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American National Standard Requirements for Electrical Analog Indicating Instruments

Secretariat

National Electrical Manufacturers Association
Scientific Apparatus Makers Association

Approved March 30, 1981

American National Standards Institute, Inc

American National Standard

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Foreword

(This Foreword is not a part of American National Standard Requirements for Electrical Analog Indicating Instruments, ANSI C39.1-1981.)

The development of this American National Standard dates back to 1938, when the first edition was approved and published by the American National Standards Institute. The standard has been periodically revised, updated, or expanded in order to give recognition to changes in the art; subsequent editions were published in 1949, 1951, 1955, 1964, and 1972. In this standard, efforts were made to coordinate the definitions with those of the IEEE and with the recommendations of IEC Publication 51, Indicating Electrical Measuring Instruments and Their Accessories.

This standard is intended to ensure 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.

The present edition has, to a considerable extent, updated the contents of ANSI C39.1-1972. The greatly expanded definitions and detailed test procedures initiated in the 1972 edition have been further clarified and amended where practice has indicated this need. A new safety requirement requiring the marking of instruments with the rated circuit-to-ground voltage has been added to help prevent misapplication. A number of other changes have been made to further align this standard with IEC Publication 51.

In accordance with the policy of the U.S. National Committee of the IEC (International Electrotechnical Commission), the following statement is included to indicate in what respects U.S. standards differ significantly from the applicable IEC Recommendations, in IEC Publication 51:

(1) Scale length in IEC is defined to be the length of arc passing through the middle of the shortest scale division.

(2) The IEC term "variation with influence quantity" corresponds to our ANSI term "influence."

(3) IEC accuracy classes are 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2.5, and 5.

(4) Preconditioning of instruments for determination of intrinsic accuracy. IEC specifies time between connection into circuit and determination of errors of at least 1/2 hour for instrument of classes 1 . . . 5 and any time (for convenience) limited to one hour for instruments of classes 0.05 . . . 0.5.

(5) IEC reference conditions include a requirement of total absence (with tolerance of 1 kV/m) for external electric field.

(6) Unless marked to the contrary, the external circuit impedance in the case of milliammeters and ammeters is assumed to be more than 50 times that of the instrument, and in the case of millivoltmeters and voltmeters less than 1/50 that of the instrument.

(7) Influence of self-heating on instruments of classes 1 . . . 5 shall be determined by taking the difference in indication after 2 minutes and after 30 minutes of operation at 80% of the upper limit of the effective range. Classes 0.05 . . . 0.5 require recording indications in steps, holding energization at 80% scale for at least one hour and recording steps of decreasing indication.

(8) Continuous overload at 120% rated voltage or current, or both, for 2 hours and cooling to reference temperature requires the instrument to comply to its accuracy class.

(9) IEC temperature limits of operation are −25°C to +40°C for classes 1.5 . . . 5 and −10°C to +35°C for other instruments.

(10) IEC zero adjuster range is required to not less than 2% of a scale length with lack of discrimination not larger than one-fifth of the class index.

(11) IEC requires a symbol of operating position to be marked on a visible part of the instrument. Absence of such marking assumes that changing range of use from 0 to 90 degrees will not result in change in indication of more than half the class index.

(12) IEC requires marking of symbols for the following:

(a) Date (at least the year) of manufacture for instruments of classes 1 . . . 5. (Serial number for instruments of classes 0.05 . . . 0.5).

(b) Symbol for accuracy class.

(c) Symbol for test voltage.

(d) Operating method, together with symbol indicating degree of protection against external magnetic or electric fields.

(e) Nature of supply and number of measuring elements.

(f) Symbol for position.

(g) Magnetic induction from external source expressed in milliteslas for which the limits of variation correspond to the class index.

(h) Nature and thickness of the panel for which the instrument is calibrated.

(i) Value of external impedance for determination of damping or to perform overload tests of short duration, or both.

The differences listed in (1) through (12) are the results of differences in conditions and practice between the United States and internationally agreed-upon recommendations. Such differences occur in the standards of practically all developed countries. The listing is not meant to be conclusively complete but only to indicate certain significant differences to those interested. It is hoped that further collaboration between ANSI and IEC in the future will minimize such differences.

(13) This standard includes panel cutout and mounting hole dimensions that differ from IEC Publication 473, which at present deals only with square and rectangular instruments with concentric barrel. Work on coordinating ANSI C39.1 with IEC mounting dimensions has been postponed until the next edition when IEC dimensions for instruments with eccentric barrel are expected to be available.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, Inc, 1430 Broadway, New York, N.Y. 10018.

This standard was processed and approved for submittal to ANSI by American National Standards Committee on Electrical Measuring Instruments, C39. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the C39 Committee had the following members:

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American National Standard Requirements for Electrical Analog Indicating 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) Synchroscopes
(8) Indicating instruments of the aforementioned kinds, but indicating derived quantities
(9) Indicating instruments of the aforementioned kinds with self-contained electronic devices when the supply is obtained from the measured quantity

1.2 This standard may apply, with suitable exceptions, to instruments constructed for special requirements – for example, ultrasensitive dc 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
(3) Instruments that contain active devices such as transistors, electron tubes, etc, unless the supply for these active devices is obtained from the measured quantity
(4) Indicating instruments for the measurement of resistance, conductance, or impedance
(5) Multifunction instruments or clamp-on ammeters

2. Classification

2.1 General. Electrical analog indicating instruments, as covered by this standard, shall be broadly classified in accordance with 2.2 through 2.5.

2.2 Use

(1) Panel type, including edgewise
(2) Switchboard type
(3) Portable, including laboratory standard

2.3 Principle of Operation

(1) Electrodynamic
(2) Permanent-magnet moving coil
(3) Moving iron
(4) Thermocouple
(5) Rectifier
(6) Self-contained transducer/permanent-magnet moving coil

2.4 Method of Suspension of Moving Element

(1) Pivot and jewel
(2) Taut band

2.5 Accuracy Class. The following accuracy classes are included: 0.25, 0.5, 1.0, 2.0, 3.0, and 5.0.

3. Definitions

accuracy. The quality of closeness to a specified value under stated reference conditions, quantitatively expressed by uncertainty.

accuracy, intrinsic. The limit of the accuracy of an instrument when used under reference conditions, expressed in percentage of the fiducial value.

This concept of accuracy is concerned with the intrinsic qualities of the instrument (for example, the accuracy of the scale marking) in contradistinction to the variation in indication that may arise when it is used under conditions other than the reference conditions.

Intrinsic accuracy is the uncertainty of the instrument in the "as received" condition, without the application of corrections from a chart, curve, or tabulation.

accuracy, rated (class). The assigned classification, which represents the value of uncertainty that the intrinsic accuracy of the instrument will not exceed.

balance. The change in the position of the pointer from zero when the axis of the moving element moves from the vertical position to the horizontal position. The balance is expressed as percentage of the scale length.

circuit, incoming. An ac supply that is about to be connected to a running circuit.

circuit, running. An energized ac supply.

current loading (as applicable to voltage circuits and voltage-measuring instruments). The value of current passing through the voltage circuit when the applied voltage corresponds to either the nominal end-scale indication or to the rated voltage of the voltage circuit expressed either in ohms per volt or units of current.

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

current, rated. The specified current that the instrument will carry continuously under the usual service conditions for which it is designed.

damping. The manner in which the pointer settles at its steady indication after a change in the value of the measured quantity. There are two general classes of damped motion, as follows:

(1) Periodic, in which the pointer oscillates about the final position before coming to rest.

(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."

An instrument is considered to be critically damped when overshoot is present but does not exceed an amount equal to half the rated accuracy of the instrument.

damping factor. 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 degrees.

(The use of this term is deprecated. Use "overshoot," which is the reciprocal of the damping factor. See *overshoot*.)

effect. The permanent change in instrument performance that remains after the influence quantity causing the change is removed from the instrument.

end-scale value. 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 used.

Examples:

Instrument	*End-Scale Values*	*End-Scale Values (for Ratings)*
0–150	0, 150	150
50–0–150	50, 150	150
150–0–150	150, 150	150
90–140	90, 140	140

error. The difference between the indicated value and the true value of the quantity being measured. Error is expressed in units of the quantity being measured or as a percentage of either the fiducial or the indicated value. A positive error denotes that the indicated value is greater than the true value.

error, pivot friction. Error caused by friction between the pivots and the jewels.

error, zero-shift (residual deflection). The part of the deflection of a mechanically controlled moving element that remains after the excitation producing the deflection has been removed and all the measuring circuits are de-energized.

excitation. The electrical quantity applied to the instrument to cause the instrument to indicate in its intended manner.

fiducial value. The value to which reference is made in order to specify the accuracy of an instrument.

Examples:

Instrument	*Fiducial Value*
0–150	150
50–0–150	200
150–0–150	300
90–140	140

NOTE 1: When the mechanical zero is at one end of the scale or outside the scale, the fiducial value corresponds to the higher end-scale value, except for those instruments covered in Note 3.

NOTE 2: When the mechanical zero is displaced within the scale, the fiducial value is the arithmetic sum of the absolute electrical values corresponding to the two limits of the range.

NOTE 3: The fiducial value of phase-angle meters and power-factor meters corresponds to 90 electrical degrees.

NOTE 4: If means for electrical zero suppression are provided, the fiducial value corresponds to the higher end-scale value.

NOTE 5: The fiducial value of synchroscopes corresponds to 90 mechanical degrees.

frequency, dropout differential (for synchroscopes). The difference between the frequencies of the incoming and running circuits when rotation of the moving element stops. This condition occurs when the frequency of the incoming circuit progressively departs from the frequency of the running circuit.

frequency, pull-in differential (for synchroscopes). The difference between the frequencies of the incoming and running circuits when rotation of the moving element begins. This condition occurs when the frequency of the incoming circuit progressively approaches the frequency of the running circuit.

full-scale value. The arithmetic sum of the two end-scale values. When zero is not on the scale, the full-scale value is the higher end-scale value.

Examples:

Instrument	*Full-Scale Value*
0–150	150*
50–0–150	200*
150–0–150	300*
90–140	140†

*When zero is on the scale.

†When zero is not on the scale.

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

influence. The temporary change in the indication of an instrument (expressed as a percentage of the fiducial value) caused solely by the departure of the specified influence quantity, or quantities, from its reference value, with all other variables held constant.

influence, circuit-to-ground-voltage. The change in the position of the pointer from zero that is caused by the voltage applied between the instrument terminals and the conducting mounting panel or platform.

influence, combined voltage and current (as applied to wattmeters). The influence that is caused solely by the departure of voltage and current from their reference values while constant power is maintained at the selected point.

influence, external-magnetic-field. The influence that is caused solely by an external magnetic field produced with a current of the same kind and frequency as the current that actuates the mechanism.

influence, external-temperature. The influence that is caused solely by a departure of the ambient temperature from the reference temperature after equilibrium is established.

influence, extreme temperature. The influence that is caused solely by the change in ambient temperature from 23°C to 65°C and also from 23°C to –20°C after equilibrium is established.

influence, ferrous panel or platform. The influence that is caused solely by the presence of a ferrous panel or platform on which the instrument is placed.

influence, frequency (in instruments other than frequency meters). The influence that is caused solely by the departure of the frequency from its reference value.

influence, interelement (in polyphase wattmeters). The influence that is caused solely by the action of one element upon the other element.

influence, operation. The maximum variation in the indication of an instrument from its initial indication when it is continuously energized with a constant value of the measured quantity under reference conditions over a stated interval of time.

Short-time operation influence is that operation influence arising from continuous operation over a period of 15 minutes.

Sustained operation influence is that operation influence arising from continuous operation over a period of 6 hours.

influence, position. The influence that is caused solely by the departure of an instrument from its normal operating position.

influence, power-factor (as applicable to wattmeters, varmeters, etc). The influence that is caused solely by a departure of the power factor from its reference value while maintaining constant power at rated voltage and not exceeding 120% of rated current.

influence, proximity. The change in indication when two indicating instruments of the same make, rating, and principle of operation are mounted in one of the normal mounting configurations and spaced to yield maximum influence.

influence, unbalanced current (polyphase wattmeters and varmeters). The influence that is caused solely by reducing the current in one current circuit to zero while maintaining the indicated power constant.

influence, voltage, at zero (for wattmeters and varmeters). Change in reading at zero when voltage circuit(s) are first energized and then de-energized while the current in the current circuit(s) is equal to zero.

influence, voltage (in instruments having voltage circuits, such as frequency meters and power factor meters, but not voltmeters, wattmeters, and varmeters). The influence that is caused solely by a departure of voltage from its rated value.

influence, waveform. The influence that is produced solely by the presence of harmonics in the alternating electrical quantity being measured.

influence quantity. One of the quantities or conditions that affects the indication of an instrument but is not the one measured by the instrument.

instrument, analog indicating. An instrument that continuously measures an electrical quantity and displays the result by a relationship between a pointer and graduated scale.

instrument, electrodynamic. An instrument that makes use of the force exerted between fixed and moving coils carrying currents and may or may not incorporate ferromagnetic material in the magnetic circuit.

instrument, expanded-scale. An instrument in which the normal deflection has been modified to expand a portion of the scale for improved readability.

instrument, light-beam-pointer. An instrument in which a moving beam of light is utilized to indicate the measured value on the scale.

instrument, moving-iron. An instrument comprising a movable piece of ferromagnetic material that is actuated by a fixed coil carrying a current or by a fixed piece of ferromagnetic material magnetized by the current.

instrument, offset-zero. An instrument in which zero appears on the scale but is not located at either end of the scale.

instrument, optical scale. An instrument in which the scale markings are projected onto the dial by optical means.

instrument, panel. A panel-mounted light-duty instrument which is designed to be used in portable or semiportable equipment, or permanent installations.

instrument, permanent-magnet moving-coil. An instrument that depends for its operation on the reaction between the current in a movable coil, or coils, and the field of a fixed permanent magnet.

instrument, portable. A portable case-mounted instrument designed to be used in laboratory and industrial environments.

instrument, self-contained. An instrument that has all necessary equipment and components built into the case or made an integral part thereof.

instrument, suppressed-zero. An instrument in which the lower portion of a given scale does not appear and cannot be indicated and where the zero is displaced outside the scale by mechanical or electrical means.

instrument, switchboard. A panel-mounted heavy-duty instrument that can be easily read from a distance and is designed for extended operation and permanent installation in severe environments such as may be encountered in industrial applications.

instrument, thermocouple-type. An instrument in which the current heats a thermocouple, the electromotive force from which is measured by a permanent-magnet moving-coil instrument.

instrument multiplier. A series resistor (impedance) that is used to extend the voltage range beyond the particular values for which the instrument is designed.

instrument shunt. A resistor intended to be connected in parallel with an associated instrument in order to produce a higher current range than can be obtained by the instrument alone. The resistance of the shunt may be so chosen that the ratio of current measured by the combination to the current measured by the instrument alone is known.

loading, apparent power (volt-ampere loss). For voltage-measuring instruments, the product of nominal end-scale voltage or the normal voltage at which the instrument is used and the resulting current; for current-measuring instruments, the product of the nominal end-scale current and the resulting voltage. For other than current- or voltage-measuring instruments (for example, wattmeters), the apparent power loss is calculated at the rated value of current or of voltage.

loading, power (watt loss). The active power dissipated in the circuit of a current- or voltage-measuring instrument at nominal end-scale indication. For other than current- or voltage-measuring instruments (for example, wattmeters), the power loss of any circuit is calculated at the rated value of current or voltage.

mean of reversed dc values (as applied to ac instruments). The simple average of the indications when direct current is applied in one direction and then reversed and applied in the other direction.

mechanical zero (as applicable to instruments that have mechanical restoring force). The position of the pointer at equilibrium when the instrument is not energized.

mechanism. An assembly of those parts that are required for producing and controlling the motion of the indicating means, but not including the base, cover, dial, or any parts, such as series resistors or shunts, whose function it is to adapt the instrument to the quantity to be measured.

movement. See *mechanism* and *moving element.* (The use of this term is deprecated.)

moving element. An assembly of those parts that move as a direct result of a variation in the electrical quantity being measured by the instrument.

negligible influence. Any influence, such as that of ambient temperature, external field, etc, that is less than one-quarter of the rated accuracy.

overshoot. The ratio of the overtravel of the pointer 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.

pointer shift due to tapping. The displacement in the position of a moving element that occurs when the instrument is tapped lightly. The displacement is observed by a change in the indication of the instrument.

preconditioning time. The specified minimum time between the instant when a specified value of the measured quantity is applied to the input circuit and the instant when the instrument should comply with the accuracy requirement.

range. The region between the limits of display within which the input quantity is measured. Range is expressed by stating the lower and upper values of the display. (Examples: 0-100, 70-140, 50-0-50.)

reference conditions. A set of values assigned to the influence quantities used for determining the intrinsic accuracy of the instrument.

repeatability (hysteresis). The ability of an instrument to repeat its indications when the pointer is deflected upscale, compared to the indications taken when the pointer is deflected downscale, expressed as a percentage of the fiducial value.

response time. The time required after an abrupt change of the measured quantity to a new constant value until the pointer, or indicating means, first comes 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 on either side of its final position within a range equal to one-half of the accuracy rating determined in accordance with Note 1.

ripple content of dc measured quantity, percent. The ratio of the rms value of the ripple voltage (current) to the average value of the total voltage (current), expressed in percent.

scale. The array of calibrated marks from which the input quantity may be read and interpreted.

scale division. The interval between the centers of two consecutive scale marks.

scale length. The length of the path described by the indicating means of 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.

scale mark. One of the marks constituting the scale.

scale visibility. The maximum horizontal or vertical viewing angle, measured from a line perpendicular to the scale, from which all scale marks and arcs may be seen.

sensitivity (synchroscopes). The change in phase angle between the running and incoming circuits that will produce an incremental change in the pointer position.

series resistor (impedance). A resistor (impedance) intended to be connected in series with an associated instrument in order to produce a higher voltage range that can be obtained by the instrument alone.

shunt leads. Leads that connect a circuit of an instrument to an external instrument shunt. The resistance of these leads is taken into account in the adjustment of the instrument.

sticking. The condition caused by physical interference with the normal motion of the moving element.

suspension, bifilar. A suspension employing two parallel ligaments, usually of conducting material, at each end of the moving element.

suspension, taut-band. A mechanical arrangement of two ribbons under tension, one at each end of the moving element. The ribbons support the moving element, allow it to rotate freely, provide the restoring torque, and conduct current to the moving element of moving coil instruments.

symmetry (in an offset-zero instrument). The ability of the pointer to provide corresponding indications at each side of zero when the polarity of the applied quantity is reversed.

symmetry error (of an offset-zero instrument). The difference in indications when the polarity of a measured quantity is reversed, expressed as a percentage of fiducial value.

thermal converter. A device that consists of one or more thermojunctions in thermal contact or integral with one or more electric heaters so that the electromotive force (EMF) 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.

thermal converter, 90% response time of. The time required for 90% of the change in output EMF to occur after an abrupt change in the input quantity to a new constant value.

thermal converter, response time of. The time required for 99% of the change in output EMF to occur after an abrupt change has occurred in the input quantity (current, voltage, or power) to a new constant value.

