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American Standard Requirements for Electrical Indicating Instruments

Panel, Switchboard,
and Portable Instruments

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Foreword

(This Foreword is not a part of American Standard Requirements for Electrical Indicating Instruments, C39.1-1955.)

The development of this American Standard has resulted from the work of the Sectional Committee on Electrical Measuring Instruments, C39. In developing the 1949 revision of the first American Standard on Electrical Indicating Instruments, C39.1-1938, approved by the American Standards Association in July 1938, the committee gave due consideration to the former American War Standard for Electrical Indicating Instruments, C39.2-1944, and incorporated those parts which were applicable to instruments for use in peacetime industrial applications.

This specification is intended to assure that instruments conforming to it will be satisfactory for general industrial use. It does not, however, necessarily cover all features or special performance requirements of instruments to which some purchasers may wish to give attention.

In the preparation of this standard, full recognition was given to the likelihood of improvement through changes in the art, and, as changes take place, revisions of this standard will be necessary. The third edition (1951) added the detailed requirements for portable instruments to the second edition, which covered panel and switchboard instruments only. Additional definitions and requirements for portable instruments were included, as well as miscellaneous minor changes which were found necessary. In the fourth revision (1955) the standard was brought up to date and additions were made covering soldering terminals and insulation tests. Also, in 1955 the National Electrical Manufacturers Association approved this standard as a NEMA Standard and therefore it also bears the NEMA designation EI 1. Some definitions have been added to the present edition, others have been revised, and changes in the requirements that were brought to light by experience in the use of this standard have been included.

Suggestions for improvement gained in the use of this standard will always be welcome. They should be sent to the American Standards Association, Incorporated, 70 East Forty-fifth Street, New York 17, N. Y.

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American Standard Requirements for Electrical Indicating Instruments Panel, Switchboard, and Portable Instruments

1. Scope

1.1 This standard applies to the following kinds of electrical indicating instruments for direct and alternating current, including instruments with prefixes such as micro-, kilo-, etc:

- (1) Ammeters
- (2) Voltmeters
- (3) Wattmeters
- (4) Varmeters (reactive-volt-ampere meters)
- (5) Frequency meters
- (6) Power-factor meters
- (7) Indicating instruments functioning on the above principles, but indicating derived quantities

1.2 This standard may apply, with suitable exceptions, to instruments constructed for special requirements. For example, ultrasensitive direct-current microammeters, high-resistance voltmeters, thermomilliammeters, thermovoltmeters of the vacuum-couple type, and instruments with special and unusual ranges.

1.3 This standard does not apply to the following kinds of instruments:

- (1) Indicating instruments provided with arrangements for curve drawing, contact making, etc
- (2) Small instruments of types and sizes where the indications are only approximate; for example, small polarized-vane ammeters used on automobiles, battery-charging outfits, etc

2. Classification

2.1 Electrical indicating instruments shall be broadly classified as indicated in 2.1.1 and 2.1.2.

2.1.1 Use

- (1) Panel (generally of 2-percent accuracy, magnetically shielded or unshielded, and not exceeding 4.5 inches in size)
- (2) Switchboard (generally of 1-percent accuracy, magnetically shielded, 4 inches or larger in size)
- (3) Portable, including laboratory standard

2.1.2 Principle of Operation

- (1) Electrodynamometer
- (2) Permanent-magnet moving coil
- (3) Moving iron
- (4) Induction
- (5) Electrostatic

3. Definitions

3.1 The definitions given herein apply to electrical indicating instruments covered by this American Standard. For additional definitions see American Standard Definitions of Electrical Terms, C42 (Series). (See Section 6.)

3.2 Indicating Instrument. An indicating instrument is an instrument in which only the present value of the quantity measured is visually indicated.

3.2.1 Self-Contained Instrument. A self-contained instrument is an instrument that has all the necessary equipment built into the case or made a corporate part thereof.

3.2.2 Magnetically Shielded-Type Instrument. For purposes of this standard, a magnetically shielded-type instrument is one in which the effect of external magnetic fields is limited to a stated value on the tabulated detailed requirement plates. The protection against this influence may be obtained either through the use of a physical magnetic shield or through the instrument's inherent construction.

3.3 Mechanism. The mechanism is the arrangement of parts for producing and controlling the motion of the indicating means. It includes all the essential parts necessary to produce these results, but does not include the base, cover, dial, or any parts, such as series resistors or shunts, whose function is to adapt the instrument to the quantity to be measured.

3.4 Moving Element. The moving element of an instrument comprises those parts that move as a direct result of a variation in the electrical quantity that the instrument is measuring. The weight of the moving element includes one half the weight of the springs.

NOTE: The use of the term "movement" is deprecated.

3.5 Voltage Circuit. The voltage circuit is that combination of conductors and windings of the instrument to which is applied the voltage of the circuit in which a given electrical quantity is to be measured, or a definite fraction of that voltage, or a voltage or current dependent upon it.

3.6 Current Circuit. The current circuit is that combination of conductors and windings of the instrument that carries the current of the circuit in which a given electrical quantity is to be measured, or a definite fraction of that current, or a current dependent upon it.

3.7 Instrument Shunt. An instrument shunt is a particular type of resistor designed to be connected in parallel with a circuit of an instrument to extend its current range. The shunt may be internal or external to the instrument.

3.8 Shunt Leads. Shunt leads are leads which connect a circuit of an instrument to an external shunt. The resistance of these leads is taken into account in the adjustment of the instrument. (See 4.17.)

3.9 Series Resistor. A series resistor is a resistor that forms an essential part of the voltage circuit of an instrument and generally is used to adapt the instrument to operate on some designated voltage or voltages. The series resistor may be internal or external to the instrument.

