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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
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Letter Circular 342

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Information Section
Bureau of Standards, Washington

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TESTING OF ELECTRICAL INSTRUMENTS, METERS, AND INSTRUMENT TRANSFORMERS

This letter circular supplements the Bureau's Fee Schedules (Nos. 132 to 1313) covering tests of electrical instruments. Its contents should be carefully noted before requesting tests of electrical instruments, meters, or instrument transformers.

Circular No. 20 of the Bureau of Standards, entitled "Electrical Measuring Instruments," contains additional information bearing on the principles of operation of electrical measuring instruments, the advantages and limitations of the various types, sources of error and their avoidance, and discusses some points of design which are of interest to the user. A brief discussion of current and voltage transformers, and an outline of the equipment required for the precision testing of electrical instruments are also given. A copy of this circular may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 15 cents.

1. Arrangement for Tests

All tests should be arranged for in advance of shipment of apparatus.

(a) Test instructions.--Complete information must be supplied as to the nature of the test desired (i.e., ranges, frequency, number of scale points tested, etc.) before the test can be begun. The particular conditions to be specified for certain types of apparatus are given below. In general, it is desirable to give as complete a statement as feasible as to the reasons for requesting the test and the purpose for 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 "Bureau of Standards, Washington, D. C." Later communications and the shipment of apparatus should also bear the test number which is assigned to each test by the Bureau.

(c) Precedence.--In general, tests in any one laboratory are undertaken in the order in which complete information con-

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cerning them has been received. Special precedence will not be given in emergency cases except when a complete explanation of the situation makes this justifiable in the opinion of the Bureau. When it is desired that the apparatus to be tested be out of normal service for a minimum interval, complete arrangements for the test should be made in advance. The Bureau will then set a date at which the material should reach Washington in order that the test may be begun immediately on its arrival.

(d) Time for completion of test.--Because of the nature of our precise measurements, frequently involving repetitions of the work under various test conditions, it is impossible to make a precise estimate of the time which will be required for the completion of a given test, and it is requested that customers be content with only an approximate estimate. Time spent by our staff in preparing replies to repeated "follow-ups" is necessarily taken from the laboratory work.

(e) Witnessing tests.--Technical visitors are always welcome in the Bureau laboratories and are invited to discuss in detail the apparatus and procedure used in the testing work. Experience has shown, however, that the presence of visitors in the laboratory during a test tends to distract the attention of the staff and thus to delay and hinder the test. The literal "witnessing" of tests is therefore, in general, impracticable.

2. Kinds of Instruments

The fees listed under the first headings in Schedule 132 to 136, inclusive, apply to the test of regular portable and switchboard instruments of the deflection type, of a stated accuracy not exceeding 1/4 per cent. Tests of instruments of the laboratory standard type, having a greater period and a higher stated accuracy, require more time and care and more often involve repetition of readings. The fees such as 132a-x are, therefore, set at one and one-half times those for the portable instruments. Similarly, instruments of the Kelvin-balance type, which are also of long period and require manual adjustment of the torsion head to secure a reading, are subject to fees such as 134a-y which are double those for portable instruments.

3. Condition of Instruments

The Bureau can not undertake the repair or adjustment of apparatus received in poor condition. All apparatus should be in good working condition, the insulation adequate and contacts clean, etc., as apparatus which is not in good working order

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will not be tested. If repairs or adjustments are needed, they should be made by the applicant, or the apparatus should be sent to the maker before it is submitted for test. When defects are found after a test has been begun, which exclude an apparatus from receiving the usual certificate, a report will be rendered giving such information as has been found. In such cases a special fee may be charged, depending upon the time consumed. All possible care will be taken in handling apparatus, but the risk of injury or breakage in shipment or under test must be borne by the applicant. Instruments provided with a zero adjuster will be set to indicate zero on open circuit at the beginning of the test unless there is a definite request to test them "as received."

The verb "to calibrate" is used in various senses; for example, as used by some engineers it denotes the act of making the initial adjustment of an instrument which brings its readings into substantial agreement with the scale markings. As interpreted by other workers, however, it means simply to check the instrument by comparing its indications with those of another instrument taken as a standard. Because of the ambiguity of the words "calibrate" and "recalibrate" it is requested that their use be avoided in requesting tests of instruments.