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

thermal converter, time constant (63% response time) of. The time required for 63% of the change in output EMF to occur after an abrupt change in the input quantity to a new constant value.

thermal current converter. A type of thermal converter in which the EMF developed at the output terminals gives a measure of the current through the input terminals.

thermal power converter (thermal watt converter). 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.

thermal voltage converter. A thermoelement having a low-current input rating and associated with a transformer or series impedance such that the EMF developed at the output terminals gives a measure of the voltage applied to the input terminals.

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

tracking. The ability of an instrument to indicate at the scale mark being checked when energized by the proportional value of actual end-scale excitation.

tracking error. The error in indication at a scale mark, expressed in percentage of fiducial value, when the instrument is energized by the proportional value of the actual end-scale excitation. On offset-zero indicators, the higher end-scale value should be used as the reference value.

transducer, self-contained. A device internal to an instrument that changes an electrical input into an electrical output, of either the same or a different kind, in such a manner that the desired characteristics of the input are measured by a permanent-magnet moving-coil mechanism.

uncertainty. The allowance for systematic error, together with the random error contributed by the imprecision of the measurement process.

usage effect. Change in indication after the instrument has been periodically energized and de-energized during a specified time period, expressed as a percent of fiducial value.

variation due to influence quantity. An IEC term, synonymous with influence as used in this standard.

voltage circuit (shunt circuit). A measuring circuit energized by a voltage that is a prime factor in determining the indication of the measured quantity. It may be the voltage directly involved in the measurement or a proportional voltage supplied by a voltage transformer or a voltage divider.

voltage, circuit-to-ground. The peak voltage between ground and any terminal of the instrument when mounted on a panel or on any other mounting surface.

voltage drop (applied to current circuits). In a current-measuring instrument, the value of the voltage between the terminals when the applied current corresponds to nominal end-scale deflection. In other instruments the voltage drop is the value of the voltage between the terminals at rated current.

NOTE: When an external shunt is used, the voltage drop includes the voltage drop in the shunt leads.

voltage, maximum. The specified voltage in an instrument that will not cause electrical breakdown or any observable physical degradation when applied continuously at the maximum operating temperature of the instrument and with any other circuits in the instrument energized at rated values.

voltage, rated. The specified voltage that an instrument, such as a wattmeter, power-factor meter, or frequency meter is designed to carry continuously under usual service conditions. This is also the value of applied voltage used for test purposes.

walk. The displacement of the pointer that is induced by vibration.

4. Test Conditions

4.1 General. The tests described in Section 5 shall be made under the conditions described in 4.2 through 4.11 unless otherwise specified.

4.2 Reference Conditions. The reference conditions shall be as follows:

Atmospheric pressure: 575–800 mm Hg
Relative humidity: 30–60%
External magnetic field: earth's field only
External electric field: 1 kV/m max
Vibration: negligible
Ambient temperature: +23°C ± 2°C (+73.4°F ± 3.6°F) for panel and switchboard instruments; ±23°C ± 1°C (+73.4°F ± 1.8°F) for portable instruments.[1]

4.3 Mounting. Panel and switchboard instruments shall be mounted on a nonferrous panel and tested with the plane of the instrument dial in a vertical position.

Portable instruments shall be tested on a horizontal nonferrous platform with the instrument in its specified operating position.

4.4 Number of Readings. A minimum of six readings shall be taken at approximately equidistant scale marks, including the zero mark (if on the scale) and the lowest and highest end-scale marks. Unless otherwise specified, each reading shall fall within the specified limits.

4.5 Parallax. Care shall be taken to avoid the effect of parallax when taking instrument readings.

For edgewise instruments, the line of vision shall be perpendicular to the instrument dial at the pointer tip location.

For instruments with knife-edge pointers and mirror scales, the line of vision shall be such that the pointer tip is coincident with its reflection in the mirror.

[1] The instruments may be tested at other ambient temperatures, but the results shall be corrected back to 23°C.

4.6 Power Source. The instability and total harmonic distortion of the power source shall not contribute to the uncertainty of the measurement by more than one-tenth of the rated accuracy of the instrument under test.

4.6.1 The power source shall be stable for at least twice the total period of time required to read the instrument under test and the reference instrument consecutively (usually a minimum of 20 seconds). During the stable period, the amplitude variations of the power source, expressed in percent, shall not exceed one-tenth of the rated accuracy of the instrument.

4.6.2 Alternating-current measurements shall be made with a sinusoidal wave having a total harmonic distortion not exceeding 0.5% for average responding instruments and 3% for rms responding instruments.

4.6.3 Alternating-current measurements shall be made at 60 Hz unless otherwise specified. All test frequencies shall be within ± 3% of the specified value, except for frequency meters.

4.6.4 The ripple content of the dc power source shall not contribute to the uncertainty of the measurement by more than one-tenth of the rated accuracy of the instrument under test.

4.7 Tapping. Immediately prior to taking a reading, either the instrument or its support shall be tapped lightly as with the finger or the eraser end of a pencil.

4.8 Test Equipment Accuracy. All tests shall be made with reference instruments having an accuracy at least four times better than the accuracy rating of the instrument under test. The use of reference instruments with an accuracy ten times better than that of the instrument under test is strongly recommended.

The value being indicated by the reference standard shall be derived from National Reference Standards.

4.9 Thermal Stability. All instruments shall be allowed to remain at the temperature specified in 4.2 long enough to eliminate large temperature gradients; usually 2 hours is sufficient.

4.10 Preconditioning Time. Preconditioning time shall not be required unless specified by the manufacturer.

4.11 Zero Adjustment. Before each set of readings is taken, pointers shall be set on the zero mark with the zero adjuster, as follows:

(1) Adjust the zero adjuster in a direction that will drive the pointer toward the zero scale mark of the instrument.

(2) While continuing to drive the pointer in the direction selected in (1), set the pointer on the zero scale

mark while tapping the instrument case. Once it has been selected, do not change the direction of drive until the pointer is on the zero mark.

(3) With the pointer set on the zero mark, reverse the direction of motion of the zero adjuster, and drive it far enough to introduce mechanical freedom (play) in the zero adjuster, but not far enough to disturb the position of the pointer.

5. Test Procedures

5.1 General. The test conditions in Section 4 apply to all of the test procedures described in Section 5 unless specific instructions are given to the contrary in an individual test procedure. These test procedures outline the method of test and the method (if applicable) of computing the allowable error or influence.

5.1.1 Limits. Limits of test results are given in the plates in Section 7.

5.1.2 Sequence of Tests. It is recommended that tests be run in the following sequence. It should be recognized that it is not necessary to run all of the tests to determine the suitability of an instrument for a given application, nor are all tests applicable to all types of panel, switchboard, and portable instruments.

Test	*Section*
Balance, moving-element	5.3
Influence, position	5.28
Zero adjustment, range of	5.54
Sticking	5.44, 5.45, 5.46
Accuracy, intrinsic	5.2
Repeatability error	5.39
Tracking error	5.49, 5.50
Symmetry error (offset-zero instruments)	5.47
Overshoot	5.38
Response time	5.41
Frequency, pull-in differential	5.15
Frequency, drop out differential	5.14
Sensitivity (synchroscopes)	5.43
Dielectric test	5.5
Thermal converter, 90% response time	5.48
Current loading in voltmeters	5.4
Voltage drop (current-measuring instruments)	5.51
Voltage drop in current circuits (wattmeters, varmeters, and power-factor meters)	5.52
Loading, apparent power (volt-ampere loss)	5.36, 5.37
Resistance test (dc instruments)	5.40
Scale length	5.42
Influence, ferrous-panel (panel-type instruments only)	5.24
Influence, ferrous-platform (portable instruments only)	5.25
Influence, external magnetic field	5.20
Influence, proximity	5.30
Influence, frequency	5.23
Influence, waveform	5.34
Impedance test (ac instruments)	5.16
Influence, voltage (frequency meters and power-factor meters)	5.33
Influence, combined voltage and current (wattmeters and varmeters)	5.17
Influence, power-factor (wattmeters and varmeters)	5.29
Influence, interelement (polyphase wattmeters)	5.26
Influence, unbalanced current	5.31
Influence, voltage, at zero	5.32
Influence, operation	5.27
Influence, electrostatic field on window	5.19
Influence, external-temperature	5.21
Zero-shift error, short-term	5.55
Zero-shift error, long-term	5.56
Insulation test for leakage current	5.35
Influence, circuit-to-ground-voltage	5.18
Influence, extreme temperature	5.22
Effect of extreme temperature	5.6
Effect of momentary overload on current circuits	5.8
Effect of sustained overload on all circuits	5.11
Effect of short-time overload (thermoelement and rectifier-type instruments)	5.10
Effect of humidity	5.7
Window test	5.53
Effect of vibration	5.13
Effect of shock	5.9
Effect of usage	5.12

5.2 Accuracy, Intrinsic

5.2.1 Procedure. The intrinsic accuracy of an instrument shall be determined under reference conditions as follows:

(1) Apply sufficient excitation to bring the pointer to the exact end-scale mark (B_x), and record that value of excitation (B_r).

(2) Within 15 minutes, reduce the value of excitation to bring the pointer to each of at least five other approximately equidistant scale marks including the zero mark (B_x), and measure and record the value of excitation (B_r) at each scale mark.

5.2.2 Computation. The accuracy in percent shall be computed as follows:

$$\left(\frac{B_x - B_r}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.2.3 Requirement. See plates in Section 7.

NOTE: In the case of instruments having nonlinear scales, the stated accuracy applies only to 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. The limit of the range at which this accuracy applies may be marked with a small isosceles triangle whose base marks the limit and whose point is directed toward the portion of the scale having the specified accuracy.

5.3 Balance, Moving-Element

5.3.1 Procedure

(1) Select the sketch showing the type of instrument to be tested from Fig. 1 through 4.

(2) Place the instrument in Position 1 and set the pointer at zero. If the instrument is of the suppressed-

zero type, apply sufficient excitation to bring the pointer to the first scale mark.

(3) Place the instrument in Position 2 and note the indication.

(4) Place the instrument in Position 3 and note the indication.

5.3.2 Computation. The maximum deviation of the pointer in Position 2 or 3 from the setting in Position 1 shall be considered as the moving-element balance and shall be expressed as a percentage of full-scale length.

5.3.3 Requirement. See plates in Section 7.

5.4 Current Loading in Voltmeters (Ohms per Volt)

5.4.1 Procedure

(1) Connect a current-measuring instrument in series with the voltmeter being tested.

(2) Apply rated voltage to the voltage circuit or nominal end-scale voltage to the voltmeter.

(3) Read the current loading (I) from the current-measuring instrument.

5.4.2 Computation. The ohms per volt shall be computed as $1/I$.

5.4.3 Requirement. See plates in Section 7.

5.5 Dielectric Test. The applied voltage shall be raised to its full value gradually and, upon completion of the 60-second test, shall be gradually reduced to avoid voltage surges.

A test probe having a 0.250-inch diameter and a 0.125-inch-radius tip shall be used on all exposed surfaces.

When the dielectric test voltage is applied to nonmetallic zero adjusters, a high-potential test electrode of suitable shape and size to provide a normal fit shall be inserted into the zero adjuster slot.

5.5.1 Procedure

5.5.1.1 Panel and Switchboard Instruments with Nonmetallic Cases

(1) Mount the instrument on a metal panel with the mounting hardware furnished with the instrument.

(2) Connect the instrument terminals together.

(3) Apply the 60-Hz dielectric test voltage specified in Section 7 for 60 seconds between the terminals and the mounting panel and between the terminals and all exposed metallic surfaces of the front face, including the zero adjuster.

5.5.1.2 Panel and Switchboard Instruments with Metallic Cases

(1) Connect the instrument terminals together.

(2) Apply the 60-Hz dielectric test voltage specified in Section 7 for 60 seconds between the terminals and one of the mounting studs and between the terminals and all exposed metallic surfaces on the front face, including the zero adjuster.

5.5.1.3 Portable Instruments

(1) Connect the terminals together.

(2) Apply the 60-Hz dielectric test voltage specified in Section 7 between the terminals and all exposed metallic surfaces, including the zero adjuster.

5.5.2 Requirement. There shall be no damage or flashover during or following this test.

5.6 Effect of Extreme Temperature

5.6.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) at the reference temperature.

(2) Subject the instrument to a temperature of 65°C ± 2°C for 16 hours.

(3) Subject the instrument to a temperature of −20°C ± 2°C for 8 hours.

(4) Repeat Step 2.

(5) Repeat Step 3.

(6) Repeat Step 2. Immediately after completion of the 16-hour cycle and while still at 65°C, apply excitation, increasing it gradually until the pointer reaches the end-scale mark; then slowly reduce the excitation to zero.

(7) Repeat Step 3. Immediately after completion of the 8-hour cycle and while still at −20°C, apply excitation increasing it gradually until the pointer reaches the end-scale mark; then slowly reduce the excitation to zero.

(8) Return the instrument to the reference temperature, maintain it at that temperature for at least 2 hours, and record the accuracy readings (B_x) as in Step 1.

5.6.2 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.6.3 Requirement.

(1) The instrument shall indicate freely at the temperature extremes of −20°C and 65°C (Steps 6 and 7).

(2) The effect shall not exceed the value shown in the plates in Section 7.

5.7 Effect of Humidity

5.7.1 Procedure

(1) Measure and record the scale length (B_{sl}).

(2) Divide the scale into five equal scale divisions and record that value of excitation for each selected division scale mark.

(3) Subject the instrument to a temperature of 65°C ± 2°C for 6 hours at 90% ± 5% relative humidity with the instrument energized at between two-thirds and three-fourths of end-scale excitation.

(4) Shut the heat off, de-energize the instrument, and allow it to cool to the reference temperature in the same chamber for 18 hours. Take precautions to protect the instrument from dripping water and moisture.

(5) Stabilize the instrument under reference conditions for 24 hours. Reset the pointer to zero and record the deviation (B) from the selected division scale marks, using the same values of excitation as in Step 2.

5.7.2 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B}{B_{s1}}\right) \times 100$$

5.7.3 Alternate Method for Linear Scales. In order to simplify taking of data, instruments with approximately linear scales may be assumed to have equal scale divisions, and the change in fiducial value may be assumed to be proportional to the change in scale length.

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Subject the instrument to a temperature of 65°C ± 2°C for 6 hours at 90% ± 5% relative humidity with the instrument energized at between two-thirds and three-fourths of end-scale excitation.

(3) Shut the heat off, de-energize the instrument, and allow it to cool to the reference temperature in the same chamber for 18 hours. Take precautions to protect the instrument from dripping water and moisture.

(4) Stabilize the instrument under reference conditions for 24 hours. Reset the pointer to zero and record accuracy readings (B_x) as in Step 1.

5.7.4 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.7.5 Requirement

(1) The instrument shall indicate freely after the completion of this test.

(2) See plates in Section 7.

5.8 Effect of Momentary Overload on Current Circuits. (This test method is not applicable to rectifier or thermoelement instruments.)

5.8.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions with the voltage circuits, if any, energized at rated voltage.

(2) Apply the following overload current to the instrument under test for 10 cycles of 1/2 second on and 1 minute off:

Accuracy Class of Instrument	*Momentary Overload Current, Times Rated End-Scale Value*
3	10
2	10
1 (Panel)	5
1 (Switchboard)	10
0.5	2
0.25	2

(3) One hour after the completion of Step 2, reset the pointer to zero and record the accuracy readings (B_x) as in Step 1.

5.8.2 Computation. The effect in percent shall be calculated as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.8.3 Requirement

(1) No permanent damage shall occur as a result of the test.

(2) See plates in Section 7.

5.8.4 Additional Procedures and Requirements for AC Switchboard and Portable Instruments. In addition to the foregoing, the following test shall be applied to the current circuits (which are rated from 1 through 10 amperes) of alternating-current switchboard and portable instruments:

(1) For switchboard instruments, apply 40 times the rated end-scale current rms for 2 seconds. For portable instruments, apply 20 times the rated end-scale current. (Low-power-factor wattmeters should not be subjected to this test.)

(2) The instrument need not be operative at the end of this test; however, it shall not be open-circuited.

5.9 Effect of Shock

5.9.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Subject the instrument to ten shocks at an acceleration value of 50 *g* each, at a rate of buildup and decay as defined for shock-testing mechanisms complying with the American National Standard Shock Testing for Electrical Indicating Instruments, ANSI C39.3-1976.

(3) Repeat Step 2 with the mounting panel rotated 90 degrees counterclockwise in the plane of mounting.

(4) Repeat Step 2 with the instrument mounted in a face-up position.

(5) Reset the pointer to zero and record accuracy readings (B_x) as in Step 1.

5.9.2 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.9.3 Requirement

(1) No bearings, pivots, or other parts of the instrument shall become loosened or damaged enough to adversely affect the operation of the instrument.

(2) See plates in Section 7.

5.10 Effect of Short-Time Overload (Thermocouple and Rectifier-Type Instruments)

5.10.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Apply excitation equal to 150% of the rated end-scale value for 2 minutes.

(3) Twenty minutes after the completion of Step 2, reset the pointer to zero and record the accuracy readings (B_x) as in Step 1.

5.10.2 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.10.3 Requirement

(1) No permanent damage shall occur as a result of this test.

(2) See plates in Section 7.

5.11 Effect of Sustained Overload on All Circuits

5.11.1 Procedure

(1) Measure and record the scale length (B_{sl}).

(2) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(3) Apply excitation equal to 120% of the rated end-scale value for 6 hours.

(4) Reduce the excitation slowly to zero without overshoot and immediately read and record the position (B_0) of the pointer.

(5) Approximately 16 hours after the completion of Step 4, reset the pointer to zero and record the accuracy readings (B_x) as in Step 2.

NOTES:

(1) On frequency meters and synchroscopes the potential circuit(s) is subjected to a voltage overload.