3.10 Instrument Multiplier. An instrument multiplier is a particular type of series resistor that is used to extend the voltage range beyond some particular value for which the instrument is already complete.

3.11 Thermal Converter. A thermal converter is a device that consists of one or more thermojunctions in thermal contact with one or more electric heaters, or integral therewith, so that the emf (electromotive force) developed at the output terminals by thermoelectric action gives a measure of some function of the input. Auxiliary internal resistors or transformers, or both, may be included.

3.11.1 Thermoelement. A thermoelement is the simplest type of thermal converter. It consists of a thermocouple, the measuring junction of which is in thermal contact with an electric heater or integral therewith.

3.11.2 Thermal Current Converter. A thermal current converter is a type of thermal converter in which the emf developed at the output terminals gives a measure of the current through the input terminals.

3.11.3 Thermal Voltage Converter. A thermal voltage converter is a thermoelement of low current input rating with an associated series impedance or transformer, such that the emf developed at the output terminals gives a measure of the voltage applied to the input terminals.

3.11.4 Thermal Power Converter (Thermal Watt Converter¹). A thermal power converter is a complex type of thermal converter having both potential and current input terminals. It usually contains both current and potential transformers or other isolating elements, resistors, and a multiplicity of thermoelements. The emf developed at the output terminals gives a measure of the power at the input terminals.

3.11.5 Response Time of a Thermal Converter. The response time of a thermal converter is the time required for the output emf to come to its new value after an abrupt change has occurred in the input quantity (current, voltage, or power) to a new constant value.

NOTE 1: Since, in some thermal converters, the response time depends upon the magnitude and direction of the change, the value obtained for an abrupt change from zero to rated input quantity is used for rating purposes.

NOTE 2: The output emf shall be considered to have come to its new value when all but 1 percent of the change in emf has occurred.

3.11.6 Apparent Time Constant of a Thermal Converter (63-Percent Response Time) (Characteristic Time). The apparent time constant of a thermal converter is the time required for 63 percent of the change in output emf to occur after an abrupt change in the input quantity to a new constant value.

NOTE: See Note 1 of definition of Response Time of a Thermal Converter, 3.11.5.

3.11.7 Ninety-Percent Response Time of a Thermal Converter. The 90-percent response time of a thermal converter is the time required for 90 percent of the change in output emf to occur after an abrupt change in the input quantity to a new constant value.

NOTE: See Note 1 of definition of Response Time of a Thermal Converter, 3.11.5.

3.12 Influence. The influence of a specified variable or condition on an instrument is the change in the indication of the instrument caused solely by a departure of the specified variable from its reference value, all other variables being held constant.

¹ Deprecated.

3.12.1 External-Temperature Influence. The external-temperature influence is the percentage change (of full-scale value) in the indication of an instrument that is caused solely by a difference in ambient temperature from the reference temperature.

3.12.2 Sustained-Operation Influence. The sustained-operation influence is the change in indication, including zero shift, caused solely by energizing the instrument over extended periods of time, as compared to the indication obtained at the end of the first 15 minutes of the application of energy. It is to be expressed as a percentage of full-scale value.

NOTE: For the purposes of this standard, the influence is determined at the specified frequency of calibration and with stated conditions of deflection as indicated on the detailed requirements sheets.

3.12.3 External-Field Influence. The external-field influence is the percentage change (of full-scale value) in indication caused solely by a specified external field. Such a field is produced by a standard method² with a current of the same kind and frequency as that which actuates the mechanism. This influence is determined with the most unfavorable phase and position of the field in relation to the instrument.

3.12.4 Position Influence. The position influence is the change in the indication of an instrument which is caused solely by a position departure from the normal operating position.

NOTE: When the angle of test cited in the detailed requirements sheets is less than 6 degrees, the result may be obtained by tilting the instrument 5 times the specified value, and dividing the change found by 5.

3.12.5 Voltage Influence. The voltage influence in instruments having voltage circuits other than indicating voltmeters is the percentage change (of full-scale value) in the indication of an instrument that is caused solely by a voltage departure from a specified reference voltage.

3.12.6 Frequency Influence. The frequency influence, in instruments other than frequency meters, is the percentage change (of full-scale value) in the indication of an instrument that is caused solely by a frequency departure from a specified reference frequency.

3.12.7 Power-Factor Influence (as Applicable). The power-factor influence in wattmeters,

² The coil used in the standard method shall be approximately 40 inches in diameter, not over 5 inches long, and carrying sufficient current to produce the required field. The current to produce a field to an accuracy of ± 1 percent in air shall be calculated without the instrument in terms of the specific dimensions and turns of the coil. In this coil, 400-ampere turns will produce a field of approximately 5 oersteds. The instrument under test shall be placed in the center of the coil.

varmeters, etc, is the percentage change in the indication of an instrument that is caused solely by a power-factor departure from a specified reference power factor maintaining constant watts at rated voltage.

3.12.8 Interelement Influence. The interelement influence in polyphase wattmeters is the percentage change in the indication of an instrument that is caused solely by the action of the stray field of one element upon the other element. The influence is determined at the specified frequency of calibration with rated current and rated voltage in phase on both elements or such lesser value of equal currents in both elements as gives end-scale deflection. Both current and voltage in one element shall then be reversed, and, for rating purposes, one half the difference in the readings in percent is the interelement influence.

3.12.9 Magnetic-Platform Influence. The magnetic-platform influence is the change in indication caused solely by the presence of a magnetic platform on which the instrument is placed.

NOTE: For the purposes of this standard, the influence is determined as the percentage change in indication when the instrument is placed in its normal operating position on a demagnetized steel plate, extending at least 6 inches beyond the instrument on all sides, and at least 0.25 inch thick as compared with its indication when isolated from extraneous magnetic material.

