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NATIONAL BUREAU OF STANDARDS  
WASHINGTON 25, D. C.

Letter  
Circular  
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(Superseding  
LC475)

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TESTING OF ELECTRICAL INSTRUMENTS, METERS  
AND RANGE-EXTENDING AUXILIARIES

This letter circular supplements the Bureau's Fee Schedules Nos. 201.301 to 201.313 covering tests of electrical instruments. Its contents should be carefully noted before requesting tests of electrical instruments, meters, instrument transformers, transformer testing sets or volt boxes.

Some of the methods and equipment used at the Bureau in such testing are described in a number of publications which are listed in letter circular LC672, available on application without cost.

1. Arrangement for Tests

(a) Test instructions. - A letter or purchase order stating the tests desired should be sent to the Bureau in advance of shipment of apparatus. In the case of routine or periodic tests, the letter may be sent at the time of shipment. Complete information must be supplied stating in detail the tests desired (i.e., ranges, frequency, number of scale points tested, etc.) before testing can be started. The particular conditions to be specified for certain types of apparatus are given in the following paragraphs. In general, it is desirable to state the purpose of the test and the manner in which the results are to be used, as such information often enables our staff to detect unsuspected difficulties and to make constructive suggestions as to the most suitable type of test.

(b) Address. - Initial correspondence may be addressed simply "National Bureau of Standards, Washington 25, D. C." Later communications should also bear the test number which is assigned to each test by the Bureau. If the test number has been assigned previous to the shipment of apparatus, it should be marked on the shipping container. If a test number has not been assigned, an invoice referring to the previous correspondence or purchase order (or giving test information) should be enclosed to identify the shipment. This information is needed at the time of receipt by the Bureau shipping room in order that there be no delay in delivering the shipment to the proper laboratory. The apparatus should be carefully packed (see section 11 of this letter circular).

(c) Precedence. - In general, tests in each of the Bureau's laboratories are undertaken in the order in which requests are received, providing the information necessary to their performance has been received by the time the test is scheduled to start. Special precedence can be given in emergency cases only when a complete explanation of the situation justifies this in the opinion of the Bureau. When it is desired that the apparatus be out of normal service for a minimum time, complete arrangements for the test should be made in advance of shipment. The Bureau will then set a date at which the material should reach Washington in order that the test may be started immediately on its arrival.

(d) Time for completion of test. - The time required for completion of tests generally depends on a number of factors which cannot be accurately estimated in advance. In addition to such considerations as the extent to which laboratory equipment and personnel is occupied in other test work, it is often necessary in nonroutine tests of a precision nature to repeat the work under various test conditions. Customers must therefore be content with approximate time estimates.

## 2. Condition of Instruments

All apparatus submitted for test should be in good operating condition, with adequate insulation, clean contacts, etc., as apparatus which is not in good working order cannot be tested. The Bureau is not in a position to undertake the repair or adjustment of apparatus received in poor condition. If repairs or adjustments are needed, they should be made by the applicant, or the apparatus should be sent to the maker to be put into good condition before it is submitted for test. When defects are found after a test has been begun, which exclude an apparatus from certification, a report will be rendered giving such information as has been found. In such a case the fee charged will depend on the extent of the work completed. All possible care will be taken in handling apparatus, but the risk of damage in shipment or testing must be assumed by the applicant.

## 3. Testing of Instruments

Tests of an instrument usually consist of determinations of the values of the measured quantity required to deflect the instrument pointer to specified scale marks. Normally at least two determinations, with increasing and decreasing values respectively, are made at each specified scale mark, and the average of these results is reported in tabular form. Unless otherwise requested, all tests are made at room temperature and after the instrument pointer has been set to the zero mark on open circuit. Voltmeters and the voltage circuits of wattmeters are energized for at least 20 minutes before tests are begun.

Unless otherwise requested, single-range instruments are tested at 5 scale marks, which should preferably be selected from those that the maker used as cardinal calibration points in laying out the scale. Multi-range instruments are tested at 5 such marks on one range and 2 on each other range. From the ratios of the tabulated results, a multiplying factor can be determined by which the values stated for the 5 points on the base range can be used to determine the values for the corresponding points on other ranges. Only in exceptional cases will such computed values be in error by more than the certified accuracy.