(2) On wattmeters, varmeters, phase angle meters, and power-factor meters the potential circuits and current circuits are individually overloaded, and the other circuits are excited with their rated voltage or current.

5.11.2 Computation. The temporary zero shift shall be computed as follows:

$$\left(\frac{B_0}{B_{sl}}\right) \times 100$$

The effect on accuracy shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.11.3 Requirement. See plates in Section 7 for effects on temporary zero shift and accuracy.

5.12 Effect of Usage

5.12.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) For a total period of 100 hours, apply end-scale excitation having a cycle of 5 minutes on and 1 minute off.

(3) Reset the pointer to zero, and record accuracy readings (B_x) as in Step 1.

NOTE: Do not subject the instruments previously tested for vibration, shock, or humidity to a usage test.

5.12.2 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.12.3 Requirement. See plates in Section 7.

5.13 Effect of Vibration

5.13.1 Procedure (See 5.13.2)

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Energize the instrument being tested to indicate 20% of end-scale deflection and then subject it to a simple harmonic motion in the X plane having an amplitude of 0.009 to 0.010 inch (0.018- to 0.020-inch total excursion), the frequency being varied uniformly between 500 and 2500 cycles per minute for 20 minutes. The entire frequency range, from 500 to 2500 cycles per minute and return to 500 cycles per minute, shall be traversed at a rate of change of frequency of 200 cycles per minute ± 25 cycles per minute.

(3) Repeat Step 2 with the instrument energized at 50% of end-scale deflection.

(4) Repeat Step 2 with the instrument energized at 80% of end-scale deflection.

(5) Repeat Steps 2, 3, and 4 with the motion applied in the Y plane.

(6) Repeat Steps 2, 3, and 4 with the motion applied in the Z plane.

(7) Set the pointer to zero and record accuracy readings (B_x) as in Step 1.

(8) Perform the repeatability test (see 5.34)

5.13.2 Alternate Procedure. As an alternate procedure, 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 minute, 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 cycles per minute ± 25 cycles per minute. The complete run shall take 20 minutes ± 2 minutes. Three runs shall be made with the pointer electrically maintained at 20, 50, and 80 percent of end-scale deflection from the zero position of the scale.

Set the pointer to zero and record accuracy readings (B_x) as in Step 1 of 5.13.1. Perform the repeatability test (see 5.34).

5.13.3 Computation. The effect in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f} \times 100\right)$$

where A_f = fiducial value.

5.13.4 Requirement

(1) No screws, bearings, pivots or other parts of the instrument shall become loosened or damaged enough to affect adversely the operation of the instrument.

(2) See plates in Section 7 for effect of vibration on accuracy and repeatability.

5.14 Frequency, Dropout Differential (for Synchroscopes)

5.14.1 Procedure

(1) Apply 90% of rated voltage at rated frequency (B_r) under reference conditions to the running and incoming circuits.

(2) Decrease the frequency of the incoming circuit until rotation of the moving element stops (B_{x1}).

(3) Increase the frequency of the incoming circuit until it is the same as that of the running circuit.

(4) Continue increasing the frequency of the incoming circuit until rotation of the moving element reverses and then stops (B_{xh}).

5.14.2 Computation. The differential dropout frequencies are computed as follows: $|B_r - B_{x1}|$ and $|B_{xh} - B_r|$.

5.14.3 Requirement. See Plate 12 in Section 7.

5.15 Frequency, Pull-in Differential (for Synchroscopes)

5.15.1 Procedure

(1) Apply 90% of rated voltage at rated frequency (B_r) to the running circuit.

(2) Apply 90% of rated voltage to the incoming circuit at a frequency sufficiently lower than rated frequency so as not to cause rotation of the moving element.

(3) Increase the frequency of the incoming circuit until rotation of the moving element begins (B_{x1}).

(4) Continue to increase the frequency of the incoming circuit until rotation of the moving element reverses and then stops.

(5) Decrease the frequency of the incoming circuit until rotation of the moving element begins (B_{xh}).

5.15.2 Computation. The pull-in differential frequencies are computed as follows: $|B_r - B_{x1}|$ and $|B_{xh} - B_r|$.

5.15.3 Requirement. See Plate 12 in Section 7.

5.16 Impedance Test (AC Instruments)

5.16.1 Procedure

(1) Connect an rms current-measuring instrument in series with the instrument under test.

(2) Apply end-scale excitation at rated nominal frequency and read the current measuring instrument (A_{es}).

(3) While maintaining end-scale current, connect a high impedance rms voltmeter across the terminals of the instrument under test and read the end-scale voltage drop (V_{es}).

5.16.2 Computation. The impedance of the instrument shall be computed as follows:

$$|Z| = \frac{V_{es}}{A_{es}}$$

5.16.3 Requirement. See plates in Section 7.

NOTE: In some instances it is desirable to denote the complex form of impedance; the manufacturer may, at his option, specify the resistive and reactive components of impedance.

5.17 Influence, Combined Voltage and Current (Wattmeters and Varmeters)

5.17.1 Procedure

(1) With the instrument in the normal mounting position, set the pointer to zero.

(2) On polyphase wattmeters and varmeters connect voltage circuits in parallel and current circuits in series.

(3) Varying the current as required, calibrate a minimum of six approximately equidistant reference points on the scale at rated voltage and unity power

factor. Calibrate the same points for each of the following power factors and voltages, varying the current as required:

Step Number	*Power Factor*	*Percent of Rated Voltage*
1	1.0*	110
2	1.0*	90
3	0.5 leading†	Rated
4	0.5 leading†	110
5	0.5 leading†	90
6	0.5 lagging†	Rated
7	0.5 lagging†	110
8	0.5 lagging†	90

*For single-phase varmeters use zero power factor.

†The current shall not exceed 120% of rated current.

5.17.2 Computation

(1) The combined voltage and current influence at 1.0 power factor is the difference between the reference calibration and Step 1 and between the reference calibration and Step 2. (For single-phase varmeters use zero power factor.)

(2) The combined voltage and current influence at 0.5 leading power factor is the difference between Steps 3 and 4 and between Steps 3 and 5.

(3) The combined voltage and current influence at 0.5 lagging power factor is the difference between Steps 6 and 7 and between Steps 6 and 8.

The combined current and voltage influence is the highest of the six results given in (1) through (3).

5.17.3 Requirement. See plates in Section 7.

5.18 Influence, Circuit-to-Ground-Voltage

5.18.1 Procedure

(1) Mount panel and switchboard instruments on a conducting panel with the mounting hardware supplied with the instrument.

(2) Place portable instruments on a conducting platform.

(3) Set the pointer to zero.

(4) Apply circuit-to-ground voltage given on the plates in Section 7 for 1 minute between one of the instrument terminals and the panel or platform, and note the change in the position of the pointer.

(5) Repeat Step 4, but apply the voltage between the other instrument terminal and the mounting panel or platform.

5.18.2 Requirement. While the voltage is applied, the change in pointer position, expressed in percent of scale length, shall not exceed the values shown in Section 7.

5.19 Influence, Electrostatic Field on Window

5.19.1 Procedure. The influence of the electrostatic field created by the charge on the window of an instrument shall be determined under reference conditions as follows:

(1) Using a suitable pad of clean, white, folded cheesecloth saturated with distilled water, clean the outside surface of the window. Remove all excess moisture with another pad of clean, folded cheesecloth. Do not touch the clean window with the bare skin. Allow the window to dry for at least 4 hours.

(2) Set the indicating pointer to zero. Do not touch the window with the bare hands.

(3) Take a piece of clean, untreated, white cheesecloth approximately 18 inches square and form it into a wad.

(4) Without touching the window with the bare hand and using the wad described in Step 3, rub the viewing area of the window briskly for about 10 seconds (approximately 30 strokes).

(5) Measure and record the time required for the pointer to return to zero to within 1 percent of full-scale deflection.

5.19.2 Requirement. The time required in Step 5 shall not exceed 30 seconds.

5.20 Influence, External-Magnetic-Field

5.20.1 Procedure

(1) Apply sufficient excitation to bring the pointer to the end-scale value, and record that value of excitation (B_r). (Only one reading shall be taken for permanent-magnet moving-coil instruments; for moving-iron or electrodynamic instruments, a minimum of six readings shall be taken.)

(2) Subject the instrument to an external magnetic field of 500 microteslas (5 gauss) produced by a current of the same kind and frequency as that which actuates the mechanism. The field shall be produced by a coil approximately 40 inches (1 meter) in diameter and not more than 5 inches (130 mm) long. In this coil, 400 ampere-turns will produce a field of approximately 500 microteslas (5 gauss). The instrument under test shall be placed in the center of the coil. The influence shall be determined by rotating the coil and changing the phase of the external magnetic field (where applicable) to produce the greatest influence.

(3) Repeat Step 1 under the most unfavorable conditions as determined by Step 2 and record the value (B_x).

NOTE: Wattmeters, varmeters, and power-factor meters shall have rated voltage applied to the voltage circuit. For wattmeters and varmeters, the current applied shall be at unity power factor.

5.20.2 Computation. The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.20.3 Requirement. See plates in Section 7 for switchboard and portable instruments.

5.21 Influence, External-Temperature

5.21.1 Procedure. External temperature influence is given for a 10°C change in ambient temperature but, for more practical measurements, is determined by one-half the difference over a 20°C temperature change.

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Subject the instrument to a temperature of 20°C above the reference temperature until thermal stability is attained, but for not less than 2 hours, and record the accuracy readings as in Step 1 (B_x).

(3) Cool the instrument at the reference temperature until thermal stability is attained but for not less than 2 hours, and record the accuracy readings (B_t).

(4) Subject the instrument to a temperature of 20°C below the reference temperature until thermal stability is attained but for not less than 2 hours, and record the accuracy readings (B_y).

(5) Allow the instrument to warm at the reference temperature until thermal stability is attained but for not less than 2 hours and record the accuracy reading (B_s). If the reading B_s differs from B_r by more than one-fourth of the accuracy class, repeat the tests.

5.21.2 Computation. One-half of the difference between each reading at the high-temperature and the corresponding reading at the reference temperature shall be expressed as a percentage of the fiducial value (A_f), as follows:

$$\left(\frac{B_r - B_x}{2A_f}\right) \times 100$$

A similar calculation shall be made for the readings at the low temperature, as follows:

$$\left(\frac{B_t - B_y}{2A_f}\right) \times 100$$

If the influences above and below the reference temperature at not equal, the greater value shall be considered to be the temperature influence.

5.21.3 Requirement. See plates in Section 7.

5.22 Influence, Extreme Temperature

5.22.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(2) Subject the instrument to a temperature of 65°C ± 2°C until thermal stability is attained, but for not less than 2 hours, and record the accuracy readings (B_x).

(3) Cool the instrument at the reference temperature until thermal stability is attained but for not less than 2 hours, and record the accuracy readings (B_t).

(4) Subject the instrument to a temperature of –20°C ± 2°C until thermal stability is attained but for not less than 2 hours and record the accuracy readings (B_y).

5.22.2 Computation. The difference between each reading at the high temperature and the corresponding reading at the reference temperature shall be expressed as a percentage of the fiducial value (A_f), as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

A similar calculation shall be made for the readings at low temperature, as follows:

$$\left(\frac{B_t - B_y}{A_f}\right) \times 100$$

If the influences above and below the reference temperature are not equal, the greater value shall be considered to be the temperature influence.

5.22.3 Requirement. See plates in Section 7.

5.23 Influence, Frequency

5.23.1 Procedure

(1) Take and record a set of initial accuracy readings (B_r) under reference conditions at the reference frequency of the instrument being tested.

(2) Vary the frequency of the excitation within the limits shown in Section 7 and repeat Step 1 at each frequency deviation (B_x).

For wattmeters operating at 60 Hz, the influence shall be determined at 60 Hz ± 6 Hz for power factors of 1.0 and 0.5 lagging.

5.23.2 Computation. The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.23.3 Requirement. See plates in Section 7.

5.24 Influence, Ferrous-Panel (Panel-Type Instruments Only)

5.24.1 Procedure

(1) Mount the instrument on a nonferrous panel. The cutout on the panel shall be of the dimensions specified by the manufacturer.

(2) Take and record a set of initial accuracy readings (B_r) under reference conditions.

(3) Mount the instrument in a similar manner on a 0.090-inch-thick ferrous panel and repeat Step 2 (B_x).

5.24.2 **Computation.** The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.24.3 **Requirement.** See plates in Section 7.

5.25 Influence, Ferrous-Platform (Portable Instruments Only)

5.25.1 **Procedure**

(1) Place the instrument in the horizontal position on a surface at a distance from any extraneous magnetic material.

(2) Take and record a set of initial accuracy readings (B_r).

(3) Place the instrument, still in a horizontal position, on a demagnetized steel plate that is at least 0.25 inch thick and extends at least 6 inches beyond the instrument on all sides.

(4) Take and record a set of accuracy readings as in Step 2 (B_x).

5.25.2 **Computation.** The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.25.3 **Requirement.** See plates in Section 7.

5.26 Influence, Interelement (Polyphase Wattmeters)

5.26.1 **Procedure**

(1) Connect the voltage circuits in parallel and the current circuits in series.

(2) Apply rated voltage and sufficient current at rated frequency and unity power factor to bring the pointer to the end-scale mark (B_r).

(3) Reverse the connections to the current circuit and voltage circuit of one element. Record the indicated value (B_x).

5.26.2 **Computation.** The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{2A_f}\right) \times 100$$

where A_f = fiducial value.

5.26.3 **Requirement.** See plates in Section 7.

5.27 Influence, Operation

5.27.1 **Procedure**

(1) Apply excitation sufficient to bring the pointer to 80% of the end-scale value and immediately record the value of excitation (B_r).

(2) To determine the short-time-operation influence, maintain the same excitation for a period of 15 minutes. To determine the sustained-operation influence, maintain the same excitation for a period of 6 hours.

(3) Adjust the excitation to bring the pointer to 80% of the end-scale value and record the value of excitation (B_x).

NOTE: For wattmeters, apply rated voltage and sufficient current at unity power factor.

5.27.2 **Computation.** The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.27.3 **Requirement.** See plates in Section 7.

5.28 Influence, Position

5.28.1 **Procedure**

(1) Place the instrument in the normal mounting position, with the plane of the instrument dial in a vertical position, and set the pointer at zero.

(2) Tilt the instrument forward 60° and note the indication.

(3) Tilt the instrument back 60° and note the indication.

5.28.2 **Computation.** The maximum deviation of the pointer from zero when tilted 60° forward or backward is the position influence and shall be expressed as a percentage of full-scale length.

5.28.3 **Requirement.** See plates in Section 7.

5.29 Influence, Power-Factor (Wattmeters and Varmeters)

5.29.1 **Procedure**[2]

(1) Using a reference wattmeter having a negligible power-factor error, apply rated voltage[2] and sufficient current[2] at unity power factor[3] to bring the pointer to one-half of the end-scale mark and record the value of excitation (B_r).

(2) Repeat Step 1 at 0.5 power factor leading and record the value of excitation (B_{x2}).

(3) Repeat Step 1 at 0.5 power factor lagging and record the value of excitation (B_{x3}).

5.29.2 **Computation.** The power-factor influence shall be the larger of the values computed as follows:

$$\left(\frac{B_r - B_{x2}}{A_f}\right) \times 100 \quad \text{or} \quad \left(\frac{B_r - B_{x3}}{A_f}\right) \times 100$$

where A_f = fiducial value.

[2] For polyphase instruments connect voltage circuits in parallel and current circuits in series.

[3] For single-phase varmeters use zero power factor.

5.29.3 Requirement. See plates in Section 7.

5.30 Influence, Proximity

5.30.1 Procedure. Two instruments of the same make, rating, and principle of operation are required for this test.

(1) Mount or place the first instrument in its normal operating position; see 4.2.

(2) Apply and record the value of excitation (B_r) required to bring the pointer of this instrument to 90% of the end-scale value under reference conditions.

(3) Mount or place the second instrument immediately adjacent to the right side of the first instrument and apply end-scale excitation to it. Then record the value of excitation (B_x) on the first instrument required to maintain the pointer at 90% of the end-scale mark.

(4) Repeat Step 3, with the second instrument to the left of the first instrument. Record the value of excitation (B_x).

(5) Repeat Step 3, with the second instrument mounted immediately above the first instrument for panel and switchboard types. For portable instruments, repeat Step 3 with the horizontal plane as the first, but in the 12 o'clock position with respect to the first. Record the value of excitation (B_x).

(6) Repeat Step 3, with the second instrument mounted immediately below the first instrument for panel and switchboard types. For portable instruments, repeat Step 3 with the second instrument mounted in the same horizontal plane as the first, but in the 6 o'clock position with respect to the first. Record the value of excitation (B_x).

5.30.2 Computation. The proximity influence shall be the maximum deviation from the reading in Step 2 from that determined in Steps 3, 4, 5, or 6 and shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.31 Influence, Unbalanced-Current (Polyphase Wattmeters and Varmeters)

5.31.1 Procedure.

(1) Connect all current circuits in series and voltage circuits in parallel.

(2) Apply rated voltage and frequency at unity power factor for wattmeters (zero power factor for varmeters). Vary the current and record the excitation (B_r) at the pointer position indicated.

Elements	*Pointer Position*	*K*
2 elements	midscale	1/2
2-1/2 elements		
single current coil	quarterscale	1/4
double current coil	midscale	1/2
3 elements	one-third scale	1/3

(3) Energize only one current circuit and apply sufficient current to bring the pointer to the same indication as in Step 2. Record the excitation (B_x). Repeat this step for the other current circuit(s).

5.31.2 Computation. The influence in percent shall be computed as follows:

$$\left(\frac{B_r - KB_x}{A_f}\right) \times 100$$

where

A_f = fiducial value

K = constant in table of 5.31.1(2)

The greatest computed value shall be considered to be the unbalanced current influence.

5.32 Influence, Voltage, at Zero (Wattmeters and Varmeters)

5.32.1 Procedure

(1) Take and record initial reading (B_r) with the voltage circuit(s) energized at rated voltage and the current circuit(s) not connected.

(2) De-energize the voltage circuit(s) and record reading (B_x).

5.32.2 Computation. The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.33 Influence, Voltage (Frequency Meters and Power-Factor Meters)

5.33.1 Procedure

(1) Apply rated voltage to the voltage circuit.

(2) Vary the frequency or power factor for each of the six readings and record the value at each reading (B_r).

(3) Repeat Step 2 with 110% of rated voltage applied and record the indication using the same frequency or power factor (B_x).