3.13 Scale Length. The scale length of an indicating instrument is the length of the path described by the indicating means or the tip of the pointer in moving from one end of the scale to the other. In the case of knife-edge pointers and others extending beyond the scale division marks, the pointer shall be considered as ending at the outer end of the shortest scale division marks. In multiscale instruments the longest scale shall be used to determine the scale length. In the case of "antiparallax" instruments of the step-scale type with graduations on a raised step in the plane of and adjacent to the pointer tip, the scale length shall be determined by the end of the scale divisions adjacent to the pointer tip.

3.14 Full-Scale Value. The full-scale value is equal to the largest value of the actuating electrical quantity which can be indicated on the scale or, in the case of instruments having their zero between the ends of the scale, the full-scale value is the arithmetic sum of the values of the actuating electrical quantity corresponding to the two ends of the scale.

NOTE: Certain instruments, such as power-factor meters, are necessarily excepted from this definition.

3.15 End-Scale Value. The end-scale value of an instrument is the value of the actuating electrical quantity that corresponds to end-scale indication. When zero is not at the end or at the electrical center of the scale, the higher value is taken.

NOTE: Certain instruments such as power-factor meters, ohmmeters, etc., are necessarily excepted from this definition.

3.16 Period. The period, sometimes called the "periodic time," is the time between two consecutive transits of the pointer or indicating means in the same direction through the rest position.

3.17 Damping. Damping of an instrument is the term applied to its performance to denote the manner in which the pointer settles to its steady indication after a change in the value of the measured quantity. Two general classes of damped motion are distinguished as follows:

- (1) Periodic, in which the pointer oscillates about the final position before coming to rest; and
- (2) Aperiodic, in which the pointer comes to rest without overshooting the rest position.

The point of change between periodic and aperiodic damping is called critical damping.

NOTE: An instrument is considered to be critically damped when overshoot is present but does not exceed an amount equal to one half the rated accuracy of the instrument when determined as described in Note 1 of 3.19, Damping Factor.

3.18 Overshoot. Overshoot is the ratio of the overtravel of the indicator beyond a new steady deflection to the change in steady deflection when a new constant value of the measured quantity is suddenly applied. The overtravel and deflection are determined in angular measure and the overshoot is usually expressed as a percentage.

NOTE 1: Since, in some instruments, the ratio depends on the magnitude of the deflection, a value corresponding to an initial deflection from zero to end scale is used in determining the overshoot for rating purposes.

NOTE 2: Overshoot and damping factor have a reciprocal relationship. The percentage overshoot may be obtained by dividing 100 by the damping factor.

3.19 Damping Factor. The damping factor is the ratio of the deviations of the pointer in two consecutive swings from the position of equilibrium, the greater deviation being divided by the lesser. The deviations are expressed in angular measure.

NOTE 1: Since, in some instruments, the damping factor depends upon the magnitude of the deflection, it is measured as the ratio in angular degrees of the steady deflection to the difference between angular maximum momentary deflection and angular steady deflection produced by a sudden application of a constant electric power. The damping factor specified on the tabulated detailed requirement sheets shall be determined with sufficient constant electric power applied to carry the pointer to full-scale deflection on the first swing. The damping shall be due to the instrument and its normal accessories only.

NOTE 2: In determining the damping factor of a power-factor meter, or a frequency meter, the voltage and current as stated on the applicable detailed requirement sheet shall be applied with such phase relation as to give center-scale deflection. The pointer shall then be moved mechanically to end scale and suddenly released.

3.20 Response Time. The response time is the time required after an abrupt change has occurred in the measured quantity to a new constant value until the pointer, or indicating means, has first come to apparent rest in its new position.

NOTE 1: Since, in some instruments, the response time depends on the magnitude of the deflection, a value corresponding to an initial deflection from zero to end scale is used in determining the response time for rating purposes.

NOTE 2: The pointer is at apparent rest when it remains within a range on either side of its final position equal to one half the accuracy rating, when determined as specified in Note 1.

NOTE 3: In determining the response time of a power-factor meter, or a frequency meter, the same method shall be employed as described in Note 2 of 3.19, Damping Factor.

3.21 Accuracy Rating. The accuracy rating designates the accuracy classification of the instrument. It is given as the limit, usually expressed as a percentage of full-scale value, which errors will not exceed when the instrument is used under reference conditions.

NOTE 1: The accuracy rating is intended to represent the tolerance applicable to an instrument in an "as received condition." Additional tolerances for the various influences are permitted when applicable. It is required that the accuracy, as received, be directly in terms of the indications on the scale and without the application of corrections from a curve, chart, or tabulation.

NOTE 2: Generally the accuracy of electrical indicating instruments is stated in terms of the electrical quantities to which the instrument responds. In instruments with the zero at a point other than one end of the scale, the arithmetic sum of the end-scale readings to the right and to the left of the zero point shall be used as the full-scale value.

Exceptions:

(1) The accuracy of frequency meters shall be expressed on the basis of percentage of actual scale range. Thus, an instrument having a scale range of 55 to 65 cps (cycles per second) would have its error expressed as a percentage of 10 cps.

(2) The accuracy of a power-factor meter shall be expressed as a pure number, preferably a decimal fraction.

(3) The accuracy of instruments which indicate derived quantities, such as series-type ohmmeters, should be expressed as a percentage of scale length.

NOTE 3: In the case of instruments having nonlinear scales, the stated accuracy only applies in those portions of the scale where the divisions are equal to or greater than two thirds the width they would be if the scale were evenly divided. In other portions of the scale, the allowable limit of error will be a distance equal to two thirds the total scale length multiplied by the rated accuracy, expressed as a decimal (i.e., 0.01, 0.1).