4. Wave Form

The alternating-current tests at usual power and lighting frequencies are regularly made with currents and voltages which closely approximate to the sine-wave form.

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 132 for an ammeter of the corresponding range. If the millivoltmeter is also to be tested separately, the additional fee will be as given in schedule 133.

6. Transfer Tests

When ammeters, voltmeters, or wattmeters of the electrodynamic type which may be operated on reversed direct current*

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*Note.--The expression "reversed direct current" is used to designate the regular procedure in the use of instruments of this kind on direct current in order to avoid error caused by local magnetic field. For example, in using an electrodynamic voltmeter on direct current, two readings are taken, the direction of current flow through the instrument being reversed before taking the second reading. The mean of the two readings gives a result independent of the local magnetic field.

and on alternating current are submitted for test on alternating current, they will first be tested on reversed direct current at the desired points, after which a determination will be made of the difference between the readings on reversed direct current and on alternating current. This "transfer test" will usually be made at two scale points. The results obtained by this procedure are more accurate and valuable than those of a test using alternating current only.

7. Wattmeters

(a) Single-phase.--When single-phase wattmeters are submitted for test without specific instructions, and are of such types as may be operated on reversed direct current and on alternating current, they will be tested with reversed direct current at five points and will then be given an a.c.--d.c. transfer test (see above) at two points. This transfer test should be made at a low power factor (50 per cent) as the per cent 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 necessary only in special cases. If the wattmeters have more than one range, the d.c. test will be made at five points on one range, and at two points on each of the other ranges.

(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 two elements in series and the voltage coils in parallel. A further test will be made to determine the degree of equality of the two elements at zero by opposition and at two other points on the scale by reversed d.c. tests on the separate elements. In computing the fee, the normal rating of the wattmeter so tested will be taken as the normal rating of one element.

8. Multiple-Range Instruments

Except when special resistance measurements like those suggested below are applicable, it is usually best to test multiple-range instruments at about five points on one range and at two points on each other range.

(a) Voltmeters and wattmeters.--Different voltage ranges of voltmeters and wattmeters are usually obtained by the use of

internal series resistors of different values or of external multipliers. In such cases, in addition to the five-point test on one range, it is sometimes desirable to make a direct test of the instrument at two points on each other range, as thereby all conditions of normal operation, such as heating and capacitance effects are reproduced. However, in many cases where the latter source of error is unimportant, the instrument may be tested directly on one range only, and the performance on the other ranges deduced from the relative resistances of the voltage circuits as measured with full rated voltage. The reading error on the second range is thus eliminated and more accurate results are often secured. Fees for such resistance measurements to a relative accuracy of 0.05 per cent are given in schedules 133, 135, and 136.

(b) Millivoltmeters with shunts.--If several shunts are to be used with one millivoltmeter, it is often desirable to make the usual five-point test using one of the shunts only. The four-terminal resistances of this base shunt and of the other shunts, each with the millivoltmeter connected to it in turn, are then measured by a Kelvin double bridge. The current required for a given setting on any other range can then be obtained by multiplying the current required for the given setting on the base range by the ratio of the resistance of the base range to that of the other range. This procedure has the advantage of not requiring that the larger current used on the higher ranges be adjusted and held accurately while the instrument is read. The precision of the resistance measurement is easily made much higher than the precision of reading the millivoltmeter; and measurements on one range at light current and at full current serve to separate the error of adjustment and the error resulting from self-heating of the shunt from spring-fatigue and similar errors in the millivoltmeter.

9. Instruments Used with Transformers

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

10. Current Transformers

Information must be furnished as to the following test conditions. Test can not be begun until this information is received.

(1) Test frequency
(2) Ranges to be tested
(3) Secondary burdens
(4) Voltage-proof test, if desired.

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 current transformers having a rated secondary current of 5 amperes. The results will, in general, be certified correct to 0.1 per cent in ratio and to 3 minutes in phase angle. The observed values are, however, reported to the nearest 0.01 per cent in ratio and to the nearest minute in phase angle, and only a rather unlikely accumulation of errors in the test will cause an error of more than 2 or 3 units in the last digit reported.