(4) Repeat Step 2 with 90% of rated voltage applied and record the indication using the same frequency or power factor (B_x).

(5) Repeat Step 2 with 120% of rated voltage applied and record the indication using the same frequency or power factor (B_x).

(6) Repeat Step 2 with 80% of rated voltage applied and record the indication using the same frequency or power factor (B_x).

5.33.2 **Computation.** The maximum difference between the corresponding readings of Steps 2 and 3 and between Steps 2 and 4 shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.33.3 **Requirement.** See plates in Section 7.

5.34 Influence, Waveform

5.34.1 Procedure (except for Frequency Meters)

(1) Using a reference instrument having a negligible waveform error, apply sufficient sine-wave excitation (with less than 0.5% distortion) to bring the pointer of the instrument under test to 80% of end-scale value. Record the excitation from the reference instrument (B_r).

(2) Superimpose 30% of the third harmonic upon the fundamental frequency and adjust the amplitude of the distorted waveform to produce the same rms value on the reference instrument as was previously noted. Vary the phase between the fundamental and the third harmonic to achieve maximum influence on the instrument under test. Then change the amplitude of the distorted wave to produce the original deflection of 80% of end-scale value of the instrument under test. Record the excitation from the reference instrument (B_x).

5.34.2 Procedure (for Frequency Meters)

(1) Using a reference instrument having a negligible waveform error, apply rated sine-wave voltage (with less than 0.5% distortion) and adjust frequency to bring the pointer of the instrument under test to mid-scale. Record the frequency from the reference instrument (B_r).

(2) Superimpose 30% of the third harmonic upon the fundamental frequency and adjust the amplitude of the distorted waveform to produce rated rms voltage. At fundamental frequency (B_r), vary the phase between the fundamental and the third harmonic to achieve maximum influence on the instrument under test. Adjust the frequency to produce midscale indication. Record the frequency from the reference instrument (B_x).

5.34.3 **Computation.** The influence in percent shall be computed as follows:

$$\left(\frac{B_r - B_x}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.34.4 **Requirement.** See plates in Section 7.

5.35 Insulation Test for Leakage Current

5.35.1 Procedure

(1) Condition the instrument for 24 hours at 30°C ± 5°C and a relative humidity of 85% ± 5%.

(2) Instruments having an enclosure wholly or partially made of insulating material shall be wrapped in metal foil to within a distance of not more than 20 mm from the terminals or live metallic parts that are not exposed to the user after installation of the instrument.

(3) Apply one of the following voltages whichever is convenient between the conducting panel or foil-wrapped instrument and terminals which have been tied together, and measure and record the leakage current:

(a) 800 V, 60 Hz

(b) 120 V, 60 Hz

5.35.2 **Requirement.** See plates in Section 7.

5.36 Loading, Apparent Power (Current Circuits) (Volt-Ampere Loss)

5.36.1 **Procedure.** See 5.51 or 5.52.

5.36.2 **Computation.** Using the value of voltage drop from 5.51 or 5.52, the apparent power loading shall be calculated as the product of the voltage drop and rated current.

5.36.3 **Requirement.** See plates in Section 7.

5.37 Loading, Apparent Power, of Instruments Having Voltage Circuits (Volt-Ampere Loss)

5.37.1 Procedure

(1) Connect a current-measuring instrument with a negligible voltage drop in series with the voltage circuit of the instrument being tested.

(2) Apply end-scale voltage (for voltmeters) or the rated voltage of the voltage circuit of the instrument being tested.

(3) Read the current loading from the current-measuring instrument.

5.37.2 **Computation.** The apparent power loading shall be calculated as the product of the rated voltage and current loading.

5.37.3 **Requirement.** See plates in Section 7.

5.38 Overshoot. In instances where the damping is influenced by the circuit impedance, the impedance of the driving source shall be at least 100 times the impedance of the instrument and its normal accessories.

5.38.1 Procedure

(1) Measure and record the angular degrees between zero and end-scale (D_{es}).

(2) Suddenly apply a constant value of excitation that will swing the pointer to end-scale on the first swing.

(3) Maintain the same excitation and record the steady-state deflection in angular degrees (D_x) after the pointer has come to rest.

5.38.2 **Computation.** The overshoot in percent shall be computed as follows:

$$\left(\frac{D_{es} - D_x}{D_x}\right) \times 100$$

5.38.3 **Requirement.** See plates in Section 7.

NOTE: In the determination of the overshoot of instruments not having torque-spring control, such as a power-factor meter or a frequency meter, the instrument shall be energized as stated on the detailed requirement sheet to give center-scale deflection. The pointer shall then be moved mechanically to end-scale and suddenly released.

5.39 Repeatability Error

5.39.1 Procedure

(1) Without overshoot and without tapping, apply excitation sufficient to bring the pointer to a scale mark close to half the end-scale value and record that value of excitation (E_a).

(2) Without overshoot and without tapping, change the excitation in the same direction to deflect the indicating pointer to end-scale and back to the same scale mark as in Step 1, and record that value of excitation (E_b).

(3) Steps 1 and 2 should be performed in no more than 20 seconds.

5.39.2 **Computation.** The repeatability error in percent shall be computed as follows:

$$\left(\frac{E_a - E_b}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.39.3 **Requirement.** See plates in Section 7.

5.40 Resistance (DC Instruments)

5.40.1 Procedure

(1) Connect a current-measuring dc instrument in series with the instrument under test.

(2) Apply end-scale excitation and read the current-measuring instrument (A_{es}).

(3) While maintaining end-scale current, connect a high-impedance dc voltmeter across the terminals of the instrument under test and read the end-scale voltage drop (V_{es}).

5.40.2 **Computation.** The resistance of the instrument shall be computed as follows:

$$R = \frac{V_{es}}{A_{es}}$$

5.40.3 **Requirement.** See plates in Section 7.

NOTE: It is recognized that other test methods such as a Wheatstone bridge may produce an acceptable measurement of resistance. However, because of the possible overload of components, self-heating, etc, care must be taken when using such alternate test methods. When questions arise, the test method described herein shall be used.

5.41 Response Time

5.41.1 **Procedure.** In instances where the response time is influenced by the circuit impedance, the impedance of the driving source shall be at least 100 times the impedance of the instrument and its normal accessories.

(1) Suddenly apply a constant value of excitation that will swing the pointer to end-scale on the first swing.

(2) Note and record the time, in seconds, required for the indicating pointer to come to apparent rest when it remains within a range on either side of its final position equal to one-half the accuracy rating of the instrument.

(3) Repeat Steps 1 and 2 five times.

5.41.2 **Computation.** The average length of time recorded for all measurements is the response time of the instrument.

5.41.3 **Requirement.** See plates in Section 7.

NOTE: In the determination of the response time of instruments not having torque-spring control, such as a power-factor meter or a frequency meter, the instrument shall be energized as stated on the detailed requirement sheet to give center-scale deflection. The pointer shall then be moved mechanically to end-scale and suddenly released. Note and record the time as in 5.40.1(2).

5.42 Scale Length

5.42.1 **Procedure for Instruments with Pointer Tip Not Extending beyond the Scale Marks.** Measure or calculate the length of the arc formed by the movement of the pointer tip from one end of the scale to the other. The arc may be calculated by the length of the pointer (L) from the pivot point to the tip and from the angular arc (a) covered by the pointer moving from one end of the scale to the other.

The scale length S is:

$$S = 2\pi L \times \left(\frac{a}{360}\right)$$

5.42.2 **Procedure for Instruments with Pointer Tip Extending beyond the Scale Marks.** Measure the length of the arc from one end of the scale to the other formed by the outer ends of the shortest scale marks.

5.42.3 **Requirement.** See plates in Section 7.

5.43 Sensitivity (Synchroscopes)

5.43.1 Procedure

(1) Apply rated voltage and frequency to both the running and incoming circuits.

(2) Change the phase angle between the two circuits until the pointer rotates 1 degree.

5.43.2 **Computation.** Sensitivity is the phase angle required in 5.43.1(2).

5.43.3 **Requirement.** See Plate 12 in Section 7.

5.44 Sticking above End-Scale Mark

5.44.1 Procedure

(1) Apply, for 1 minute, 120% of end-scale excitation.

(2) Reduce the excitation slowly, without tapping, from 120% to 100% and observe whether or not the pointer leaves the stop.

Offset-zero instruments shall be tested at both ends of the scale.

5.44.2 Requirement. After the instrument is tested in accordance with 5.44.1, the pointer shall break free of the stop.

5.45 Sticking below Low End-Scale Mark (Suppressed-Zero Instruments)

5.45.1 Procedure. Apply excitation, slowly increasing it from zero to a value equal to the value of the lower end-scale mark.

5.45.2 Requirement. The pointer shall break free of the stop within this range of excitation.

5.46 Sticking below Zero

5.46.1 Procedure

(1) Apply one-third of the excitation necessary to bring the pointer to the end-scale mark.

(2) Suddenly reduce the excitation to zero, without tapping.

(3) If the pointer deflects below zero, observe whether or not it leaves the stop.

(4) Apply two-thirds of the excitation necessary to bring the pointer to the end-scale mark, and repeat Steps 2 and 3.

5.46.2 Requirement. After the instrument is tested in accordance with 5.46.1, the pointer should not stick at the stop.

5.47 Symmetry Error (Offset-Zero Instruments)

5.47.1 Procedure

(1) Measure and record the value of excitation (B_x) required to deflect the pointer to each of at least three approximately equidistant scale marks on the right side of the zero mark.

(2) Reverse the polarity and measure and record the value of excitation (B_y) required to deflect the pointer to the corresponding points on the left side of the zero mark.

In the case of severely offset-zero instruments, the number of scale points to be checked may be reduced since it may not be possible to select three points on the shorter side of the zero mark.

5.47.2 Computation. The symmetry error in percent shall be computed as follows:

$$\left(\frac{B_x - B_y}{A_f}\right) \times 100$$

where A_f = fiducial value.

5.48 Thermal Converter, 90% Response Time

5.48.1 Procedure

(1) Apply rated input excitation and determine the value of the output EMF after steady-state conditions have been achieved.

(2) Reduce the input excitation to zero and allow the output to return to zero.

(3) Suddenly apply rated input excitation, and measure the time, in seconds, required for the output EMF to reach 90% of the value obtained in Step 1.

5.48.2 Computation. The time measured in 5.48.1(3) is the 90% response time of a thermal converter.

5.49 Tracking Error (Zero-Left and Zero-Right Instruments)

5.49.1 Procedure

(1) Measure the record the excitation required to bring the pointer to the end-scale mark (B_{es}).

(2) Measure and record the value of excitation required to bring the pointer to each of a minimum of four other approximately equidistant scale marks (B_a).

(3) Determine the rated value of excitation for the scale markings selected in Step 2 (A_s) and for the end-scale (A_{es}) by inspection.

5.49.2 Computation. The tracking error in percent of fiducial value shall be computed as follows:

$$\left(\frac{A_s}{A_{es}} - \frac{B_a}{B_{es}}\right) \times 100$$

5.49.3 Alternate Method. In order to simplify calculations and taking of data, it is suggested that test circuitry be adjusted to have the actual excitation-producing end-scale deflection correspond to the rated end-scale value by adding resistance, shunting, or other means. If the end-scale value is made the same as the rated value of excitation, the formula reduces to

$$\left(\frac{A_s - B_a}{A_{es}}\right) \times 100$$

5.50 Tracking Error (Offset-Zero Instruments)

5.50.1 Procedure

(1) Set the pointer to the zero mark by tapping.

(2) Measure and record the value of excitation (B_{es}) required to bring the pointer to the higher end-scale mark. For zero-center instruments, use the right-hand end-scale point.

(3) Measure and record the values of excitation (B_a) required to bring the pointer to each of a minimum of five other approximately equidistant scale marks, including the other end-scale point, but not including the zero point.

(4) Determine the rated value of excitation for the scale markings selected in Step 3 (A_s) and for the reference end-scale point (A_{es}) by inspection.

5.50.2 Computation. The tracking error in percent of fiducial value shall be computed as follows:

$$\left(\frac{A_s}{A_{es}} - \frac{B_a}{B_{es}}\right) \times \frac{A_{es}}{A_f} \times 100$$

where A_f = fiducial value.

5.50.3 Alternate Method. In order to simplify calculations and taking of data, it is suggested that test circuitry be adjusted to have the actual excitation-producing end-scale deflection correspond to the rated end-scale value by adding resistance, shunting, or other means. If the end-scale value is made the same as the rated value of excitation, the formula reduces to

$$\left(\frac{A_s - B_a}{A_f}\right) \times 100$$

5.51 Voltage Drop (Current-Measuring Instruments)

5.51.1 Procedure

(1) Connect a voltage-measuring device having negligible current drain across the terminals of the instrument under test.

(2) Apply sufficient excitation to bring the pointer of the current-measuring instrument to the end-scale mark.

(3) Read the voltage drop on the voltmeter.

5.51.2 Requirement. See plates in Section 7.

5.52 Voltage Drop in Current Circuits (Wattmeters, Varmeters, and Power-Factor Meters)

5.52.1 Procedure

(1) Connect a voltage-measuring device having negligible current drain across the current terminals of the instrument under test.

(2) Apply rated current to the current circuit of the instrument under test.

(3) Read the voltage drop on the voltmeter.

5.52.2 Requirement. See plates in Section 7.

5.53 Window Test (when Windows Are a Separate Item Assembled to the Cover or Front)

5.53.1 Procedure

(1) When the window is secured to the inside of the cover or front:

(a) Mount the instrument with the window in the horizontal plane and facing upward.

(b) Apply an 8-pound uniformly distributed static load to the window area.

(c) Subject the instrument to a temperature of 65°C ± 2°C and approximately 95% relative humidity for approximately 24 hours.

(d) Subject the instrument to a temperature of −20°C ± 2°C for 12 hours.

(2) When the window is secured to the outside surface of the instrument enclosure, the instrument shall be mounted with the window in a horizontal plane facing downward so that gravity will act in a direction to separate the window from the cover. Then follow the test procedure shown in (c) and (d) of 5.53.1(1).

5.53.2 Requirement. There shall be no perceptible shift in the position of the window.

5.54 Zero Adjustment, Range of

5.54.1 Procedure

(1) Rotate the zero adjuster to move the pointer upscale, and note the maximum deflection of the pointer.

(2) Repeat Step 1 for deflection downscale.

If the pointer stop inhibits the motion of the pointer while the zero adjuster is being operated, it is permissible to energize the instrument sufficiently to prevent the pointer from touching the pointer stop during this test.

5.54.2 Computation. The results of Steps 1 and 2 shall be expressed in percent of full-scale length or in angular degrees, whichever is applicable.

5.54.3 Requirement. See 6.16.

5.55 Zero-Shift Error, Short-Term

5.55.1 Procedure

(1) Set the pointer to zero (with tapping).

(2) Measure and record the scale length between zero and end-scale (B_{s1}).

(3) Apply excitation sufficient to bring the pointer to the end-scale mark, and maintain it for 15 minutes.

(4) Reduce the excitation to zero without overshoot and immediately note and record the deviation from zero position (B) of the pointer (with tapping).

5.55.2 Computation. The short-term zero shift in percent of scale length shall be computed as follows:

$$\left(\frac{B}{B_{s1}}\right) \times 100$$

5.56 Zero-Shift Error, Long-Term

5.56.1 Procedure

(1) Set the pointer to zero (with tapping).

(2) Measure and record the scale length between zero and end-scale (B_{s1}).

(3) Apply excitation sufficient to bring the pointer to the end-scale mark, and maintain it for 6 hours.

(4) Reduce the excitation without overshoot to zero and immediately note and record the deviation from zero position (B) of the pointer (with tapping).

5.56.2 Computation. The long-term zero shift in percent of scale length shall be computed as follows:

$$\left(\frac{B}{B_{sl}}\right) \times 100$$

6. General Requirements[4]

6.1 Safety Requirements. The applicable provisions of the American National Standard Safety Requirements for Electrical and Electronic Measuring and Controlling Instrumentation, ANSI C39.5-1974, shall apply to the instruments covered by this standard. In case of conflict the requirements given herein shall apply.

6.2 Balancing. The means for balancing the moving element shall be easily accessible. Solder or an adhesive to fix the balance weights, or to function as a part of the balance weights, shall not be used except when the instrument has a separate nonsoldered adjustable balance weight.

6.3 Bearings. In switchboard and portable instruments that have an accuracy rating of 1% or better, the jewel screws shall not be cemented in position.

6.4 Corrosion Resistance. All parts of instruments shall be sufficiently corrosion resistant so that any corrosion that might occur when the instruments are subjected to any of the tests described in this standard will not interfere with their operation.

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

6.5 Degree of Enclosure. Enclosures shall have close-fitting joints to minimize the entrance of dust and moisture that might interfere with the operation of the instrument when subjected to any of the tests described in this standard.

6.6 Finishes. Protective coatings or finishes shall not melt, crack, chip, or scale when the instruments are subjected to any of the tests described in this standard.

6.7 Hardware for Mounting. The necessary mounting hardware shall be supplied with each switchboard or panel instrument.

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

[4] All tests required by this document are type tests to be conducted on a single sample or on a small quantity of instruments.

6.9 Means of Adjustment to Accuracy. All instruments shall have a practicable means for adjustment to accuracy in the shop. In permanent-magnet instruments, remagnetizing of the magnet and magnetically treating to accuracy shall be considered as meeting this requirement.

6.10 Molded Parts. Molded parts shall have neat surfaces, smooth and free from flash projections or roughness.

6.11 Pointers. Instrument pointers shall be so formed as to permit accurate readings and permit approximate scale readings up to the distance of legibility of the scale markings. The pointer shall not become damaged or distorted when the instrument is subjected to any of the tests described in this standard.

In instruments intended for use on alternating current, the pointer shall be of rigid construction so that there will be no vibration of the pointer that might interfere with operation or use of the instrument when any value of voltage or current up to the maximum rated value is applied and when the instrument is operating over its rated frequency range.

6.12 Scale Visibility. Except for edgewise and portable types, instruments shall be so designed that the entire scale will be readable at any angle up to 45 degrees when viewed from below and 20 degrees to the right and left, when measured from a perpendicular to the middle of the dial.

When illuminated from above and in front and at an angle of 45 degrees from the same axis, there shall be no objectionable shadows on the graduated scale.