NOTE 4: Instruments having an accuracy rating of 0.1 percent are frequently referred to as "laboratory standards." Portable instruments having an accuracy rating of 0.25 percent are frequently referred to as "portable standards."

3.22 Safe Working Voltage to Ground. The safe working voltage to ground is the highest safe voltage, in terms of maximum peak value, that should exist between any terminal of the instrument proper on the panel, or other mounting surface, and ground.

3.23 Current Loss. Current loss applies to voltage circuits, and in a voltage-measuring instrument is the value of the current when the applied voltage corresponds to nominal end-scale indication. In other instruments, the current loss is the current in the voltage circuit at rated voltage.

3.24 Voltage Loss. Voltage loss applies to current circuits, and in a current-measuring instrument is the value of the voltage between the terminals when the applied current corresponds to nominal end-scale deflection. In other instruments the voltage loss is the value of the voltage between the terminals at rated current.

NOTE: By convention when an external shunt is used, the voltage loss is taken at the potential terminals of the shunt. The over-all voltage drop resulting may be somewhat higher due to additional drop in shunt lugs and connections.

3.25 Apparent Power Loss (Volt-Ampere Loss).

The apparent power loss of the circuit of an instrument is, for voltage-measuring instruments, the product of nominal end-scale voltage and the resulting current; and for current-measuring instruments, it is the product of the nominal end-scale current and the resulting voltage. For other than current- or voltage-measuring instruments, for example, in wattmeters, the apparent power loss is expressed at a stated value of current or of voltage.

3.26 Power Loss (Watt Loss). The power loss in the circuit of a current- or voltage-measuring instrument is the active power at its terminals for nominal end-scale indication. For other current- or voltage-measuring instruments, for example, wattmeters, the power loss of any circuit is expressed at a stated value of current or voltage.

3.27 Rated Voltage. The rated voltage of an instrument, such as a wattmeter, power-factor meter, or a frequency meter, is the normal continuous operating voltage and is the normal value of applied voltage used for test purposes.

3.28 Maximum Voltage. The maximum voltage of an instrument, such as a wattmeter, power-factor meter, or frequency meter, is a stated voltage that, if applied continuously at maximum stated operating temperature and with any other circuits in the instrument energized at rated values, will not cause electrical breakdown or any observable physical degradation.

3.29 Rated Current. The rated current of an instrument, such as a wattmeter or power-factor meter, is the normal value of current used for design purposes.

3.30 Maximum Current. The maximum current of an instrument, such as a wattmeter or power-factor meter, is a stated current that, if applied continuously at maximum stated operating temperature and with any other circuits in the instrument energized at rated values, will not cause electrical breakdown or any observable physical degradation.

4. General Requirements

4.1 Screw Threads. All threaded parts normally employed in the application or normal use shall comply with American Standard Unified and American Screw Threads for Screws, Bolts, Nuts, and Other Threaded Parts, B1.1-1949; American Standard Screw Thread Gages and Gaging, B1.2-1951; American Standard Square and Hexagon Bolts and Nuts, B18.2-1955; and American Standard Slotted and Recessed Head Screws, Machine, Cap, Wood, Tapping and Slotted Headless Types, B18.6-1947 and partial revisions B18.6.1-1956, B18.6.2-1956, and B18.6.4-1958. (See Section 6.) Where practicable, all other screw threads shall also comply with these standards.

4.2 Molding. Molded parts shall have a neat workmanlike surface with all surfaces smooth and free from flash projections or roughness.

4.3 Degree of Enclosure. Instruments shall be designed and constructed with close-fitting joints in the enclosure to minimize the entrance of dust and moisture that impairs their successful operation over an extended period of time, or when they are subjected to any of the test conditions specified herein.

4.4 Dials. The instrument dials shall be made of such material and so constructed as to insure freedom from warping, fading, discoloring, or deterioration when operated for an extended period of time, or when subjected to any of the test conditions specified herein. All dials shall be firmly secured to the mounting and so constructed as to facilitate removal from the instrument and replacement in the original position. Black markings on a white background shall be considered standard.

4.4.1 Unit Designation of Quantity Measured. The unit designation of the quantity measured is determined by the end-scale value. The units preferably used over the various ranges are as shown in Table 1.

4.4.2 Preferred Full-Scale Ranges for Zero Left Self-Contained Instruments. The preferred full-scale ranges for zero left self-contained instruments covered by this specification shall be as shown in Table 2, or shall be an integral power of 10 or its

reciprocal times these values. The ranges indicated by the †, however, are used but not preferred.

4.4.3 Scale Divisions. The value of each scale division shall, wherever practicable, be either 1, 2, or 5 of the units measured, or an integral power of 10 or its reciprocal times these values. In the case of multiple-range instruments, or of instruments for other than specialized uses, exceptions to this requirement may be necessary, but shall be avoided where reasonably possible.

4.4.4 Numbering of Scales. The figures shall be as large and as legible as practicable, considering all ranges, and they shall be of such shape as to minimize the risk of different figures being confused with one another. They shall also be so spaced as to render individual numbers clearly distinguishable from adjacent numbers.

4.4.5 Dial Marking. Instruments shall be distinctly marked, with the applicable details specified below. These markings shall not, however, be so conspicuous as to distract attention from the scale markings specified in 4.4.3 and 4.4.4.

4.4.5.1 The following information shall be legibly marked on the dial or on the front of the instrument case:

- (1) Manufacturer's name, trade-mark, or symbol
- (2) Manufacturer's type, or model number, or both

TABLE 1*
Unit Designations

Quantity Measured	Range
Millivolts	1 – 999
Volts	1 – 999
Kilovolts	Above 999 volts
Microamperes	1 – 999
Milliamperes	1 – 999
Amperes	1 – 999
Kiloamperes	Above 999 amperes
Microwatts	1 – 999
Milliwatts	1 – 999
Watts	1 – 999
Kilowatts	1 – 999
Megawatts	Above 999 kilowatts
Vars	1 – 999
Kilovars	1 – 999
Megavars	Above 999 kilovars
Cycles per second	1 – 999
Kilocycles per second	1 – 999
Megacycles per second	Above 999 kilocycles

* Although the units used over the various ranges are preferably those given in this table, ranges of 1000, 1500, 2000, etc, are deemed satisfactory and may be used.

