. |        |

## SCHEDULE 73.

RESISTANCE BOXES, WHEATSTONE BRIDGES, POTENTIOMETERS, RATIO COILS, AND OTHER RESISTANCE APPARATUS.

## GRADE B.

To provide for calibrations in which a minor degree of accuracy will suffice and for the calibration of apparatus not suitable for measurements of the highest precision, such apparatus may be submitted for verification under this schedule. Corrections will be given to 0.01 per cent.

For calibration at a single temperature:

|                                |        |
|--------------------------------|--------|
| (a) First coil .....           | \$1.00 |
| (b) Each additional coil ..... | .15    |

Resistance apparatus may also be submitted to determine whether a specified accuracy of adjustment, not greater than 0.02 per cent, has been attained. In this case no corrections will be given, and the coils will be checked at one temperature.

|                                |        |
|--------------------------------|--------|
| (c) First coil .....           | \$0.50 |
| (d) Each additional coil ..... | .10    |

## SCHEDULE 74.

RESISTANCE STANDARDS FOR CURRENT MEASUREMENT, AMMETER SHUNTS, ETC.

Apparatus under this head must be of approved design. Suitable resistance materials must be employed; suitable connecting lugs must be provided.

\*Submultiples of the unit must be provided with potential terminals, and designed for oil immersion.

Determination of value within 0.01 per cent at one temperature, about 20° C, when carrying a stated current:

|  |        |
|--|--------|
| (a) For currents of 50 amperes or less .....   | \$1.50 |
| (b) For currents exceeding 50 and not exceeding 200 amperes.....   | 2.50   |
| (c) For currents exceeding 200 and not exceeding 500 amperes.....  | 3.50   |
| (d) For currents exceeding 500 and not exceeding 1,000 amperes.....  | 4.00   |
| (e) Additional tests at specified temperatures, or when carrying stated currents, each half of the above rate. |        |

#### SCHEDULE 75.

##### ELECTRICAL RESISTIVITY AND CONDUCTIVITY OF MATERIALS.

Specimens submitted must be of uniform cross-sectional area and should have a length of at least 1.25 meters.

Determination of electrical resistivity and conductivity:

|  |        |
|--|--------|
| (a) Resistance of specimen 0.001 ohm or more .....   | \$2.00 |
| (b) Resistance of specimen greater than 0.0001 ohm and less than 0.001 ohm.....  | 2.50   |
| (c) Resistance of specimen less than 0.0001 ohm .....  | 3.00   |
| The resistivity and conductivity are determined at approximately 20° C, to within 0.05 per cent.   |        |
| (d) For the measurement of resistivity at two additional temperatures for the determination of the temperature coefficient, the additional fee is equal to that named above. |        |
| (e) Calibration of conductivity standards at five points and at a single temperature, double the fees given in the schedule above.   |        |
| (f) Thermoelectric properties of materials.....  | 2.50   |

#### SCHEDULE 76.

##### STANDARD CELLS.

For the present, all measurements of electromotive force will be referred to the mean value of a number of Clark standard cells, constructed in accordance with the legal specifications.

Verification of standard cells; values stated to 0.0001 volt:

|   |        |
|---|--------|
| (a) At one temperature .....                              | \$1.50 |
| (b) At three temperatures between 15° and 30° C.....      | 2.50   |
| Verification of attached thermometer at four points ..... | .25    |

## II.—ELECTRICAL MEASURING INSTRUMENTS.

### DIRECT AND ALTERNATING CURRENT.

Measurements of direct electromotive force are made by means of potentiometers and Weston cells, the values of the latter being known in terms of the standards of the Bureau. Alternating electromotive forces are measured by means of instruments which admit of accurate calibration by means of direct electromotive forces. Direct electric currents are measured by means of standard resistances, potentiometers, and Weston cells, and alternating currents are measured by instruments which admit of accurate calibration by means of direct currents. Similarly, the electric power of alternating currents is measured by wattmeters which admit of calibration by means of direct currents. Thus all current, voltage, and power measurements, direct and alternating, are referred to standard resistances and standard cells.