6.13 Screw Threads. All external threaded parts shall comply with one or more of the following American National Standards. Where practicable, all other screw threads shall also comply with these standards:

Unified Inch Screws Threads (UN and UNR Thread Form), ANSI B1.1-1974

Gages and Gaging for Unified Screw Threads, ANSI B1.2-1974

Square and Hex Bolts and Screws, Including Askew Head Bolts, Hex Cap Screws, and Lag Screws, ANSI B18.2.1-1972

Square and Hex Nuts, ANSI B18.2.2-1972

Slotted and Recessed Head Wood Screws, ANSI B18.6.1-1972 (R1977)

Slotted Head Cap Screws, Square Head Set Screws, and Slotted Headless Set Screws, ANSI B18.6.2-1972 (R1977)

Slotted and Recessed Head Machine Screws and Machine Screw Nuts, ANSI B18.6.3-1972 (R1977)

Slotted and Recessed Head Tapping Screws and Metallic Drive Screws, ANSI B18.4-1966 (R1975)

6.14 Terminals

6.14.1 Hardware for Terminals. Threaded terminals, when used, shall be provided with the necessary nuts, screws, and washers.

6.14.2 Marking of Terminals. All instruments that require terminal identification shall be legibly and permanently marked or provided with instructions that identify the proper connections.

On direct-current switchboard and panel instruments, and where the polarity is important, the left-hand terminals shall be the positive terminal, viewed from the back of the instrument in its normal mounting position. The marking "plus" or "+" shall be on or near this terminal.

On edgewise instruments the location and marking of the positive terminal shall be the left terminal from the rear for horizontal-scale instruments, and the top terminal for vertical-scale instruments.

On all panels or switchboard self-contained radio-frequency instruments, the left-hand terminal shall be the low-potential terminal, viewed from the back of the instrument in its normal mounting position. The marking "G" for ground shall be on or near this terminal.

On portable instruments, terminals shall be marked to identify polarity, the range on multiple-range instruments, and the circuit when there is more than one circuit.

6.14.3 Mounting of Terminals. Terminal studs or binding-post bodies shall be firmly anchored to the instruments to prevent any turning or movement that might cause internal damage. Recommended minimum torque values and the test procedure are shown in Appendix B.

6.14.4 Solder-Type Terminals. If used, solder-type terminals shall be designed to accommodate at least a minimum of one 0.064-inch (1.626-mm) diameter (No. 14 AWG) wire and to allow for external application of a soldering iron without causing internal damage to the instrument.

6.15 Windows. Instrument windows shall be free from discolorations, scratches, electrostatic effect, or other defects that might interfere with the use of the instrument. Windows shall not become loose when subjected to any of the tests described in Section 5.

6.16 Zero Adjuster. Instruments with a mechanical restoring force shall have a zero adjuster accessible from the front of the panel unless otherwise specified in Section 7. The adjuster shall provide for a range of adjustment both above and below the zero point of 3% of the scale length minimum, or 3 degrees minimum, whichever is less. Preferably, it shall be capable of rotating through 360 degrees without damaging any part of the instrument and without becoming inoperative. When the pointer stop (normally positioned below the zero point) interferes with the test for the range of zero adjustment described in 5.54, the test may be performed by applying an increment of current or voltage, as applicable, and determining the range of the zero adjuster from this new point. The zero adjuster shall not shake loose or change the zero adjustment when subjected to the tests described in Section 5.

6.17 Dials. The instrument dials (or scale plates) shall be free from warping, fading, discoloring, or deterioration when the instruments are subjected to any of the tests described in Section 5. All dials shall be firmly secured to the mounting but shall be capable of being easily removed from the instrument and replaced in their original position.

6.18 Marking. Instruments shall be distinctly marked with the applicable information given in 6.18.1 through 16.18.3. These markings shall not, however, be so conspicuous as to distract attention from the scale markings required in 6.20 and 6.22.

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

(1) Manufacturer's name, trademark, or symbol.

(2) Designation of the quantity measured (volts, kilovolts, amperes, milliamperes, watts, etc) or their symbols from Table F1.

(3) The words direct current, alternating current, radio frequency, etc, or their abbreviations.

(4) The accuracy class shall be marked (see symbols E1 through E3 of Table F1) for all portable instruments, for panel instruments of class 1.0 or more accurate, and for switchboard instruments of class 0.5 or more accurate.

6.18.2 The following information shall be legibly marked on the dial or somewhere on the instrument case and should, preferably, be visible from the front:

(1) Manufacturer's type, model number, or both.

(2) The electrical quantity or symbol for producing end-scale deflection when this differs from the end-scale value; for example:

(a) ES (end-scale) = 50 mV.

(b) Wattmeters and varmeters: 1-ϕ (single-phase) test, ES = 469 W.

(3) The rated current or voltage, or both (or the ranges of these quantities, unless they are the same as the end-scale value).

(4) On portable instruments, the maximum current and voltage in the case of wattmeters, power-factor meters, etc.

(5) The frequency (if other than 60 Hz) 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.

(6) Shunt lead resistance where the lead resistance affects instrument accuracy and is not the value specified.

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

(8) On alternating-current instruments designed for use with current and potential transformers, the ratio of the appropriate potential (voltage) transformer, expressed as 2400:120 or 2400/120; or 20:1 or 20/1 and the appropriate current transformer expressed as 1000:5 or 1000/5 or 200:1 or 200/1.

In alternating-current instruments where the transformer ratio is not essential to the proper calibration of the instrument (such as is the case with frequency meters and power-factor meters), the marking need include only the voltage or current value, or both, which is to be applied at the instrument terminals, or to its external devices if any are used.

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

Use with external shunt	ES = 50 mV
Use with external resistor	ES = 1 mA

6.19 Designation of Linear Scales. Linear scales may be designated by a code consisting of three numbers.

(1) The first number specifies the number of major divisions into which the complete scale is divided.

(2) The second number specifies the number of intermediate divisions into which each major division is divided.

(3) The third number specifies the number of minor divisions into which each intermediate division is divided. Thus, Fig. 5 would be specified as 5 X 2 X 5.

6.20 Numbering of Scales. The figures shall be as large and legible as practicable.

6.21 Preferred End-Scale Values for Self-Contained Instruments where Zero Is at the Left. See Appendix C.

6.22 Scale Divisions. The value of each scale division shall, wherever practicable, be 1, 2, or 5 of the units measured or decimal multiples of these values.

6.23 Supplemental Data for Portable Instruments — Rated Accuracy Class 0.25. The information shown in Table 1 shall be legibly marked on the instrument or on a certificate furnished with the instrument.

6.24 Unit Designation of Quantity Measured. See Appendix D.

6.25 Bonding. If necessary to minimize electrostatic effects, all metallic parts shall be suitably treated or connected together and to one of the terminals so that the instrument will meet the performance requirements of this publication within the circuit-to-ground voltage set by the manufacturer.

For self-contained radio-frequency instruments, connection shall be made to the left-hand terminal looking at the back of the instrument in its normal mounting position. In a radio-frequency instrument that is actuated by an external thermoelement, the magnetic system, dial, and internal bezel ring shall be electrically connected to a third terminal for connection in turn to the low-potential heater terminal of the thermoelement.

6.26 Ferrous Panels. When ferrous panels are specified, suitable allowance shall be made in the calibration of instruments affected by such panels. When such calibration is required, instruments will be calibrated for the ferrous panel thickness specified in Section 7.

6.27 Shunt Leads. Where shunt leads are required for panel and switchboard instruments, they shall have a nominal length of 5 feet and a resistance of 0.065 ohm ± 0.010 ohm. For portable instruments of accuracy classes 0.25 and 0.5, the shunt lead shall have a nominal length of 5 feet and a resistance of 0.026 ohm ± 0.005 ohm. This resistance applies at the reference temperatures.

6.28 Other General Requirements. The following sections contain other general requirements:

Dielectric test 5.5
Effect of extreme temperature 5.6
Effect of humidity 5.7
Effect of momentary overload on current circuits 5.8
Effect of shock 5.9
Effect of short-time overload (thermoelement and rectifier-type instruments) 5.10
Effect of sustained overload on all circuits. 5.11
Effect of vibration 5.13
Influence, electrostatic field on window 5.19
Influence, circuit-to-ground-voltage. 5.18
Sticking below low end-scale mark (suppressed-zero instruments). 5.45
Sticking above end-scale mark. 5.44
Sticking below zero. 5.46
Window test (when windows are a separate item assembled to the cover or front) 5.53

6.29 Portable-Type Instruments (Introductory Notes and General Requirements). The portable instruments covered in Plates 14 through 17 embrace a wide variety of characteristics and applications. This standard is intended to ensure that instruments conforming to it will be satisfactory for general industrial and laboratory use as well as for standardizing in the higher-accuracy types.

It is to be noted that the intrinsic accuracy is obtained under controlled reference conditions, and a lesser degree of accuracy is obtained where certain listed influences apply. Where specific influences may be dominant, such as a high external field, or long sustained service at a higher than normal rating, special-service instruments designed to lessen the effect of these influences are usually procurable.

In the case of instruments having nonlinear scales, the accuracy limits for influences apply to 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.

The symbol "%" given in the plates under the column heading "Unit" refers to percent of fiducial value unless otherwise indicated.

All low-potential measuring instruments such as millivoltmeters and low-range ac voltmeters, whose accuracy is likely to be affected by changes in resistance of the connecting leads, shall be calibrated and supplied with leads having the resistance value specified in the plates.

Since portable instruments are used for numerous purposes for varying periods of time, many items are left to the discretion of the designer and user. Some of these items are as follows:

(1) Case shape, size, and material; handles and feet (the use of insulating materials for cases is recommended for future designs)

(2) Whether or not covers are furnished, and the type of hinging

(3) Type and location of terminals

(4) Ranges and type of range changing

(5) Push-button or other types of switches

For purposes of standardization of characteristics, portable microammeters, low-power-factor wattmeters, and certain other less common types of instruments are considered to be outside the scope of this standard. Although they are used widely, their characteristics of response time, loss, etc, are frequently beyond the normal limits and require special consideration.

Instruments designed for intermittent use only, with nonlocking push-button switches, are considered nonstandard and not within the purview of this standard.

All portable instruments conforming to this standard should be provided with permanent external identification by engraving or other suitable means signifying the electrical quantity to be measured and the rating of the instrument – for example, AC-DC Watts, 1000/500/250 W, 200/100 V, 5/2.5 A. Lettering should be 3/32 inch in height or larger to permit reading at a distance. The identification should be located at the side of the instrument that will make it visible when the instrument is placed on a shelf with its handle at the top and its cover or scale at the left. Other information, such as manufacturer's serial numbers, maximum ratings for potential and current circuits, resistance and inductance values for these circuits, frequency range, etc, is desirable but preferably should be on the scale or on the certificate inside the cover of the instrument. A few examples follow:

DC Volts: 300/150/75

AC-DC Amperes: 5/2.5

AC-DC Watts: 2/1/0.5/0.25 kW; 200/100/50 V; 10/5 A

Instruments of 0.1% accuracy are no longer manufactured in the United States.

7. Dimensional Characteristics and Detailed Requirements

The dimensional characteristics and detailed requirements for the instruments covered by this standard are given as follows:

Panel-type instruments
- Detailed requirements, Plates 1–4
- Dimensional characteristics, Fig. 6–8
- Back of panel cutout dimensions, Fig. A2

Panel-type instruments (edgewise) (horizontal or vertical)
- Detailed requirements, Plates 5–6
- Dimensional characteristics, Fig. 9 and A1

Rectangular switchboard-type instruments
- Detailed requirements, Plates 7–13
- Dimensional characteristics, Fig. 10 and 11

Portable-type instruments
- Detailed requirements, Plates 14–17

External resistors and boxes, Appendix I
Abbreviations and unit symbols, Appendix E
Markings and symbols, Appendix F

Table 1
Data to Be Furnished with 0.25 Accuracy Class Portable Instruments

Data	Direct-Current		Alternating-Current		
	Voltmeter	Ammeter	Voltmeter	Ammeter	Wattmeter
Manufacturer's name	x	x	x	x	x
Type or model	x	x	x	x	x
Serial number	x	x	x	x	x
Kind of instrument* or units measured	x	x	x	x	x
Reference temperature	x	x	x	x	x
Accuracy class	x	x	x	x	x
Ranges	x	x	x	x	x
Resistance	x	x	x	x	x
Resistance of leads†	x	—	x	—	x
Ambient-temperature influence or correction	x	x	x	x	x
Frequency influence or correction	—	—	x	x	x
Maximum rating	—	—	—	—	x
Principle of operation	x	x	x	x	x
Shielding	x	x	x	x	x
Data regarding use on direct current	—	—	x	x	x
Range-changing information†	x	x	x	x	x
Multiplying constants†	x	x	x	x	x
Inductance	—	—	x	x	x
Sustained operation influence	x	x	x	x	x
Power-factor influence	—	—	—	—	x

*Voltmeter, ammeter, wattmeter, etc.

†If applicable.

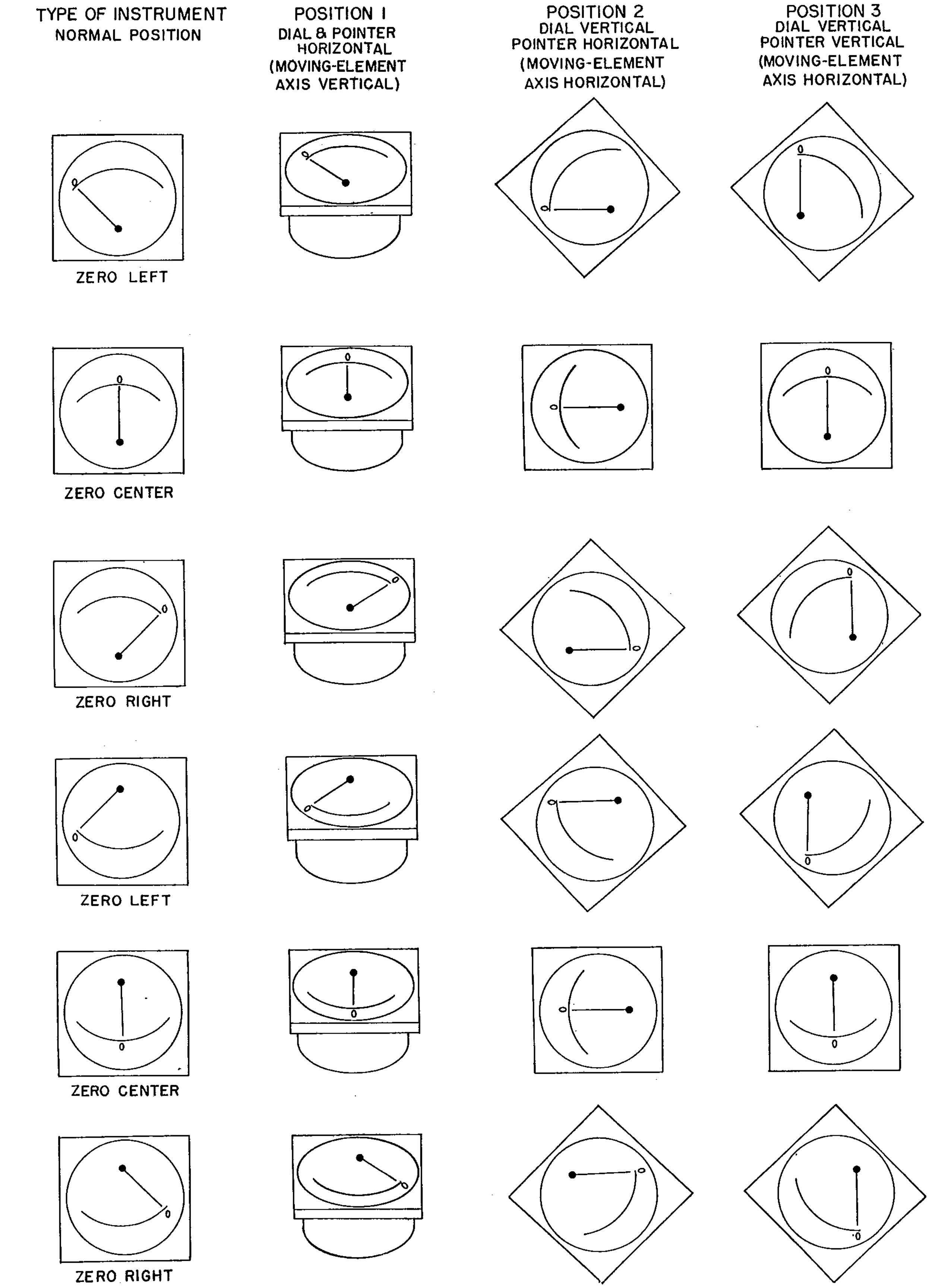


Fig. 1
Positions for Checking Balance Error in Round and Rectangular 90-Degree Instruments