TABLE 2
Preferred Full-Scale Ranges

Full-Scale Value	d-c Volt-meters	d-c Am-meters	a-c Volt-meters	a-c Am-meters	Watt-meters
1	*	*	†	*	*
1.2	—	—	—	—	†
1.5	*	†	*	†	*
2	*	*	—	*	*
2.5	—	—	—	—	†
3	*	†	*	†	*
4	—	—	—	—	†
5	*	*	—	*	*
6	—	—	†	—	†
7.5	*	—	*	—	—
8.0‡	*	†	*	†	*

* Preferred full-scale ranges.

† Full-scale ranges used but not preferred.

‡ The full-scale value of 8.0 is preferred over the 7.5 value for the smaller panel instruments where a 75 division scale would tend to be crowded.

NOTE 1: For ranges above 1,000 amperes or 1,000 volts any of the full-scale values listed may be used in lieu of the preferred ranges.

NOTE 2: All ranges listed, whether marked as preferred or used or merely carrying a dash, are deemed satisfactory for use of multirange portable instruments if they bear a ratio of 1, 2, or 5, or a decimal multiple or submultiple thereof, to a preferred range provided on the instrument.

(3) Designation of the quantity measured (volts, kilovolts, amperes, milliamperes, watts, etc)

(4) The words "direct current," "alternating current," "radio frequency," etc, or their abbreviations

(5) The electrical quantity for producing end-scale deflection when this differs from the end-scale value; for example: FS = 50 millivolts

(6) Serial number, on portable instruments of rated accuracy class 0.1, 0.25, and 0.5 only

(7) Data pertaining to the use of external accessories (shunts, resistors, thermoelements, etc) on portable instruments only

4.4.5.2 The following information shall be legibly marked on the dial or elsewhere on the instrument case, preferably visible from the front:

(1) The rated current, voltage (or the ranges of these quantities), or such of them as apply, unless the same as end-scale value.

(2) The maximum current and voltage in the case of wattmeters, power-factor meters, etc.

(3) The frequency for which the instrument is calibrated or the frequency span over which errors, due to frequency only, are less than one half the rated accuracy. If for 60-cps service, it need not be stated.

(4) Shunt lead resistance where the lead resistance affects instrument accuracy and is not the value specified on the detailed requirement sheets.

4.4.5.3 Instruments designed for use with external accessories (shunts, resistors, reactors, thermoelements, etc), upon which the scale marking is dependent, shall be marked to indicate the necessity for such devices. If the instrument rating differs from the end-scale marking, and the instrument is of a type which can be tested independently, the rating, not including the accessories, shall also be marked on the dial.

For example:

Use with external shunt
FS = 50 mv
Use with external resistor
FS = 1 ma

Alternating-current instruments designed for use with current and potential transformers shall have the following additional markings as required:

Ratio of the appropriate current transformer, expressed as: 1000:5 or 1000/5 or 200:1 or 200/1.

Ratio of the appropriate potential (voltage) transformer, expressed as: 3300:110 or 3300/110 or 30:1 or 30/1.

In the case of instruments such as frequency meters and power-factor meters, however, where the transformer ratio is not essential to proper calibration of the instrument, it is sufficient to mark only the voltage or current values, or both, that are to be applied at the instrument terminals, or to its external devices, if any are used.

TABLE 3
Data to Be Included in Certificates for Portable Instruments

Data	Type of Instrument								
	0.1 Class					0.25 Class			
	d-c		a-c		W*	d-c		a-c	W*
	V*	A*	V*	A*		V*	A*	V*	A*
1. Manufacturer's name	X	X	X	X	X	X	X	X	X
2. Type or model	X	X	X	X	X	X	X	X	X
3. Serial number	X	X	X	X	X	X	X	X	X
4. Kind of instrument* or units measured	X	X	X	X	X	X	X	X	X
5. Reference temperature	X	X	X	X	X	X	X	X	X
6. Accuracy class	X	X	X	X	X	X	X	X	X
7. Ranges	X	X	X	X	X	X	X	X	X
8. Resistance	X	X	X	X	X	X	X	X	X
9. Resistance of leads†	X	—	X	—	X	X	—	X	—
10. Ambient-temperature influence or correction	X	X	X	X	X	X	X	X	X
11. Frequency influence or correction	—	—	X	X	X	—	—	X	X
12. Direction of earth's field†	X	X	—	—	—	—	—	—	—
13. Maximum rating	—	—	—	—	X	—	—	—	—
14. Certification date and place	X	X	X	X	X	—	—	—	—
15. Principle of operation	X	X	X	X	X	X	X	X	X
16. Shielding	X	X	X	X	X	X	X	X	X
17. Data regarding use on direct current	—	—	X	X	X	—	—	X	X
18. Range-changing information†	X	X	X	X	X	X	X	X	X
19. Multiplying constants†	X	X	X	X	X	X	X	X	X
20. Inductance	—	—	X	X	X	—	—	X	X
21. Sustained-operation influence	X	X	X	X	X	X	X	X	X
22. Scale correction	X	X	X	X	X	—	—	—	—
23. Power-factor influence	—	—	—	—	X	—	—	—	—

* Voltmeter, ammeter, wattmeter, etc

† These items shall apply as pertinent.