High-quality instruments which are intended for use as laboratory standards in testing other instruments should preferably be tested on the base range at each cardinal scale mark used by the maker in laying out the scale, so that suitable corrections may be applied by linear interpolation to readings at intermediate points.

Unless otherwise specifically requested, instruments which can equally well be used with direct and alternating current will first be tested with direct current at 5 points on one range and 2 points on each other range. Determinations of the difference of indication on reversed direct current and on alternating current of the specified frequency will then be made at 1 or 2 scale points on each range of the instrument. The mean of values for the 2 directions of current flow through the instrument (reversed dc) best represents the performance of the instrument on direct current since it minimizes the effect of the local magnetic field and of residual magnetism in the instrument shield. The results obtained by these procedures (tests on reversed dc followed by a transfer test) are more accurate than those obtained from a test on alternating current only. They are also of greater value since the ac-dc differences are relatively permanent for an instrument so that subsequent tests will generally need to be made only on reversed direct current.

#### 4. Wattmeters

(a) Single Phase. - When single-phase wattmeters are submitted for test without specific instructions, and are of a type which may be operated on direct current and on alternating current, they will be tested with reversed direct current at 5 points on a base range and at 2 points on each other combination of ranges. They will then be given an ac-dc transfer test at two scale points (the determination of the difference in indication between the mean of results obtained with the two directions of direct current and the results with alternating current constitutes an ac-dc transfer test). This transfer test should be made at a low power factor (50 percent) on each voltage range, as the percentage errors resulting from inductance in the voltage circuit are much greater at low than at high power factor. A transfer test at unity power factor is generally necessary only on one range.

(b) Polyphase. - Unless otherwise specified polyphase wattmeters will be tested first for interaction by applying alternating voltage to the voltage circuit of one element and alternating current to the current circuit of the other element and vice versa. If the interaction is sufficiently small the wattmeter will then be tested on reversed direct current with the current coils of the 2 elements in series and the voltage coils in parallel. A further test will be made to determine the departure from equality of the two elements at zero by opposition and at 2 other points on the scale by reversed d-c tests on the separate elements. In computing the fee, the normal rating of one element will be taken as the normal rating of the wattmeter.

#### 5. Millivoltmeter and Shunt

The combination of a millivoltmeter and a shunt will be tested as an ammeter, and the fee will be the same as that given in schedule 201.302 for an ammeter of the same range. If the millivoltmeter is also to be tested separately, the additional fee will be that given in schedule 201.303.

#### 6. Instruments Used with Transformers

Alternating-current instruments used with externally connected transformers should preferably be tested separately, as the transformers will probably have a very constant ratio over a long period of time while the instruments are more liable to change with time and use. When an instrument and a separate transformer are so tested, they will be counted as two pieces of apparatus, and fees will be charged accordingly. After separate tests of the instrument and transformer, it is sufficient thereafter to test the instrument alone at suitable intervals, provided that the transformer is well constructed of good material and is properly used.

#### 7. Watthour Meters

Tests of watthour meters consist of determinations of their percentage registration "as received". Before tests can be started the test conditions must be completely specified as regards current and voltage ranges to be tested, frequency, applied voltage and current, and power factor. It is recommended that meters be cleaned and well adjusted before being submitted for tests, as the Bureau cannot undertake the cleaning or adjustment of meters. Unless otherwise specified, test runs on portable standard watthour meters (rotating standards) are of 100 seconds duration, after an initial warm-up period of 30 minutes with the rotor stationary and with the test voltage only applied.

### 8. Measurement Voltage Dividers (Volt Boxes)

Measurement voltage dividers (volt boxes) which are used to extend the range of potentiometers are tested by determining the actual voltage ratio of each range at the desired voltage. Unless otherwise specified, dividers which have not been previously submitted will be tested at 20 percent and 100 percent of rated voltage on each range, to determine the extent of changes which result from self-heating. They need be tested thereafter only at rated voltage.