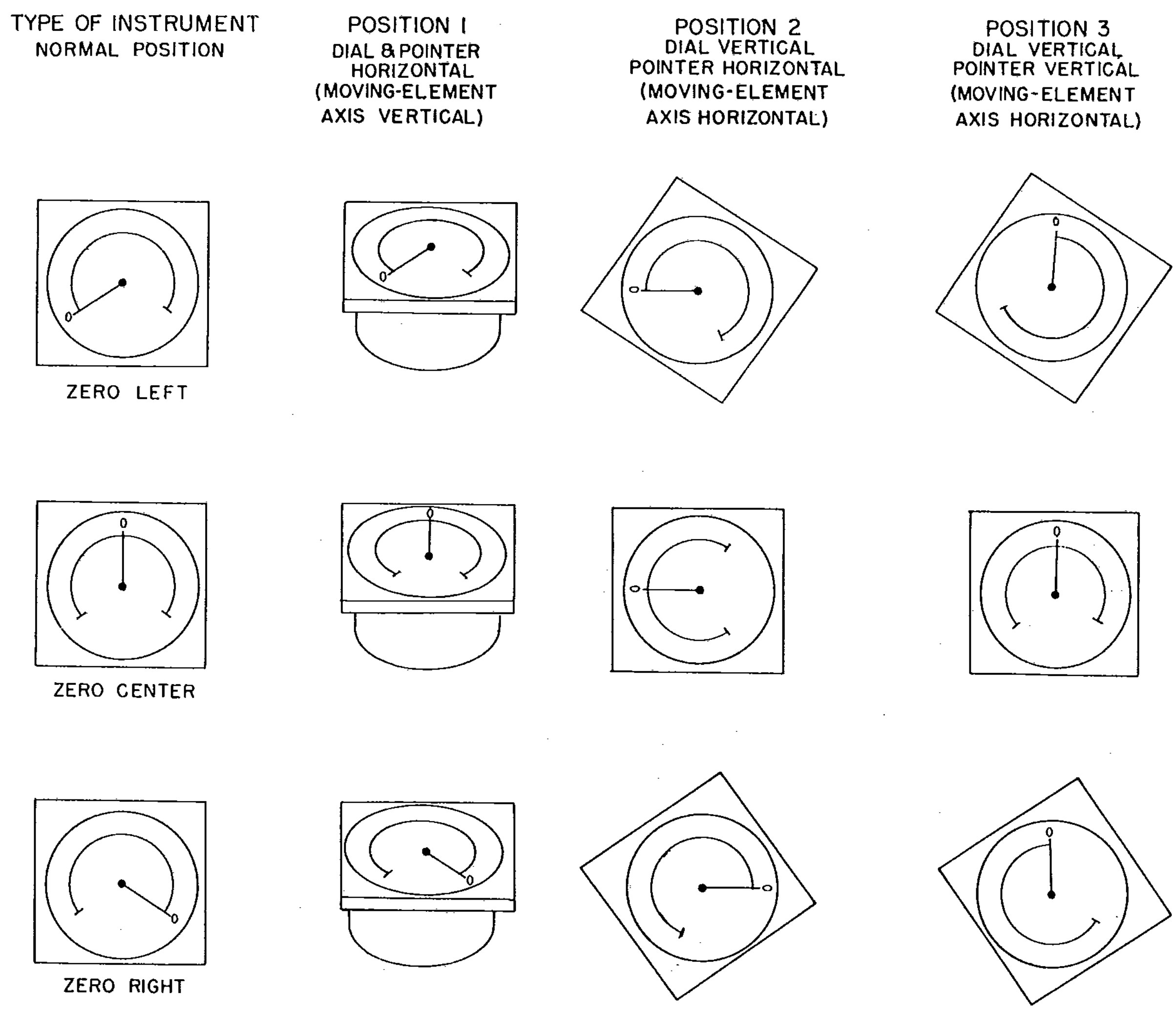


Fig. 2
Positions for Checking Balance Error in Round and Rectangular 250-Degree Instruments

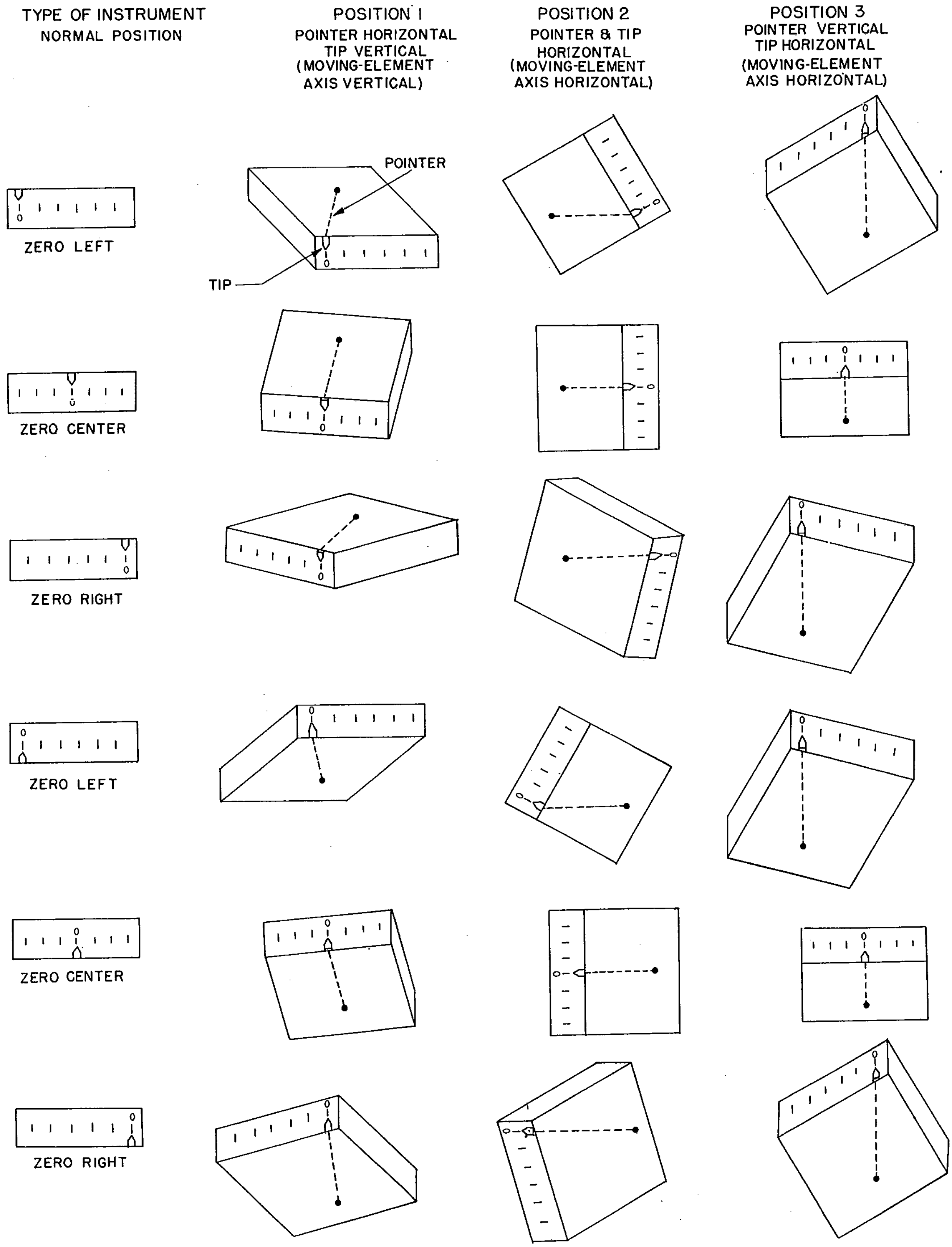


Fig. 3
Positions for Checking Balance Error in Horizontal Edgewise Instruments

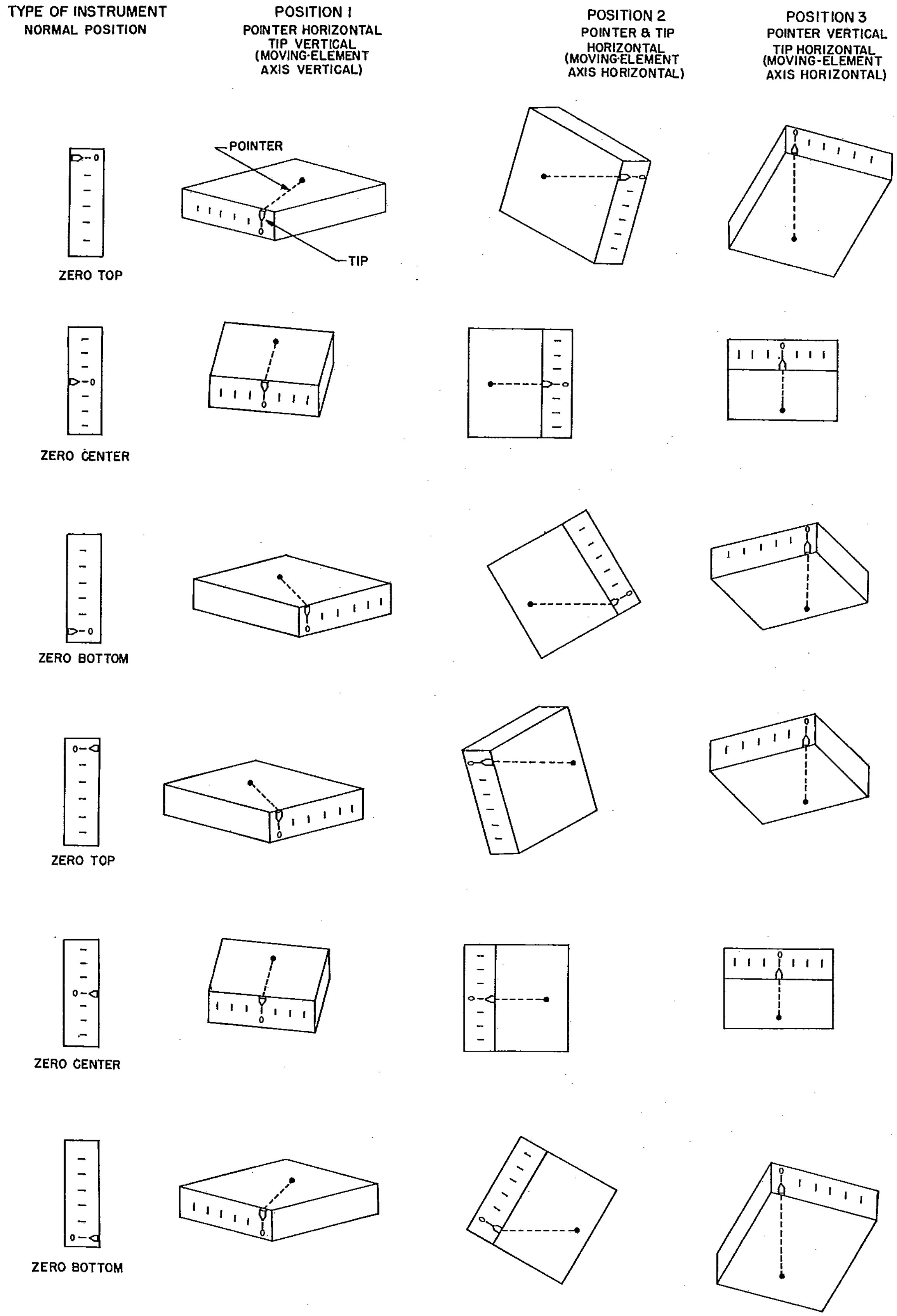
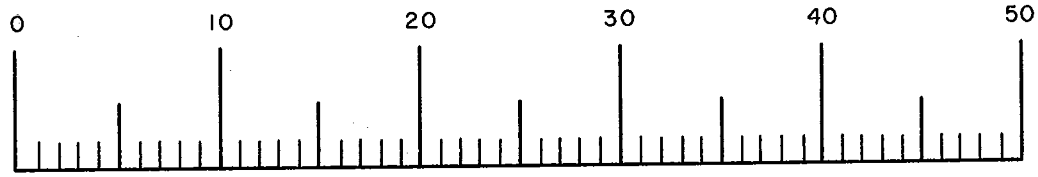
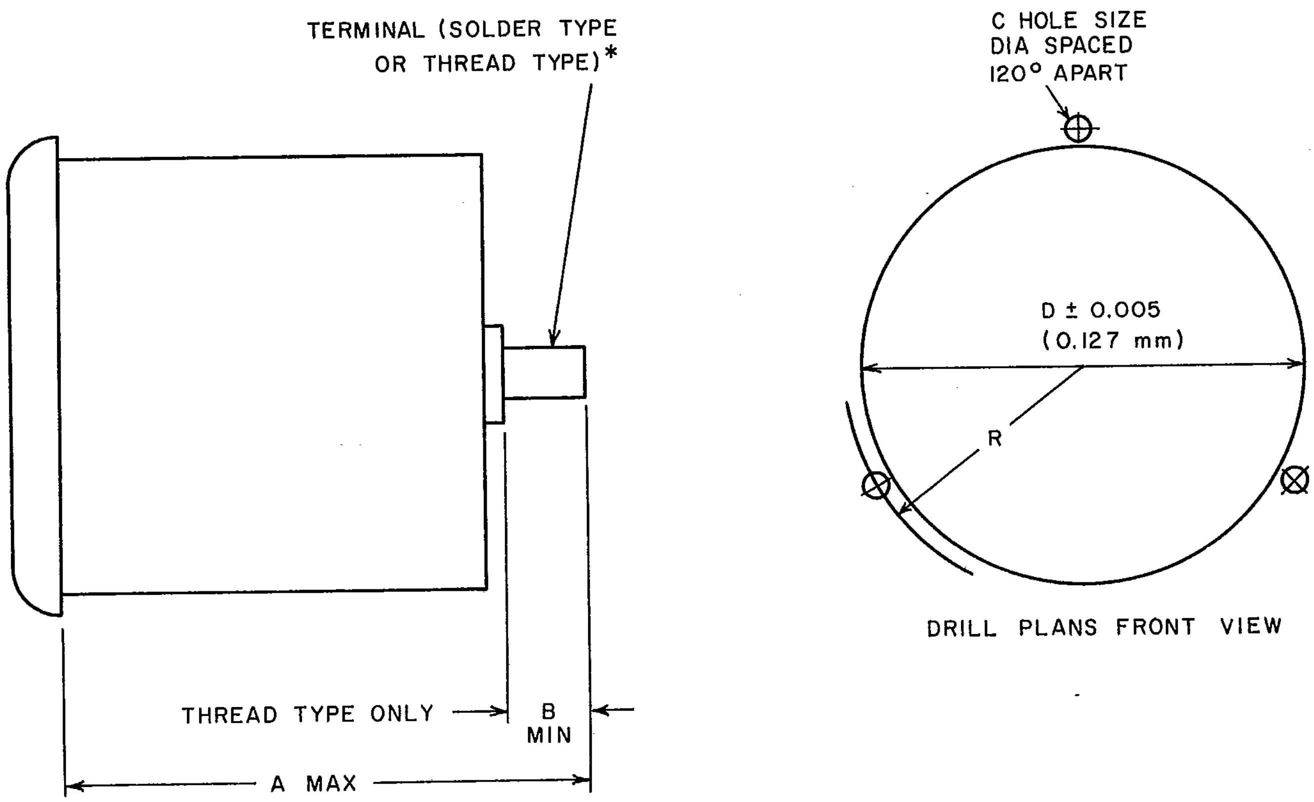


Fig. 4
Positions for Checking Balance Error in Vertical Edgewise Instruments



NOTES:
(1) As described in 6.19, the product of three numbers gives the total number of divisions; here, 5 X 2 X 5 = 50. For scales having no intermediate markings, the second number becomes 1.
(2) Scale numbers and their location may be specified – for example, 0, 10, 20, 30, 40, and 50 above (or below) scale.
(3) The linear scale designation may be used on nonlinear scales, suppressed zero scales, or expanded scales, but with the understanding that minor divisions may be omitted or reduced in number at the compressed portions of the scale and that the product of the three numbers describes the scale as if all the subdivisions were marked.

Fig. 5
Linear Scale

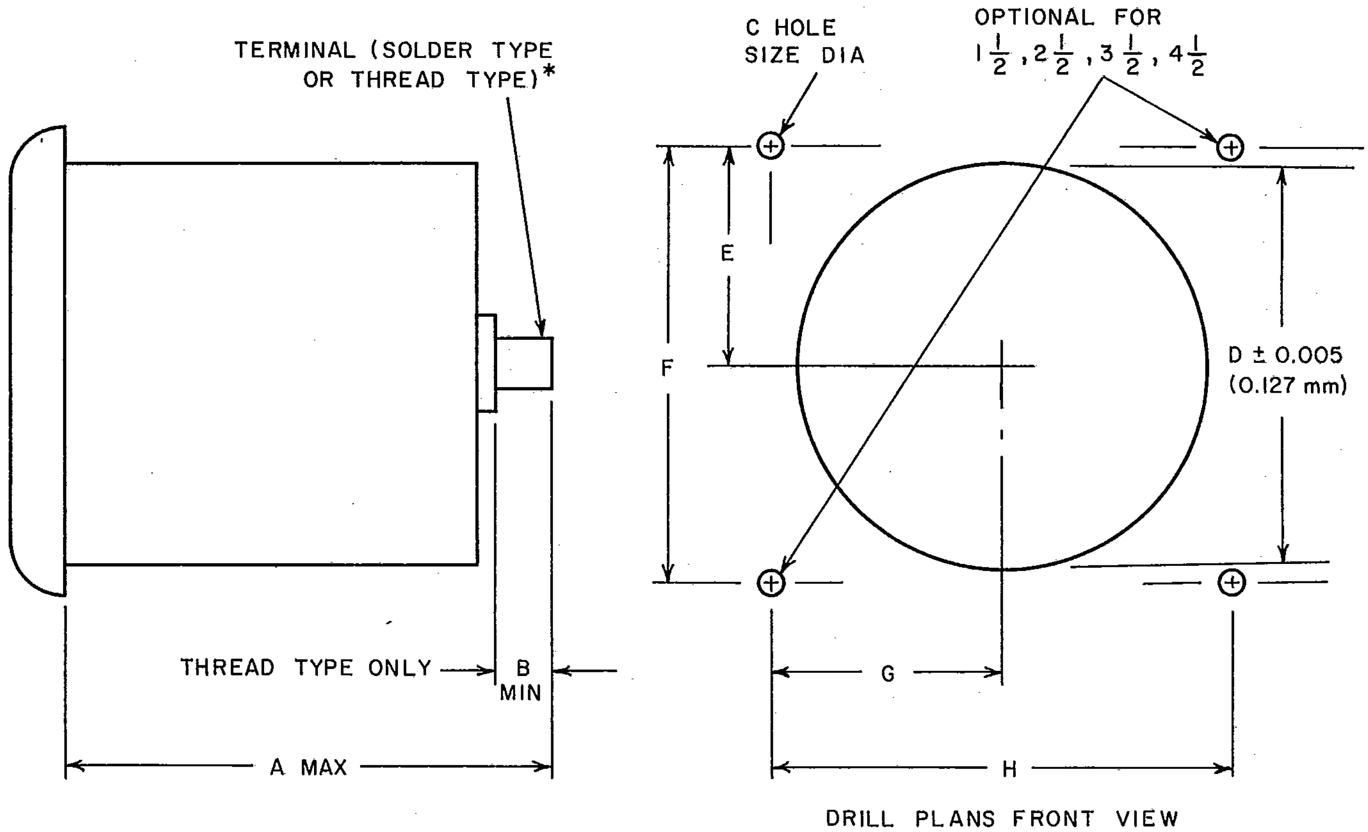


Case Size Reference	A	B	C	D	R
2.5	2.360 (59.9)	0.500 (12.7)	0.125 (3.2)	2.220 (56.4)	1.220 (30.1)
3.5	2.510 (63.7)	0.500 (12.7)	0.166 (4.2)	2.820 (71.6)	1.580 (40.1)

*Preferred terminal stud spacing and size for future design. See Appendix G.

NOTE: All dimensions are in inches (millimeters).