4.5 Supplemental Data for Portable Instruments

4.5.1 Rated Accuracy Class of 0.1. A certificate signed by an individual authorized by the manufacturer shall be provided with all portable instruments in the rated accuracy class of 0.1. Certificates shall carry the data indicated by X pertaining to the items enumerated in Table 3, the intent being to give additional data for obtaining optimum results.

4.5.2 Rated Accuracy Class of 0.25. The information enumerated in the tabulation in Table 3 for rated accuracy class 0.25 shall be legibly marked on the instrument or on a certificate furnished with the instrument.

4.5.3 Negligible Influences. Any influence, such as that of ambient temperature, external field, etc, may be stated as negligible if less than one quarter of the rated accuracy.

4.6 Scale Visibility. The instrument shall be so designed that the entire scale can be easily read at any angle up to 45 degrees below the horizontal centerline on the vertical centerline, and 20 degrees to either side of the vertical centerline on the horizontal centerline. Under these conditions general illumination shall come from above and in front, and at an angle of 45 degrees from the same axis, and there shall be no objectionable shadows on the graduated scale.

4.7 Windows. Instruments shall be provided with windows free from discolorations, scratches, objectionable electrostatic effect, or other detrimental defects which interfere with the satisfactory use of the instrument. The windows shall be secured by a mechanical means in addition to any sealing compound which may be used.

4.8 Pointers. Instruments shall have pointers suitably formed to permit accurate readings at the usual viewing distance and permit approximate scale readings up to the distance of legibility of scale markings. The pointer shall be sufficiently rugged for its intended purpose and shall not become damaged or distorted when subjected to any of the tests of this specification.

In instruments used on alternating current, the pointer shall be of rigid construction so that there will be no vibration of the pointer, over the rated frequency range, which interferes with its normal operation or use when any value of voltage or current up to maximum is applied.

4.9 Means of Adjustment to Accuracy. All instruments shall have a practicable shop means for adjustment to accuracy.

NOTE: In permanent-magnet instruments, remagnetizing of the magnet and magnetically treating to accuracy shall be considered as meeting this requirement.

4.10 Zero Adjuster. Instruments having spring control shall have a zero adjuster accessible from the front of the case. It shall provide for a range of adjustment above and below the zero point of not less than 3 percent of the scale length and preferably shall be capable of rotating through 360 degrees without damage to any part of the instrument, and without becoming inoperative. The zero adjuster shall have sufficient friction to prevent it from shaking loose and changing adjustment when subjected to tests specified herein.

4.11 Balancing. The moving element shall be balanced by a means which will provide an easily accessible method for rebalancing. The use of solder, or an adhesive such as shellac, to hold the balance weights, or to function as a part of the balance weight, shall not be acceptable.

4.12 Jewel Bearings. In all instruments, switchboard and portable, having accuracy ratings of 1 percent or better, the jewel screws shall not be cemented in position.

4.13 Terminals

4.13.1 Mounting of Terminals. Terminal studs or binding post bodies shall be firmly anchored to the instruments in such a manner as to prevent turning or movement sufficient to cause damage to internal construction.

4.13.2 Hardware for Terminals. The necessary nuts, or screws, and washers shall be supplied where threaded terminals are furnished.

4.13.3 Soldering Terminals. If furnished as an alternate to threaded terminals, soldering terminals shall be of such design as to allow for the external application of a soldering iron without any hazard of damage to the internal construction.

4.13.4 Marking of Terminals. All instruments which require terminal identification shall be legibly and permanently marked or provided with suitable instructions to identify the proper connections.

On switchboard and panel instruments having direct-current actuated mechanisms and where the polarity is important, the left-hand terminal, looking at the rear of the instrument in its normal mounting position, shall be the positive terminal. There shall be a marking "Plus" or "+" on or near this terminal.

On all panel or switchboard self-contained radio-frequency instruments the left-hand terminal, looking at the rear of the instrument in its normal mounting position, shall be the low-potential terminal and shall be marked "G" for ground on or near this terminal.

On portable instruments, terminals shall be marked to suitably identify polarity where important,

range on multiple-range instruments, and circuit, where there is more than one circuit.

4.14 Bonding. All permanent-magnet moving-coil instruments shall have the magnetic system and dial electrically connected to one terminal. Insulated cases having metallic bezel rings shall have this ring connected to the same terminal by means of a brush contact so that the mechanism may be readily withdrawn. (For self-contained radio-frequency instruments this shall be the left hand terminal, looking at the rear of the instrument in its normal mounting position.) In radio-frequency instruments actuated by an external thermoelement, the magnetic system, dial, and bezel ring as above may be electrically connected to a third terminal for connection in turn to the low-potential heater terminal of the thermoelement.

4.15 Magnetic Panels. Instrument panels are usually considered to be nonmagnetic. When magnetic panels are specified, suitable allowance shall be made in the calibration of instruments affected by such panels. When magnetic-panel calibration is required, unless otherwise specified, instruments will be calibrated for the steel panel thickness specified in the applicable detailed requirement sheet. Instruments calibrated for use on these panels will have little additional error when used on magnetic panels of other commonly used thicknesses.

4.16 Hardware for Mounting. The necessary mounting bolts (screws), nuts, and lock washers shall be supplied with each switchboard or panel instrument.

4.17 Shunt Leads. Where shunt leads are required for panel and switchboard instruments they shall be ordered; if lengths other than 5 feet are required the length shall be specified.

4.18 Corrosion Resistance. All parts of instruments shall be sufficiently corrosion resistant so that no impairment of operation due to corrosion will result during normal service life or when the instruments are subjected to any of the tests described herein.

NOTE: An adequate degree of polish on hardened steel pivots is considered as satisfactory protection from corrosion on these parts.

4.19 Finishes. Protective coatings or finishes shall not melt, crack, chip, or scale during normal service life or when instruments are subjected to any of the tests described herein.