### 9. Current Transformers

Tests cannot be started until information is furnished concerning the following test conditions: (1) test frequency; (2) secondary test currents; (3) secondary burdens; (4) ranges to be tested. It is customary to make tests at 0.5, 1, 2, 3, 4 and 5 amperes (secondary), and the specification of other values within this range should be avoided if possible.

Only well-designed transformers of good construction should be submitted for test. The Bureau reserves the right to decline to make extended tests on transformers which show unduly large errors in ratio or phase angle, or which fail to repeat their performance. The Bureau's equipment is suitable for testing only those current transformers whose rated secondary current is 5 amperes. The results will, in general, be certified to 0.05 percent in ratio and to 1 minute in phase angle.

Current transformers should be tested with burdens which approximate those with which they are to be used. The "standard burdens" listed in the "American Standard for Instrument Transformers, C57.13" are for rating purposes only, and do not correspond to actual instrument burdens. The ASA standard burdens differ so greatly from the usual instrument burdens that tests made using them do not provide values of ratio and phase angle sufficiently accurate for use with actual instrument loads. Hence the inclusion of tests at ASA burdens is not recommended. The test apparatus regularly used at the Bureau imposes a minimum test burden of about 0.16 ohm with a minimum inductance of about 10 microhenries. In the advance planning of tests, the burden should if possible be chosen larger than this minimum burden (preferably 0.2 ohm). The difference between an actual instrument burden and 0.2 ohm can easily be made up as series resistance (or lead resistance). Generally there is very little to be gained in transformer performance by making the burden less than 0.2 ohm, because of the fact that the resistance of the secondary winding of the transformer is itself usually several tenths of an ohm. Tests with lower burdens may be made with special equipment when necessary, but arrangements for such tests must be made in advance and higher fees must be charged. If the burden is specified in terms of measured resistance and inductance, the leads used to connect the instruments to the transformer should be included in the measurement. If it is not convenient to make this measurement, it will suffice in most cases to state the maker's name,

type and serial number of each instrument used in the burden, and the size and length of wire used in the secondary circuit.

Multiple-range current transformers, in which the same sections of primary winding are used in series and in parallel, usually have phase angles and ratio factors which are equal on the several ranges to within the accuracy needed for almost any measurement purpose. Hence a test at 6 values of secondary current on one range is nearly always sufficient to determine the characteristics of the transformer. Further tests, often made at 0.5 and 5 secondary amperes on each additional range, merely serve as a safeguard by means of which mistakes in winding may be detected. When the various ranges of a multirange transformer are obtained by taps on either winding, this relation does not necessarily hold, particularly in the case of secondary taps; and tests in addition to the initial 6-point test on one range should be made using at least two values of secondary current on each of the ranges so obtained. Transformers of certain designs, however, show very little difference in ratio factor and phase angle on the various ranges, and the Bureau should be consulted before tests on a large number of ranges are ordered.

Unless otherwise specified, current transformers will be demagnetized before being tested. If it is desired to have a transformer tested as submitted (without demagnetization), this fact should be specifically stated.

#### 10. Voltage Transformers

Tests cannot be started until information is furnished concerning the following test conditions: (1) test frequency; (2) secondary test voltages; (3) secondary burdens; (4) ranges to be tested.

Only well-designed transformers of good construction should be submitted for test. The Bureau reserves the right to decline to make extended tests on transformers which show unduly large errors in ratio or phase angle, or which fail to repeat their performance. The results will, in general, be certified correct to 0.05 percent in ratio and to 1 minute in phase angle.

The ratio and phase angle of a voltage transformer change linearly with changes in secondary current at constant voltage, frequency and power factor within its rating. Hence, if values of ratio and phase angle are determined for 2 secondary burdens having the same power factor, values for intermediate currents may be found by interpolation. It is also possible to compute with good accuracy the performance of a voltage transformer at any burden within its rating from data obtained at open circuit and at one non-inductive load (preferably the full load indicated by the name plate rating of the transformer) at the same secondary voltage and frequency. Formulas for this purpose are printed on the back of the Bureau's certificate form for voltage transformers. When a secondary burden of fixed impedance is used, the ratio and phase angle of a voltage

transformer are nearly independent of the secondary voltage within its normal operating range. Hence a test at one secondary voltage is generally sufficient, unless the transformer is to be used over a considerable range of secondary voltages. The "standard burdens" of the American Standard for Instrument Transformers, ASA C57.13, are for rating purposes only, and their inclusion as specified burdens is not recommended. The performance of a voltage transformer with such burdens may readily be computed from values taken at unity power-factor burdens, using the formulas printed on the back of the Bureau's certificate form.