Fig. 6
Dimensions and Drill Plans for
Three-Hole Panel-Mounted Instruments

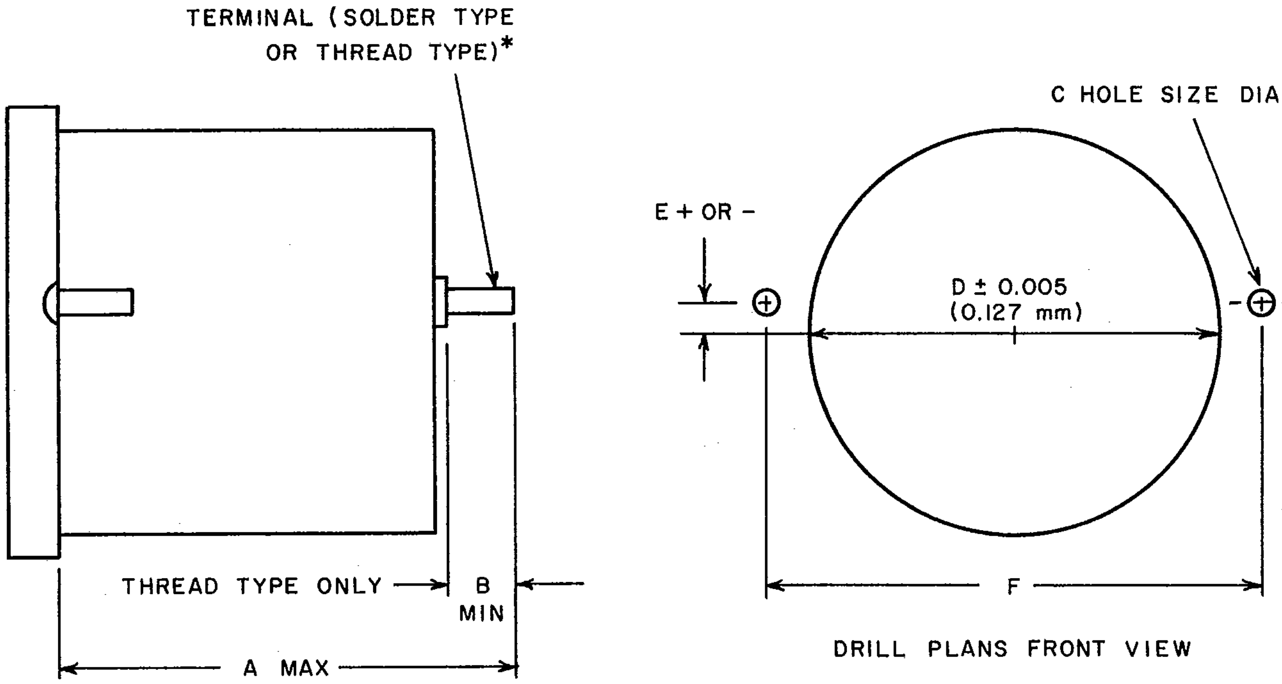


Case Size Reference	A	B	C	D	E	F	G	H
1.5	1.562 (39.7)	0.125 (3.2)	0.125 (3.2)	1.546 (39.3)	0.656 (16.7)	1.312 (33.4)	0.656 (16.7)	1.312 (33.3)
2.5	2.360 (59.9)	0.500 (12.7)	0.125 (3.2)	2.220 (56.4)	0.940 (23.9)	1.880 (47.7)	0.940 (23.9)	1.880 (47.7)
3.5	2.510 (63.8)	0.500 (12.7)	0.125 (3.2)	2.820 (71.6)	1.125 (28.6)	2.250 (57.2)	1.125 (28.6)	2.250 (57.1)
4.5	2.510 (63.8)	0.500 (12.7)	0.166 (4.2)	2.820 (71.6)	2.020 (51.3)	3.562 (90.5)	2.000 (50.8)	4.000 (101.6)
5.5	2.620 (66.5)	0.500 (12.7)	0.166 (4.2)	2.820 (71.6)	2.150 (54.6)	3.000 (76.2)	2.625 (66.7)	5.250 (133.3)
7.5	2.620 (66.5)	0.500 (12.7)	0.166 (4.2)	3.525 (89.5)	3.500 (88.9)	4.500 (114.3)	3.000 (76.2)	6.000 (152.4)
10.0	2.620 (66.5)	0.500 (12.7)	0.201 (5.1)	3.40 (102.8)	5.607 (142.4)	7.000 (177.8)	3.92 (99.6)	7.840 (199.0)

*Preferred terminal stud spacing and size for future design. See Appendix G.

NOTE: All dimensions are in inches (millimeters) and are nominal except as noted.

Fig. 7
Dimensions and Drill Plans for
Four-Hole Panel-Mounted Instruments



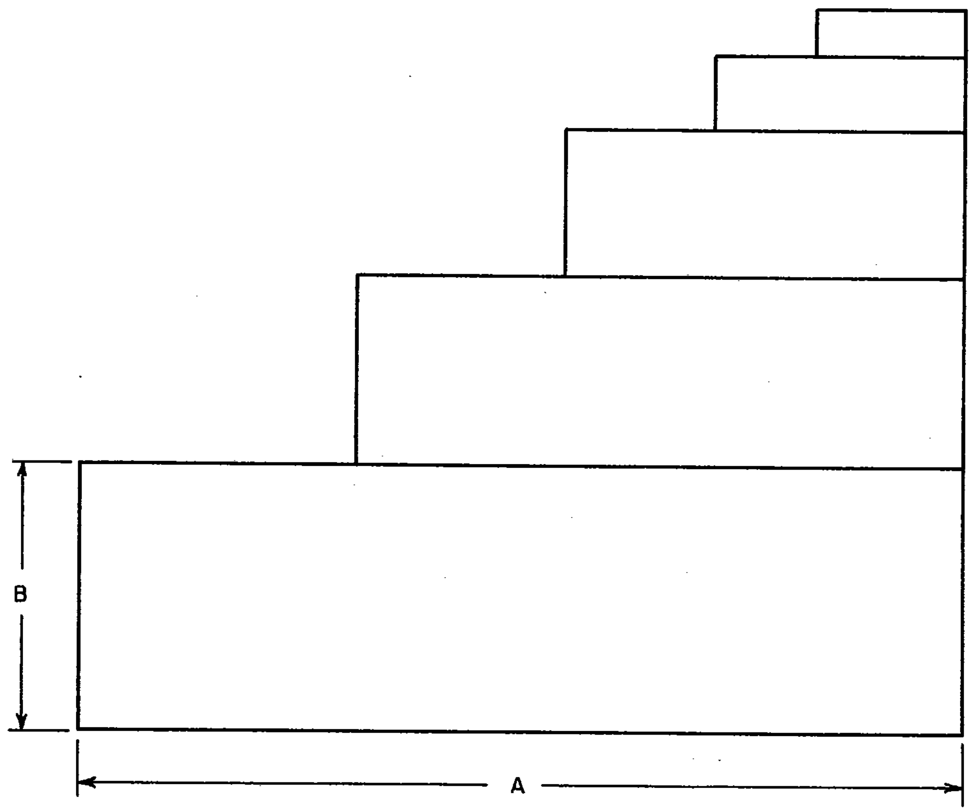
Case Size Reference	Face Size Reference	A	B	C	D	E	F
	3.5 x 3	2.070	0.500	0.156	2.250	0	2.625
		(52.6)	(12.7)	(4.0)	(57.2)		(66.7)
3.5	4.0 x 2.5	2.070	0.500	0.156	2.360		2.936
		(52.6)	(12.7)	(4.0)	(59.9)		(74.6)
	4.5 x 3.0	2.070	0.500	0.156	2.360	+0.194	3.500
		(52.6)	(12.7)	(4.0)	(59.9)	(4.9)	(88.9)
4.5	4.5 x 4.0	2.070	0.500	0.182	3.000	0	3.500
		(52.6)	(12.7)	(4.6)	(76.2)		(88.9)
	5.5 x 4.5	2.070	0.500	0.182	4.00	0	4.5
5.5		(52.6)	(12.7)	(4.6)	(101.6)		(114.3)

*Preferred terminal stud spacing and size for future design. See Appendix G.

NOTE 1: When the height of the instrument is such that the body extends more than 2 inches beyond the barrel, a mounting hole shall be provided to accommodate a third mounting stud, which will be located on the vertical centerline of the instrument, a minimum of 1/4 inch from the top edge and on the largest 1-inch numerical dimension measured from the horizontal centerline – that is, 6 inches or 5 inches or 4 inches or 3 inches, in that order of preference.

NOTE 2: All dimensions are in inches (millimeters) and are nominal except as noted.

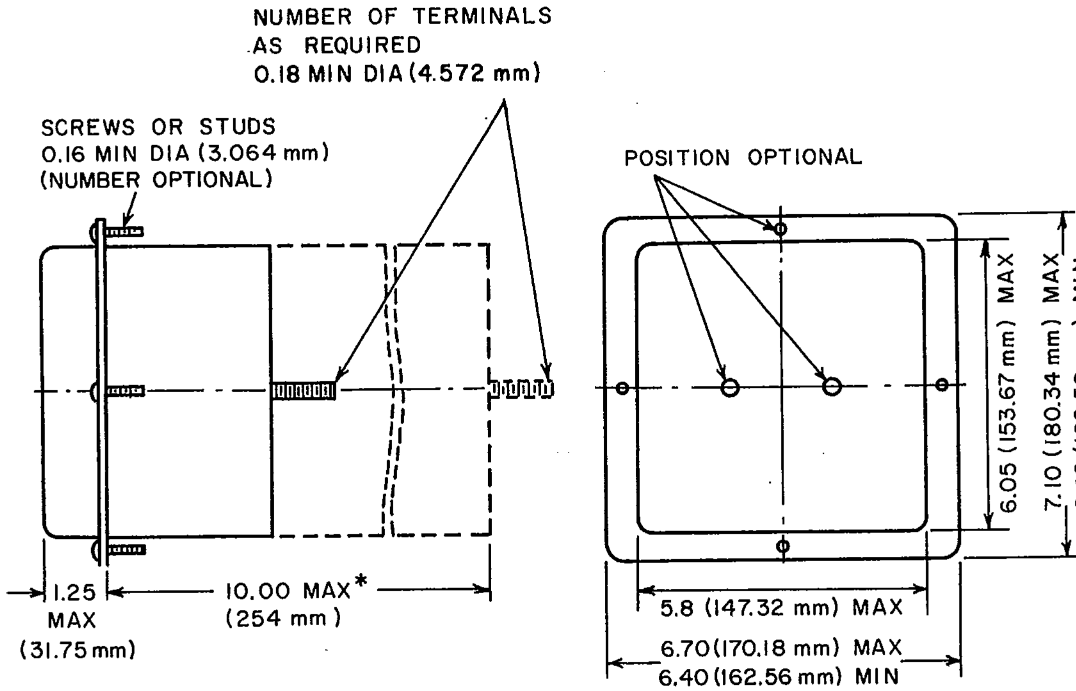
Fig. 8
Dimensions and Drill Plans for Two-Hole Panel-Mounted Instruments



Min Scale Length	Conventional Case Size Reference	Max Panel Opening A	Max Panel Opening B
1.0 (25.4)	1.5	1.66 (42.2)	0.51 (13.0)
1.6 (40.6)	2	2.26 (57.4)	0.76 (19.3)
2.5 (63.5)	3	3.32 (84.3)	1.14 (29.0)
4.0 (101.6)	5	5.52 (140.2)	1.90 (48.3)
6.3 (160.0)	8	8.53 (216.7)	3.03 (77.0)

NOTE: All dimensions are in inches (millimeters).

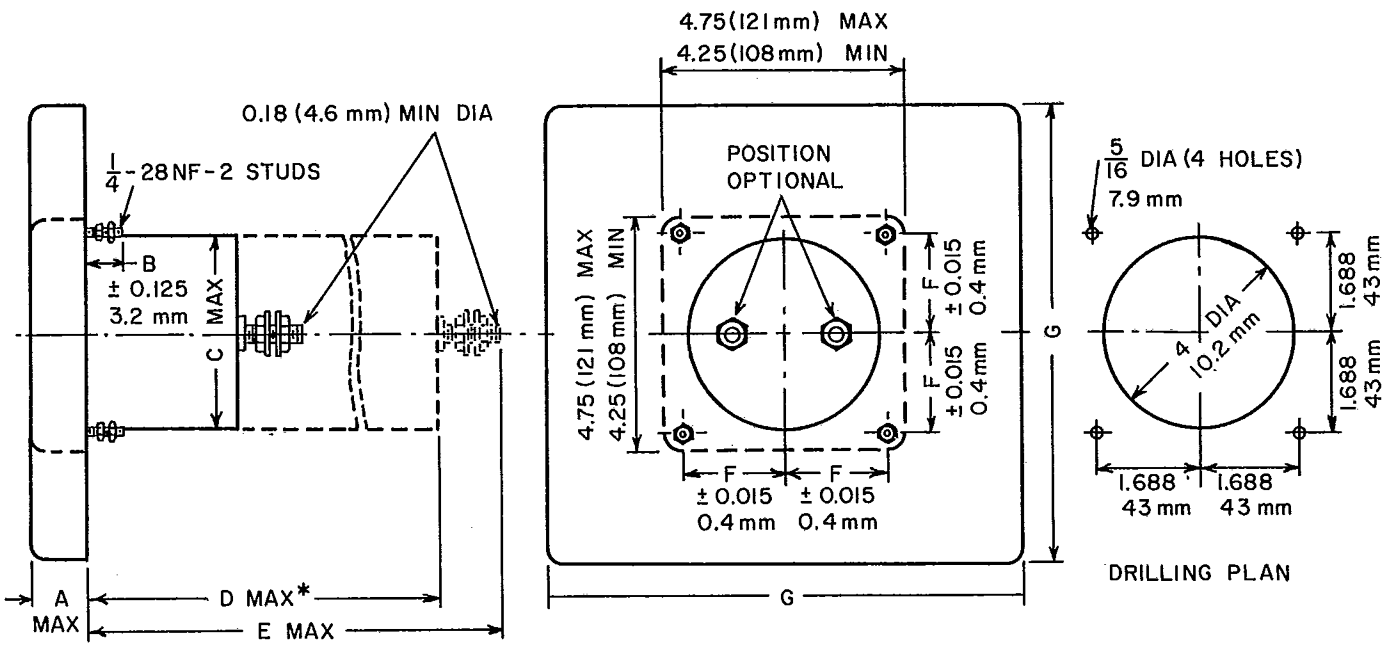
Fig. 9
Dimensions of Edgewise Panel Cutouts
(See Appendix A for Existing Designs)



*This dimension has been chosen to allow the mounting of accessories on instrument proper.

NOTE: All dimensions are in inches (millimeters).

Fig. 10
Dimensional Characteristics of
6-Inch 90-Degree Switchboard-Type Instruments



	A	B	C	D	E	F	G
4.5 inch (114 mm)	1.00 (25.4)	0.625 (15.9)	3.98 (101)	9.00 (229)	10.00 (254)	1.688 (43)	(see Fig.) (see Fig.)
8.5 inch (216 mm)	1.125 (29)	0.625 (15.9)	3.98 (101)	9.00 (229)	10.00 (254)	1.688 (43)	8.75 (222)

*This dimension has been chosen to allow the mounting of accessories on instrument proper.

NOTE: All dimensions are in inches (millimeters) and are nominal unless otherwise specified.

Fig. 11
Dimensional Characteristics of
4-1/2-Inch and 8-3/4-Inch 250-Degree Switchboard-Type Instruments

Plate 1
Panel Instruments (Except Edgewise)
Millivoltmeters, Voltmeters, Kilovoltmeters, Milliammeters, Ammeters
Accuracy Class: 0.5–3.0
Application or Use: Direct Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				0.5	1.0	2.0	3.0
Factors Relating to Accuracy Class							
Intrinsic accuracy		5.2	% fiducial	0.5	1.0	2.0	3.0
Scale length	see size requirements	5.42	inches min	3.70	2.5	1.5	1.0
			mm min	94	64	38	25
Repeatability	micam ⩾ 200 μA	5.39	% fid max	0.5	1.0	1.0	1.5
	micam ⩽ 200 μA			0.5	1.0	2.0	3.0
Balance	< 5-inch case size and all instruments ⩾ 50 μA	5.3	% scale length max	1.0	1.0	2.0	3.0
	⩾ 5-inch case size and all instruments ⩽ 50 μA		% scale length max	1.5	1.5	2.0	3.0
Influences							
External temperature	micam	5.21	% fid max	0.5	0.5	0.5	1.0
	mam < 10 mA		% fid max	0.5	0.5	0.5	1.0
	vm		% fid max	0.5	0.5	0.5	1.0
	mam ⩾ 10 mA		% fid max	1.0	1.0	1.0	1.0
	amm		% fid max	1.0	1.0	1.0	1.0
	mvm ⩾ 50 mV		% fid max	1.0	1.0	1.0	1.0
Ferrous panel	thickness applicable only where required	5.24	mm	2.3	2.3	2.3	2.3
			inches	0.09	0.09	0.09	0.09
Sustained operation		5.27	% fid max	0.5	0.75	1.5	2.5
Proximity	adjacent dc instrument	5.30	% fid max	0.75	0.75	0.75	1.0
Voltage, rated circuit-to-ground		5.18	% scale length max	0.5	1.0	2.0	3.0
Effects							
Extreme temperature		5.6	% fid max	2.0	2.0	2.0	3.0
Usage		5.12	% fid max	0.5	0.75	1.5	2.5
Momentary overload		5.8	% fid max	1.0	1.0	2.0	3.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.5
	accuracy	5.11	% fid max	0.5	0.75	1.0	1.5
Shock		5.9	% fid max	2.0	2.0	2.0	3.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	2.0	2.0	3.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	5.0

Plate 1 (*continued*)

Item*	Comments	Test	Unit	Limits						
Factors Relating to Physical Size										
Case size reference			inches mm	1.5 38	2.5 64	3.5 89	4.5 114	5.5 140	7.5 190	10.0 254
Voltage, rated circuit-to-ground			V peak	350	1100	1100	1100	1100	1100	1100
Overshoot		5.38	% max	20	20	25	25	30	30	30
Response time	micam ⩾ 50 to 999 μA	5.41	seconds max	2.0	3.0	3.0	3.0	5.0	5.0	6.0
	mvm ⩾ 50 mV		seconds max	2.0	2.0	2.0	2.0	4.0	4.0	5.0
	vm		seconds max	2.0	2.0	2.0	2.0	4.0	4.0	5.0
	kvm		seconds max	2.0	2.0	2.0	2.0	4.0	4.0	5.0
	amm and mam		seconds max	2.0	2.0	2.0	2.0	4.0	4.0	5.0
Dielectric test voltage (Note 3)		5.5	V rms	1500	2600	2600	2600	2600	2600	2600
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20	20	20	20
Scale length	see accuracy class requirements	5.42	inches min mm min	1.0 25	1.5 38	2.5 64	3.5 89	4.5 114	6.5 165	9.0 229
Self-contained ranges			A max	10	50	50	50	50	50	50
			V max	150	300	500	800	800	800	800
Dimensions and drill plans (Fig. 6, 7, and 8)										
Normal operating position			dial	vertical	vertical	vertical	vertical	vertical	vertical	vertical
Current loading voltage drop, and resistance (excluding ammeters)	micam (Note 2)	5.40	ohms max	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$
	mam (Note 2)	5.40	ohms max	$\frac{150}{I_f (mA)}$	$\frac{150}{I_f (mA)}$	$\frac{150}{I_f (mA)}$	$\frac{150}{I_f (mA)}$	$\frac{200}{I_f (mA)}$	$\frac{250}{I_f (mA)}$	$\frac{300}{I_f (mA)}$
	mvm	5.4	Ω/V min	80	80	80	80	80	80	80
	vm (Note 1)	5.4	Ω/V ± 5%	1000	1000	1000	1000	1000	1000	1000
	kvm (Note 1)	5.4	Ω/V ± intrinsic accuracy	1000	1000	1000	1000	1000	1000	1000
Voltage drop for self-contained ammeters		5.51	mV ± 10%	50	50	50	50	50	50	50

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: When higher resistance is required, the preferred value is 5000 Ω/V ± intrinsic accuracy.