4.20 Interior Cleanliness. The interior of instruments shall be free from metal filings, excessive grease or oil, foreign material, dust, or loose particles which might interfere with the normal operation of the instrument.

5. Test Requirements

5.1 Temperature

5.1.1 Reference Temperature. Unless otherwise specified, the reference temperature is taken to be $+25^{\circ}\text{C}$ ($+77^{\circ}\text{F}$).

5.1.2 Operating Temperatures. Instruments shall be capable of indicating freely when operated continuously at any temperatures from -20°C (-4°F) to $+50^{\circ}\text{C}$ ($+122^{\circ}\text{F}$).

5.1.3 Extreme Temperatures. Instruments shall be capable of withstanding a temperature of $+65^{\circ}\text{C}$ ($+149^{\circ}\text{F}$) for a period of 16 hours, and while at this temperature shall be capable of indicating freely. When instruments are subjected to such a temperature, the change in indication throughout the scale from the reference temperature of $+25^{\circ}\text{C}$ ($+77^{\circ}\text{F}$) shall not exceed 5 times the allowance for external temperature influence specified on the applicable detailed requirement sheet. Following subsection of instruments to $+65^{\circ}\text{C}$ ($+149^{\circ}\text{F}$) for 16 hours they shall be returned to $+25^{\circ}\text{C}$ ($+77^{\circ}\text{F}$) where they shall be maintained for 8 hours; and then the calibration shall be checked throughout the scale. The change in indication, due to the effect of heat at $+65^{\circ}\text{C}$ ($+149^{\circ}\text{F}$), shall not exceed an amount equivalent to the rated accuracy.

5.2 Effect of Overload

5.2.1 Momentary Overload, Current Circuits (Not Applicable to Rectifier or Radio-Frequency Instruments). Alternating-current and direct-current instruments having current circuits shall be capable of withstanding the series of momentary overloads given below.

An overload current of the value given below shall be applied 10 times for a duration of $\frac{1}{2}$ second, with a 1-minute interval between each successive application. If the instruments are provided with a voltage circuit, normal voltage shall be applied to the instruments for the whole period. After 1 hour the pointer shall be reset to zero and the calibration checked over the length of the scale. There shall be no damage incurred as a result of this test other than a change in indication which shall not exceed an amount equal to the rated accuracy at any point on the scale.

	Current Value Times End-Scale Value
Panel, switchboard, and 2-percent class portable instruments	10
1-percent class portable instruments	5
$\frac{1}{2}$ -percent, $\frac{1}{4}$ -percent class portable instruments	2
$\frac{1}{10}$ -percent class portable instruments	1.2



This overload requirement also applies to externally shunted instruments and their shunts, except that for shunts having ranges over 100 amperes this test may be waived on the shunts due to the difficulty of handling high currents.

In addition, the current circuits of a-c switchboard (and portable) instruments rated from 1 to 10 amperes shall be capable of withstanding 40 times (20 times for portable instruments, except for low power-factor wattmeters) rated current rms (root-mean-square) applied for 2 seconds without open-circuiting. Instruments are not, however, required to be in operating condition after this test.

5.2.2 Sustained Overload, All Circuits. All circuits of instruments shall be capable of withstanding an applied load of 20 percent greater than rated capacity for a period of 8 hours. Where a maximum rating is given, this value shall be applied rather than 20 percent greater than rated capacity.

Immediately upon disconnecting the instrument at the conclusion of the 8-hour period, the temporary zero shift shall not exceed an amount equal to 1 percent of scale length.

Sixteen hours after disconnecting the instrument, and after resetting zero, the permanent error in indication shall not exceed an amount equal to one half the rated accuracy.

Except for the above permissible errors, no permanent damage shall occur as a result of this test.

5.2.3 Short-Time Overload, Radio-Frequency and Rectifier-Type Instruments. Radio-frequency and rectifier-type instruments shall be capable of withstanding a load corresponding to 50 percent greater than end-scale value applied for a period of 2 minutes. The change in indication 20 minutes after disconnecting the instrument and after resetting zero shall not exceed 1 percent of the scale length at any part of the scale. No other permanent damage shall occur as a result of this test.

5.3 Effect of Shock (Applicable to Panel Instruments Only). Instruments shall be capable of withstanding the following series of shocks without permanent errors in indication in excess of an amount equal to the rated accuracy; and no screws, bearings, pivots, or other parts of the instruments shall become loosened or damaged so as to affect adversely the operation of the instruments.

This test shall be conducted on a shock-testing mechanism complying with the American Standard Specifications for Shock-Testing Mechanism for Electrical Indicating Instruments, C39.3-1948 (R1955). (See Section 6.) Panel instruments shall be mounted in their normal vertical mounting position and subjected to 10 shocks with an acceleration value of 50 g each, in a direction perpendicular to the axis

of the moving system, at a rate of build-up and decay as defined by the shock-testing device specified. The instruments shall then be rotated 90 degrees counterclockwise in the plane of mounting and subjected to 10 shocks of the same magnitude and direction as previously. The instruments shall then be mounted in a horizontal plane, face upward, and subjected to 10 shocks of the same magnitude as at first but in a vertical direction parallel to the axis of the moving system.

5.4 Effect of Vibration (Applicable to Panel and Switchboard Instruments Only). Instruments shall be capable of withstanding the following vibration test without permanent errors in indication in excess of an amount equal to the rated accuracy, and no screws, bearings, pivots, or other parts of the instruments shall become loosened or damaged so as to affect adversely the operation of the instruments. The difference between ascending and descending (untapped) readings also shall not exceed an amount equal to twice the rated accuracy.