The alternating-current instruments employed are as free as possible from errors due to inductance, eddy currents, etc., and, where necessary, corrections are applied for the effects due to small residual inductances. Special generating apparatus is employed, enabling the voltage, frequency, power factor, and wave form of electric currents to be controlled and varied as desired, and every effort is made to secure accurate measurements.

## SCHEDULE 81.

## I.—DIRECT-CURRENT AMMETERS.

For calibration at five points:

|  |        |
|--|--------|
| (a) Not exceeding 50 amperes .....   | \$1.50 |
| (b) Exceeding 50 and not exceeding 250 amperes .....   | 2.00   |
| (c) Exceeding 250 and not exceeding 500 amperes .....  | 3.00   |
| (d) Exceeding 500 and not exceeding 1,000 amperes .....  | 4.00   |
| (e) Exceeding 1,000 and not exceeding 5,000 amperes .....  | 5.00   |
| (f) For the determination of the temperature coefficient and the effect of continued current on the readings, in addition to the corrections at five points, the total fee will be double that stated above. |        |
| (g) Each additional instrument after the first, to be tested at the same time and through the same range, will be charged one-half of the above fee.   |        |

Combinations consisting of a millivoltmeter and a shunt will be tested together at the above rates. If a separate verification of each is desired, with the corrections for each, the fees will be charged according to the above schedule for the shunt, and 81, II for the millivoltmeter.

## II.—DIRECT-CURRENT VOLTMETERS AND MILLIVOLTMETERS.

Calibration at five points:

|  |        |
|--|--------|
| (m) Not exceeding 300 volts, at one temperature .....  | \$1.50 |
| (n) Exceeding 300 volts and not exceeding 600 volts .....  | 2.00   |
| (o) Exceeding 600 volts and not exceeding 1,000 volts .....  | 2.50   |
| (p) Each additional point above five .....   | .10    |
| (q) For the determination of the temperature coefficient and resistance, in addition to the corrections at five points, the total fee will be double that stated above.                              |        |
| (r) Laboratory standard voltmeters and millivoltmeters will be tested at ten to fifteen points unless otherwise ordered, and the fees will be double those given above for the corresponding ranges. |        |
| (s) Each additional instrument after the first, to be tested at the same time and through the same range, will be charged one-half of the above fee.   |        |

Double and triple scale instruments will be tested at five points on each scale and the extra points charged at 10 cents each.

## SCHEDULE 82.

## I.—ALTERNATING-CURRENT AMMETERS, ELECTRO-DYNAMOMETERS, ETC.

## WITH OR WITHOUT CURRENT TRANSFORMERS.\*

Calibration at five points:

|   |        |
|---|--------|
| (a) Not exceeding 50 amperes, tested at one frequency and one temperature, using currents of approximately sine wave form .....   | \$2.00 |
| (b) Exceeding 50 amperes and not exceeding 250 amperes, tested as above .....   | 2.50   |
| (c) Exceeding 250 amperes and not exceeding 500 amperes, tested as above .....  | 3.00   |
| (d) Exceeding 500 amperes and not exceeding 1,000 amperes, tested as above .....  | 4.00   |
| (e) Each additional point .....   | .15    |
| (f) For each additional frequency at which a test is made at five points the additional fee will be one-half of the above rates.  |        |
| (g) For each additional wave form at which a test is made at five points the additional fee will be equal to fee named above for the original test. This includes a determination of the wave form which will be supplied with the certificate.   |        |
| (h) For the determination of the temperature coefficient an extra fee will be charged equal to that given above. This involves a calibration at three temperatures, about 10°, 20°, and 30° C, unless otherwise specified. Where instruments are to be used in water-power plants, or other places where low temperatures are likely to prevail, or in engine rooms at relatively high temperatures, they may be tested at temperatures outside this range anywhere between 0° and 50° C. |        |
| (i) Each additional instrument after the first, to be tested at the same time and through the same range, will be charged one-half of the above fees.   |        |

\* Where alternating ammeters are used with current transformers they are tested together as one apparatus at the above rates. If a separate test is required for each, they will be counted as two pieces of apparatus, and the fee will be charged accordingly.