Multiple-range voltage transformers in which the same sections of the primary winding are used in series and in parallel to obtain several ranges, usually have phase angles and ratio factors on the various ranges which are equal to within the accuracy needed for most measurement purposes. Hence a test on one range at all the desired burdens is usually sufficient to determine the performance of the transformer for all such ranges. In addition, tests on each of the other ranges at some one burden may also be desirable in cases where extreme accuracy is required.

When a voltage transformer is submitted with fuses in the primary circuit, the test will be made (in the absence of instructions to the contrary) with the fuses considered as part of the primary winding.

#### 11. General Suggestions for Packing Electrical Instruments for Shipment to the National Bureau of Standards

Electrical measuring instruments such as ammeters, voltmeters, wattmeters and watthour meters contain extremely delicate jewels and pivots, upon which the operation of each such instrument depends. These delicate parts must be carefully protected from mechanical shocks and jars during shipment. Otherwise sensitive instruments cannot be expected to be received after ordinary shipment in satisfactory operating condition. The following suggestions are offered as a guide to packing such instruments and accessory apparatus, such as shunts and instrument transformers, for shipment to this Bureau for test. Every effort is made to handle and to repack these instruments carefully at the Bureau, and whenever possible the return shipment is made in the original container.

Before each instrument is packed, all binding posts on it should be tightened, and any externally-operated clamping device for the moving system should be switched to the "clamp" or "transit" position. Plugs and other small accessories should be enclosed in a small separate container tied to the instrument to which they belong. Instruments having no protective case should have the glass windows protected by pieces of thin wood or heavy cardboard before wrapping. Each instrument should then be wrapped in heavy manila paper or similar covering and sealed with gummed tape to prevent dust and excelsior from getting into it.

The box or boxes in which the instruments are to be packed should be amply strong, and should preferably be of wood rather than pasteboard, with tops which are screwed on in order to avoid possible damage to pivots or jewels which may be caused by the use of a hammer or nail puller. (If frequent shipments of instruments used as secondary standards are contemplated, it is desirable to construct a suitable box and keep it in storage for that purpose.) Pasteboard boxes, which are more convenient, can be used for the shipment of small light-weight instruments, but should be of the high-strength type.

Clean, fresh excelsior or its equivalent in special packaging material should be used as the shock-absorbing material. To pack the instruments, put a layer of excelsior at least 3 to 4 inches deep on the bottom of the box, pressing it down firmly. Lay the wrapped instruments inside down on this layer, packing at least 3 to 4 inches of excelsior firmly between each instrument and the next, and the same amount between instruments and the sides of the box. If there is more than one layer of instruments, put a layer of excelsior 3 to 4 inches thick, well pressed down, between each layer of instruments and the next. A space of not less than 3 to 4 inches above the top layer of instruments should be filled with excelsior, well pressed down.

High-grade pivoted instruments of the laboratory standard type, which have comparatively heavy moving systems without clamping devices, should be packed with special care and should always be individually shipped in wooden boxes with 4 to 6 inches of excelsior around the wrapped instrument. Portable standard watt-hour meters (rotating standards) should also be individually packed.

Certain heavy accessories used with instruments, such as ammeter shunts, current transformers, and voltage (potential) transformers, should be packed in boxes separate from the instruments, to avoid damage to the latter in case the excelsior should become loose or shift during transit. Heavy pieces should always be shipped in wooden boxes and held in place, if necessary, by checks or cleats. Large transformers, especially those having oil-filled iron cases, should be crated singly, and when possible arranged so that the terminals can be made accessible for tests without removing the entire crate.

The tops of boxes and crates must be marked "This Side Up" for if they are not so marked the transportation company is not liable for loss or damage resulting from improper position during shipment. For the same reason boxes containing delicate instruments should be marked "Fragile, Handle With Care", and should be marked "Glass" even if the only glass is that over the scale.