Instruments shall be mounted in a normal operating position on a vibrating platform and subjected to vibration of such a nature that a point on the instrument case will describe, in a plane inclined 45 degrees to the face of the instrument, a circle with a diameter, when vibrating at 2500 cycles per minutes, of not less than 0.018 inch or more than 0.020 inch. They shall then be vibrated increasing the frequency from 500 to 2500 cycles per minute and returning to 500 cycles per minute at a rate of change of frequency of 200 ± 25 cycles per minute. The complete run shall take 20 ± 2 minutes. Three runs shall be made with the pointer electrically maintained at 20, 50, and 80 percent of full-scale deflection from the left end of the dial.

5.5 Effect of Humidity (Applicable to Panel and Switchboard Instruments Only). Instruments shall be capable of withstanding the humidity test given below.

Instruments with covers in place and others with covers removed shall be mounted in their normal operating position in a humidity chamber. The chamber shall be maintained for 6 hours at a temperature of approximately $+65^{\circ}\text{C}$ ($+149^{\circ}\text{F}$) and a relative humidity of approximately 95 percent with the instruments energized at $\frac{2}{3}$ full-scale deflection. At the end of this time the heating means shall be shut off, the instruments de-energized and allowed to cool for 18 hours in this chamber and atmosphere. During this time the humidity rises as the temperature decreases. Precautions shall be taken to prevent dripping on the instruments. At the end of this time the instruments shall be removed from the chamber and maintained at approximately $+25^{\circ}\text{C}$ ($+77^{\circ}\text{F}$) for 24 hours. At the completion of this period the instrument shall

indicate freely, and any permanent change in indication due to the effect of this test shall not exceed 3 percent of scale length.

5.6 Dielectric Test. Instruments shall be capable of withstanding, without damage or flashover, a test voltage of the rms value specified on the applicable detailed requirement sheet, applied as follows.

Alternating voltage of nominal 60-cps frequency and approximating a true sine wave shall be applied continuously for a period of 60 seconds. The measurement of the test voltage shall be made by the voltmeter method whereby the instrument derives its voltage from the voltage of the high-potential circuit, either directly or by means of a voltmeter coil placed in the testing transformer or through an auxiliary ratio transformer.

To avoid voltage surges the applied voltage shall be raised to its full value gradually, and upon completion of the 60-second test period shall then gradually be reduced.

When applying a dielectric test to nonmetallic zero correctors, a high-potential test electrode of suitable shape and size to provide a normal fit shall be inserted into the zero corrector slot.

Panel instruments shall be tested while mounted on a 0.09-inch-thick metal panel by the mounting screws furnished with the instrument. Switchboard instruments shall be tested in a similar manner on a 0.125-inch-thick panel. When making application to an instrument face, as well as to all exposed surfaces of a portable instrument, a test probe of 0.250-inch diameter and having a 0.125-inch radius tip shall be used.

5.7 Insulation Test. The insulation (impedance) shall be measured in terms of the leakage current between all the electric circuits connected together and

the case, and between each circuit and the remaining circuit or circuits (where more than one exists). This test shall be made after the instrument shall have been held for 24 hours in an atmosphere having a temperature of $+30^{\circ}\text{C}$ ($+86^{\circ}\text{F}$) and a relative humidity of 85 percent, and after the dielectric test. The measurement shall be made at 800 volts, 60 cycles per second, or at 120 volts, 60 cycles per second, whichever is convenient.

6. Revisions of American Standards Referred to in This Document

When the following American Standards referred to in this document are superseded by a revision approved by the American Standards Association, Incorporated, the revision shall apply:

American Standard Slotted and Recessed Head Screws, Machine and Tapping Types, B18.6-1947

American Standard Slotted and Recessed Head Wood Screws, B18.6.1-1956

American Standard Hexagon Head Cap Screws, Slotted Head Cap Screws, Square Head Set Screws, and Slotted Headless Set Screws, B18.6.2-1956

American Standard Slotted and Recessed Head Tapping Screws and Metallic Drive Screws, B18.6.4-1958

American Standard Practice for Volume Measurements of Electrical Speech and Program Waves, C16.5-1954

American Standard Specifications for Shock-Testing Mechanism for Electrical Indicating Instruments, C39.3-1948 (Reaffirmed 1955)

American Standard Definitions of Electrical Terms, C42 (Series)

General Notes to be Applied as Referenced

NOTE 1: Computation of Loss. For the purpose of computing the loss of alternating-current instruments having current circuits at some selected value other than that for which it is rated, the actual loss at the rated current is multiplied by the square of the ratio of the selected current to the rated current:

Example: If a current transformer with a ratio of 500:5 amperes is used with an instrument having a scale of 0-300 amperes, and, therefore, a 3-ampere field coil, the allowable loss at end scale is as stated on the detailed requirement sheet. The allowable loss of the instrument referred to a 5-ampere basis is as follows:

$$\text{Allowable loss in volt-amperes} = (\text{allowable loss end-scale volt-amperes}) \left(\frac{5}{3} \right)^2$$

NOTE 2: Because of the dominance of 60 cycles per second as the common frequency standard in the United States, alternating-current (power-frequency) instruments are always supplied for that frequency unless otherwise specified. Reference 3.12.6.

NOTE 3: In specifying the range of multiple-range instruments, it is preferable to list the ranges in descending order, as 750/300/150.

NOTE 4: General Test Procedure. At the start of any test, to determine compliance with detailed requirements, the instrument shall be placed as specified, i.e., on a vertical panel for panel and switchboard instruments, or on a horizontal plane in the case of portable instruments, and level within the limits given. The instrument shall be adjusted to zero, as pertinent. The ambient temperature shall be recorded, and, in general, the instrument shall have been allowed to remain at that ambient temperature for a sufficient time to eliminate large temperature gradients, several hours usually being sufficient.