## II.—ALTERNATING-CURRENT VOLTMETERS.

WITH OR WITHOUT POTENTIAL TRANSFORMERS.\*

## Calibration at five points:

|  |        |
|--|--------|
| (m) Not exceeding 300 volts, tested at one frequency and one temperature, using electromotive forces of approximately sine wave form .....             | \$2.00 |
| (n) Exceeding 300 volts and not exceeding 1,000, tested as above .....   | 2.50   |
| (o) Exceeding 1,000 volts and not exceeding 2,000, tested as above .....   | 3.00   |
| (p) Each additional point .....  | .15    |
| (q) For each additional frequency at which a test is made at five points the additional fee will be one-half the above rates.                          |        |
| (r) For each additional wave form the additional fee will be equal to the above. (See 82 g.)   |        |
| (s) For the determination of the temperature coefficient the extra fee will be equal to the fee named above. (See also 82 h.)                          |        |
| (t) Determination of the inductance and resistance of an instrument .....  | 1.00   |
| (u) Each additional instrument after the first, to be tested at the same time and through the same range, will be charged one-half of the above rates. |        |

Double and triple scale instruments will be tested at five points on each scale and the extra points charged at 15 cents each.

## SCHEDULE 83.—WATTMETERS.

## I.—TESTED WITH DIRECT CURRENT.

## Calibration at five points:

|   |        |
|---|--------|
| (a) Not exceeding 25 kilowatts, at one temperature .....  | \$2.00 |
| (b) Exceeding 25 kilowatts, not exceeding 100 kilowatts, at one temperature .....   | 3.00   |
| (c) Exceeding 100 kilowatts, not exceeding 500 kilowatts .....  | 4.00   |
| (d) Each additional point .....   | .20    |
| (e) For the determination of temperature coefficient, an additional fee equal to the above will be charged. (See 82 h.)       |        |
| (f) For the determination of the inductance and resistance of an instrument which is being tested the additional fee is ..... | 1.00   |

## II.—TESTED WITH ALTERNATING CURRENT ONLY.

Calibration at five points, at one frequency and one temperature, with unity power factor and approximately sine wave form:

|   |        |
|---|--------|
| (m) Not exceeding 25 kilowatts .....  | \$2.00 |
| (n) Exceeding 25 kilowatts, not exceeding 100 kilowatts, tested as above .....  | 3.00   |
| (o) Exceeding 100 kilowatts, not exceeding 500 kilowatts, tested as above .....   | 4.00   |
| (p) Each additional point .....   | .20    |
| (q) For each additional frequency at which a test is made at five points the additional fee will be one-half of the above rates.        |        |
| (r) For each additional wave form the additional fee will be equal to the above. (See 82 g.)  |        |
| (s) For the determination of temperature coefficient the extra fee will be equal to that named above. (See 82 h.)                       |        |
| (t) For a determination at each additional power factor, half of the above rates.   |        |
| (u) When the same instrument is tested both by direct and alternating currents the fee will be 50 per cent more than for a single test. |        |

\* Where alternating voltmeters are used with potential transformers they are tested together as one apparatus at the above rates. If a separate test is required for each, they will be counted as two pieces of apparatus, and the fee will be charged accordingly.

## SCHEDULE 84.—WATT-HOUR METERS.

Calibration at five loads, viz: 5 per cent, 25 per cent, 50 per cent, full load, and 50 per cent overload, unless otherwise ordered:

## I.—DIRECT-CURRENT METERS.

|  |        |
|--|--------|
| (a) Not exceeding 25 kilowatts .....   | \$3.00 |
| (b) Not exceeding 100 kilowatts .....  | 4.00   |
| (c) Not exceeding 500 kilowatts .....  | 5.00   |
| (d) For the determination of the temperature coefficient an additional fee equal to that given above in each case will be charged. |        |
| (e) Each additional meter after the first, to be tested at the same time and through the same range, one-half of the above rate.   |        |