The wires used to connect the secondary instruments to the transformer should be included in the measurement of the resistance and reactance of the burdens. If it is not convenient to make this measurement, it will suffice for most purposes to state the maker's name, type, and serial number of each instrument, and the size and length of wire used in the secondary circuit. When the most accurate results are required, it is necessary to send the secondary instruments with the transformer. The Bureau's test apparatus introduces a minimum resistance of about 0.16 ohm in the secondary circuit of the transformer under test; therefore when instruments are submitted for use as a burden, a lead resistance of not less than 0.16 ohm should be allowed.

Because of the fact that the secondary winding itself has a resistance of several tenths of an ohm, there is little to be gained by making the external burden less than 0.15 ohm. When it is essential to know the ratio and phase angle with burdens less than this, test may be made first with the minimum burden attainable in the laboratory and second with a burden somewhat greater than this. From these two sets of data, the performance of the transformer with a burden less than the minimum can be inferred by extrapolation. Such duplicate tests will be made

only on explicit order, in the absence of which, test will be made merely with the minimum burden. (See also Electrical World, Vol. 81, p. 1083, May 12, 1923; Handbook for Electrical Metermen, 4th (1923) edition, p. 978).

It is customary to make the test at 0.5, 1, 2, 3, 4, and 5 amperes, and the specifying of other values within this range should be avoided.

Multiple-range transformers in which the same primary windings are used in series and in parallel usually have practically identical phase angles and proportional ratios. Hence a test on one range at six values of secondary current is almost always sufficient and the further tests which are often made at 0.5 and 5 amperes on each other range merely form a safeguard against mistakes in winding. When the other ranges are obtained by taps on either winding, particularly on the secondary, this relation does not hold and tests should be made with at least two values of current on each of the ranges thus obtained. Certain particular designs, however, show little difference in ratio and phase-angle performance of the various ranges, and the Bureau should be consulted before tests on a great number of ranges are ordered.

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

11. Voltage Transformers

Information must be furnished as to the following test conditions. Test can not be begun until this information is received.

(1) Test frequency
(2) Test voltages
(3) Ranges to be tested
(4) Secondary burdens
(5) Voltage-proof test, if desired.

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 0.1 per cent in ratio and to 3 minutes in phase angle. The observed values are, however, reported to the nearest 0.01 per cent in ratio and to the nearest minute in phase angle and only a rather unlikely accumulation of errors in the test will cause an error of more than 2 or 3 minutes in the last digit reported.

The ratio and phase angle of a voltage transformer change linearly with changes in secondary current at constant voltage, frequency, and power factor. Hence, if their values are determined for two burdens having the same power factor, values for intermediate currents may be found by interpolation. It is also possible to infer with fair accuracy the performance of a voltage transformer at any burden from data obtained at open circuit and at some one non-inductive burden at the same voltage and frequency. Formulas for this purpose are printed on the back of the Bureau's certificate forms. When a voltage transformer is used with a secondary burden of fixed impedance, its ratio and phase angle are almost independent of the secondary voltage over its useful range. Hence a test at one secondary voltage is usually sufficient.

When the voltage circuits (potential circuits) of instruments operated from the transformer are practically non-inductive, as is often the case, it is necessary only to measure the resistance of the voltage circuit of each instrument in order to calculate the burden which it puts on the transformer. If the voltage circuits are inductive, their volt-amperes and power factor at a specified voltage and frequency (or equivalent data) must be stated. If doubt exists about them, the maker's name, type, and serial number of each instrument may be given, but when the most accurate results are required, it is necessary to send such secondary instruments with the transformer.

Multiple-range transformers in which the same primary windings are used in series and in parallel to obtain several ranges, usually have practically identical phase angles and proportional ratios on all ranges. Hence a test on one range at all the desired burdens is usually sufficient. Tests on each of the other ranges at zero and at full rated non-inductive burden also may be desirable in important cases.

12. Voltage-Proof Test of Instrument Transformer

It is very desirable that the windings of both current and voltage (potential) transformers be well insulated. When requested to do so, the Bureau will make a voltage-proof test of

the insulation between primary and secondary windings of such transformers. In the case of new apparatus, the test should be in accordance with the Standards of the American Institute of Electrical Engineers. In the case of used apparatus a test at 1.5 times rated voltage plus 500 volts is suggested. Tests between the coils and core will be made only when a connection may be readily made to the core.