## II.—ALTERNATING-CURRENT WATT-HOUR METERS, SINGLE PHASE.

Calibration at one frequency, unity power factor, rated voltage, and approximately sine wave form on five different loads, viz: 5 per cent, 25 per cent, 50 per cent, full load, and 50 per cent overload (unless otherwise ordered):

|   |        |
|---|--------|
| (l) Not exceeding 5 kilowatts .....   | \$3.00 |
| (m) Not exceeding 25 kilowatts .....  | 4.00   |
| (n) Ditto, but at one load and <i>four different frequencies</i> , in addition to the preceding test .....  | 2.00   |
| (o) Ditto, but at one apparent load ( <i>volt-amperes</i> ) and <i>four different power factors</i> (including both lagging and leading currents, if desired) ..... | 2.00   |
| (p) Ditto, but at one current and five different voltages .....   | 2.00   |
| (q) Ditto, but at one load and at different temperatures, the charge for each temperature after the first will be .....   | 2.00   |
| (r) Ditto, but at one load and with <i>different wave forms</i> , the charge for each wave form, in addition to the initial test with sine wave form, will be ..... | 2.00   |
| (s) For ranges exceeding 25 kilowatts and not exceeding 100 kilowatts the charge will be 25 per cent greater than the rates named above.                            |        |
| (t) For ranges exceeding 100 kilowatts and not exceeding 500 kilowatts the charge will be 50 per cent greater than the rates named above.                           |        |
| (u) Each additional meter after the first, to be tested at the same time and through the same range, one-half of the above rates.                                   |        |

## III.—THREE-PHASE WATT-HOUR METERS.

(v) Three-phase watt-hour meters will be charged 50 per cent more than the foregoing rates for single-phase instruments.

## SCHEDULE 85.

## PHASE METERS, POWER-FACTOR METERS, FREQUENCY METERS, ETC.

Calibration at ten points:

|   |        |
|---|--------|
| (a) Phase meters and power-factor meters, at one frequency and one load, using approximately sine wave form ..... | \$3.00 |
| (b) Each additional calibration at ten points for other frequencies, other loads, or other wave forms .....       | 1.50   |
| (c) Frequency meters, at one voltage, using approximately sine wave form .....                                    | 3.00   |
| (d) Each additional calibration for other voltages or wave forms .....  | 1.50   |

## SCHEDULE 86.

## CAPACITIES AND INDUCTANCES.

## I.—CAPACITIES.

|   |        |
|---|--------|
| (a) Determination of the capacity of a mica, paper, or other condenser, at one temperature, by comparison with the mica standards of the Bureau, using either direct-current or alternating-current methods ..... | \$2.00 |
| (b) For each <i>additional</i> capacity of the same set .....   | .50    |
| (c) Determination of the capacity at each additional temperature, one-half of the above rate.   |        |
| (d) Determination of the absorption and leakage resistance .....  | 2.00   |
| (e) Absolute determination by rotating commutator at three frequencies, one-half greater than above .....   | 3.00   |
| (f) For each <i>additional</i> condenser after the first, tested at the same time and in the same way, one-half of the above rate.  |        |

The accuracy which may be obtained depends largely upon the quality of the condenser. If the absorption and leakage are both very small, the capacity is certified to 0.1 per cent, or even closer.

## II.—INDUCTANCES.

|   |        |
|---|--------|
| (a) Determination of the inductance of a coil in terms of the standards of the Bureau, at one temperature                           | \$2.00 |
| (b) For each additional temperature .....   | 1.00   |
| (c) Each additional coil of the same set, or similar .....  | .50    |
| (d) Determination of the inductance (and resistance) of a voltmeter, wattmeter, or other instrument which is being calibrated ..... | 1.00   |

## SCHEDULE 87.

### PHOTOMETRY.

Lamps to be used as standards should be properly aged before being submitted for the determination of candlepower.

Two independent determinations of mean horizontal candlepower at a specified voltage, or of the voltage and current at which a lamp gives a specified horizontal candlepower:

|                                       |        |
|---------------------------------------|--------|
| (a) One lamp .....                    | \$1.50 |
| (b) Two or more lamps, per lamp ..... | 1.00   |

### 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, and measuring instruments, and to place at the disposal of those interested such information relative to these subjects as may be in its possession.

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

Approved:

V. H. METCALF,  
*Secretary.*

S. W. STRATTON,  
*Director.*