NOTE 2: I_f = fiducial value.

NOTE 3: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts for all instruments other than 1-1/2-inch instruments.

Plate 2
Panel Instruments
Voltmeters, Ammeters, Milliammeters
Accuracy Class: 1, 2, and 3
Application or Use: Alternating Current (Moving-Iron Type)

Item*	Comments	Test	Unit	Limits			
Accuracy class				1.0	2.0	3.0	
Factors Relating to Accuracy Class							
Intrinsic accuracy		5.2	% fiducial	1.0	2.0	3.0	
Scale length	see size requirements	5.42	inches min mm min	2.5 64	1.5 38	1.0 25	
Repeatability		5.39	% fid max	1.5	2.0	3.0	
Balance	< 5-inch case size	5.3	% scale length max	1.0	2.0	3.0	
	⩾ 5-inch case size instruments < 50 μA	5.3	% scale length max	1.5	2.0	3.0	
Influences							
External temperature	vm	5.21	% fid max	1.0	1.0	2.0	
	amm	5.21	% fid max	0.5	0.5	0.5	
	mam	5.21	% fid max	0.5	0.5	0.5	
Frequency (Note 4)	60-Hz instruments	5.23	% fid max	0.5	0.5	0.5	
	400-Hz instruments	5.23	% fid max	2.0	2.0	2.0	
	800-Hz instruments	5.23	% fid max	2.0	2.0	2.0	
Sustained operation		5.27	% fid max	2.0	2.0	3.0	
Waveform		5.34	% fid max	1.0	1.0	1.0	
Voltage, rated circuit-to-ground		5.18	% scale length max	1.0	2.0	3.0	
Effects							
Extreme temperature		5.6	% fid max	2.0	2.0	3.0	
Usage		5.12	% fid max	2.0	2.0	3.0	
Momentary overload		5.8	% fid max	2.0	2.0	2.0	
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	
	accuracy	5.11	% fid max	1.0	1.0	1.0	
Shock		5.9	% fid max	2.0	2.0	3.0	
Humidity		5.7	% scale length max	3.0	3.0	3.0	
Vibration	accuracy	5.13	% fid max	2.0	2.0	3.0	
	repeatability after vibration	5.39	% fid max	4.0	4.0	5.0	
Factors Relating to Physical Size							
Case size reference			inches mm	2.5 64	3.5 89	4.5 114	5.5 140
Voltage, rated circuit-to-ground			V peak	1100	1100	1100	1100
Overshoot		5.38	% max	40	40	67	67

Plate 2 (*continued*)

Item*	Comments	Test	Unit	Limits			
Factors Relating to Physical Size (*continued*)							
Response time		5.41	seconds max	2.5	2.5	2.5	3.0
Dielectric test voltage (Note 3)		5.5	V rms	2600	2600	2600	2600
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Self-contained ranges	amm vm		A max V max	30 300	50 300	50 300	50 300
Scale length	see accuracy class requirements	5.42	inches min mm min	1.5 38	2.5 64	3.5 89	4.5 114
Normal operating position			dial	vertical	vertical	vertical	vertical
Dimensions and drill plans (Fig. 6, 7, and 8)							
	vm, 60 Hz	5.16	Ω/V min	$\frac{V_{fs}}{3}$	$\frac{V_{fs}}{3}$	$\frac{V_{fs}}{3}$	$\frac{V_{fs}}{3}$
	vm, 400 Hz	5.16	Ω/V min	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$
	vm, 800 Hz	5.16	Ω/V min	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$	$\frac{V_{fs}}{4}$
	mam, 60 Hz	5.16	Ω max	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$
	amm < 30 A, 60 Hz	5.16	Ω max	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$	$\frac{1}{(I_{fs})^2}$
Current loading voltage drop and impedance for self-contained instruments (Notes 1 and 2)	amm ⩾ 30 ⩽ 50 A, 60 Hz	5.16	Ω max	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$
	mam, 400 Hz	5.16	Ω max	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$
	amm < 30 A, 400 Hz	5.16	Ω max	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$	$\frac{2}{(I_{fs})^2}$
	amm ⩾ 30 ⩽ 50 A, 400 Hz	5.16	Ω max	$\frac{3}{(I_{fs})^2}$	$\frac{3}{(I_{fs})^2}$	$\frac{3}{(I_{fs})^2}$	$\frac{3}{(I_{fs})^2}$
	mam, 800 Hz	5.16	Ω max	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$
	amm < 300 A, 800 Hz	5.16	Ω max	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$	$\frac{4}{(I_{fs})^2}$
	amm ⩾ 30 ⩽ 50 A, 800 Hz	5.16	Ω max	$\frac{5}{(I_{fs})^2}$	$\frac{5}{(I_{fs})^2}$	$\frac{5}{(I_{fs})^2}$	$\frac{5}{(I_{fs})^2}$

*See Section 3 for an alphabetical listing of definitions of terms used in Plate.

NOTE 1: V_{fs} = rated full-scale voltage of instrument. The denominator denotes the maximum voltamperes.

NOTE 2: $(I_{fs})^2$ = rated full-scale current squared of instrument. The numerator denotes the maximum voltamperes.

NOTE 3: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts.

NOTE 4: With ±10% deviation from rated frequency.

Plate 3
Panel Instruments
Ammeters, Milliammeters
Accuracy Class: 2.0
Application or Use: AC or DC Thermocouple Type

Item*	Comments	Test	Unit	Limits
Accuracy class				2.0
Factors Relating to Accuracy Class				
Intrinsic accuracy		5.2	% fiducial	2.0
Scale length	see size requirements	5.42	inches min mm min	1.5 38
Balance		5.3	% scale length max	2.0
Influences				
External temperature		5.21	% fid max	2.0
Extreme temperature		5.6	% fid max	10
Calibrating frequency			Hz	60
Ferrous panel (thickness only where required)			inches mm	0.09 2.3
Voltage, rated circuit-to-ground		5.18	% scale length max	2.0
Effects				
Extreme temperature		5.6	% fid max	2.0
Usage		5.12	% fid max	2.0
Short-time overload		5.10	% fid max	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0
	accuracy	5.11	% fid max	1.0
Shock		5.9	% fid max	2.0
Humidity		5.7	% scale length max	3.0
Vibration		5.13	% fid max	2.0

Plate 3 (*continued*)

Item*	Comments	Test	Unit	Limits			
Factors Relating to Physical Size							
Case size reference			inches mm	2.5 64	3.5 89	4.5 114	5.5 140
Voltage, rated circuit-to-ground		5.15	V peak	1100	1100	1100	1100
Overshoot		5.38	% max	40	40	40	40
Response time		5.41	seconds max	2.5	2.5	2.5	2.5
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Dielectric withstanding (Note 2)		5.5	V rms	2600	2600	2600	2600
Scale length	see accuracy class requirements	5.42	inches min mm min	1.5 38	2.5 64	3.5 89	4.5 114
Self-contained ranges	thermosetting back		A max	20	20	20	20
	thermoplastic back		A max	5	5	5	5
Dimensions and drill plans (Fig. 6, 7, and 8)							
Normal operating position			dial	vertical	vertical	vertical	vertical
Voltage drop across heating element with end-scale deflection (Note 1)	> 5 mA to 150 mA inclusive	5.51	V max	1.4	1.4	1.4	1.4
	> 150 mA < 1000 mA	5.51	V max	0.8	0.8	0.8	0.8
	⩾ 1 A < 10 A	5.51	V max	0.5	0.5	0.5	0.5
	⩾ 10 A	5.51	V max	0.25	0.25	0.25	0.25

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: These values are determined using dc or 60 Hz ac and apply as well to external thermocouple converters used with instruments.

NOTE 2: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts for all instruments other than 1-1/2-inch instruments.

Plate 4
Panel Instruments (Except Edgewise)
Voltmeters, Milliammeters, Microammeters
Accuracy Class: 3.0, 5.0
Application or Use: AC (Rectifier Type)

Item*	Comments	Test	Unit	Limits	
Accuracy class				3.0	5.0
		Factors Relating to Accuracy Class			
Intrinsic accuracy		5.2	% fiducial	3.0	5.0
Scale length	see size requirements	5.42	inches min mm min	1.5 38	1.0 25
Repeatability		5.39	% fid max	2.0	3.0
Balance		5.3	% scale length max	2.0	3.0
		Influences			
External temperature	vm > 10 V	5.21	% fid max	1.0	1.0
	mam	5.21	% fid max	1.0	1.0
	micam	5.21	% fid max	1.0	1.0
Calibrating frequency			Hz	60	60
Sustained operation		5.27	% fid max	3.0	5.0
Proximity	adjacent ac rectifier-type instruments	5.30	% fid max	1.0	1.0
Voltage, rated circuit-to-ground		5.18	% scale length max	3.0	5.0
		Effects			
Extreme temperature	vm > 10 V, mam, and micam	5.6	% fid max	3.0	5.0
Usage		5.12	% fid max	3.0	5.0
Short-time overload		5.10	% fid max	1.0	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.5
	accuracy	5.11	% fid max	1.5	3.0
Shock		5.9	% fid max	2.0	3.0
Humidity		5.7	% scale length max	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	3.0
	repeatability after vibration	5.39	% fid max	4.0	6.0

Plate 4 (*continued*)

Item*	Comments	Test	Unit	Limits						
			Factors Relating to Physical Size							
Case size reference			inches mm	1.5 38	2.5 64	3.5 89	4.5 114	5.5 140	7.5 190	10.0 254
Voltage, rated circuit-to-ground			V peak	350	1100	1100	1100	1100	1100	1100
Current loading and resistance	micam and mam	5.40	Ω max	$\frac{1100}{I_{fs}}$†	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$
	vm > 10 V (pref nom value)	5.4	Ω/V ± 5%	1000	1000	1000	1000	1000	1000	1000
Overshoot		5.38	% max	20	20	25	25	30	30	30
Response time		5.41	seconds max	2.0	2.0	2.0	2.0	4.0	4.0	6.0
Dielectric test voltage		5.5	V rms	1500	2600	2600	2600	2600	2600	2600
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20	20	20	20
Scale length	see accuracy class requirements	5.42	inches min mm min	1.0 25	1.5 38	2.5 64	3.5 89	4.5 114	6.5 165	9.0 228
Self-contained ranges			mA max	20	20	20	20	20	20	20
			V max	150	300	300	300	300	300	300
Dimensions and drill plans (Fig. 6, 7, and 8)										
Normal operating position			dial	vertical	vertical	vertical	vertical	vertical	vertical	vertical

*See Section 3 for an alphabetical listing of definitions of terms used.

†I_{fs} = full-scale current of instrument in milliamperes.

Plate 5
Panel Instruments (Edgewise Only)
Millivoltmeters, Voltmeters, Kilovoltmeters, Microammeters, Milliammeters, Ammeters
Accuracy Class: 0.5–3.0
Application or Use: Direct Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				0.5	1.0	2.0	3.0
Factors Relating to Accuracy Class							
Intrinsic accuracy		5.2	% fiducial	0.5	1.0	2.0	3.0
Scale length	see physical size requirements	5.42	inches min mm min	3.7 94	2.5 64	1.5 38	1.0 25
Repeatability	micam > 200 μA micam ⩽ 200 μA	5.39	% fid max % fid max	0.5 0.5	1.0 1.0	1.0 2.0	1.5 3.0
Balance	< 5-inch case size and all instruments > 50 μA	5.3	% scale length max	1.0	1.0	2.0	3.0
	⩾ 5-inch case size and all instruments ⩽ 50 μA	5.3	% scale length max	1.5	1.5	2.0	3.0
Influences							
External temperature	micam	5.21	% fid max	0.5	0.5	0.5	1.0
	mam < 10 mA	5.21	% fid max	0.5	0.5	0.5	1.0
	vm	5.21	% fid max	0.5	0.5	0.5	1.0
	mam ⩾ 10 mA	5.21	% fid max	1.0	1.0	1.0	1.0
	amm	5.21	% fid max	1.0	1.0	1.0	1.0
	mvm	5.21	% fid max	1.0	1.0	1.0	1.0
Ferrous panel	thickness applicable only where required	5.24	mm inches	2.3 0.09	2.3 0.09	2.3 0.09	2.3 0.09
Sustained operation		5.27	% fid max	0.5	0.75	1.5	2.5
Proximity	adjacent dc instrument	5.30	% fid max	0.75	0.75	0.75	1.0
Voltage, rated circuit-to-ground		5.18	% scale length max	0.5	1.0	2.0	3.0
Effects							
Extreme temperature		5.6	% fid max	2.0	2.0	2.0	3.0
Usage		5.12	% fid max	0.5	0.75	1.5	2.5
Momentary overload		5.8	% fid max	1.0	1.0	2.0	3.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.5
	accuracy	5.11	% fid max	0.5	0.75	1.0	1.5
Shock		5.9	% fid max	2.0	2.0	2.0	3.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	2.0	2.0	3.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	5.0

Plate 5 (*continued*)

Item*	Comments	Test	Unit	Limits				
Factors Relating to Physical Size								
Case size reference			inches mm	1.5 38	2.0 51	3.0 76	5.0 127	8.0 203
Voltage, rated circuit-to-ground			V peak	350	350	350	1100	1100
Overshoot		5.38	% max	25	40	40	40	40
Response time	micam ⩾ 50 to ⩽ 999 μA	5.41	seconds max	3.0	3.0	3.0	4.0	6.0
	vm	5.41	seconds max	2.0	2.0	2.0	3.0	5.0
	mvm ⩾ 50 mV	5.41	seconds max	2.0	2.0	2.0	3.0	5.0
	kvm	5.41	seconds max	2.0	2.0	2.0	3.0	5.0
	mam	5.41	seconds max	2.0	2.0	2.0	3.0	5.0
	amm	5.41	seconds max	2.0	2.0	2.0	3.0	5.0
Dielectric test voltage (Note 1)		5.5	V rms	1500	1500	1500	2600	2600
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20	20
Scale length	see accuracy class requirements	5.42	inches min mm min	1.0 25	1.6 41	2.5 64	4.0 102	6.3 160
Self-contained ranges			A max	10	10	30	50	50
			V max	150	200	200	800	800
Dimensions and drill plans (Fig. 9)								
Current loading, voltage drop and resistance (excluding ammeters) (Note 2)	micam	5.40	ohms max	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$	$\frac{3 \times 10^5}{I_f (\mu A)}$
	mam	5.40	ohms max	$\frac{150}{I_f (mA)}$	$\frac{150}{I_f (mA)}$	$\frac{150}{I_f (mA)}$	$\frac{200}{I_f (mA)}$	$\frac{250}{I_f (mA)}$
	mvm	5.4	Ω/V min	80	80	80	80	80
	vm	5.4	Ω/V ± 5%	1000	1000	1000	1000	1000
	vm (alternate)	5.4	Ω/V ± 5%	5000	5000	5000	5000	5000
	kvm	5.4	Ω/V ± intrinsic accuracy %	1000	1000	1000	1000	1000
	kvm (alternate)	5.4	Ω/V ± intrinsic accuracy %	5000	5000	5000	5000	5000
Voltage-drop ammeters	amm, self-contained	5.51	mV ± 10%	50	50	50	50	50
Normal operating position			dial	vertical	vertical	vertical	vertical	vertical
Front zero adjuster required				no	no	yes	yes	yes

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts for all instruments other than 1-1/2-inch instruments.

NOTE 2: I_f = fiducial value.

Plate 6
Panel Instruments (Edgewise Only)
Voltmeters, Milliammeters, Microammeters
Accuracy Class: 3.0 and 5.0
Application or Use: AC (Rectifier Type)

Item*	Comments	Test	Unit	Limits	
Accuracy class				3.0	5.0
Factors Relating to Accuracy Class					
Intrinsic accuracy		5.2	% fiducial	3.0	5.0
Scale length	see physical size requirements	5.42	inches min mm min	1.5 38	1.0 25
Repeatability		5.39	% fid max	2.0	3.0
Balance		5.3	% scale length max	2.0	3.0
Influences					
External temperature	vm > 10 V	5.21	% fid max	1.0	1.0
	mam	5.21	% fid max	1.0	1.0
	micam	5.21	% fid max	1.0	1.0
Calibrating frequency			Hz	60	60
Sustained operation		5.27	% fid max	3.0	5.0
Proximity	adjacent ac rectifier-type instruments	5.30	% fid max	1.0	1.0
Voltage, rated circuit-to-ground		5.18	% scale length max	3.0	5.0
Effects					
Extreme temperature	vm > 10 V, mam, and micam	5.6	% fid max	3.0	5.0
Usage		5.12	% fid max	3.0	5.0
Short-time overload		5.10	% fid max	1.0	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.5
	accuracy	5.11	% fid max	1.5	3.0
Shock		5.9	% fid max	2.0	3.0
Humidity		5.7	% scale length max	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	3.0
	repeatability after vibration	5.39	% fid max	4.0	6.0

Plate 6 (*continued*)

Item*	Comments	Test	Unit	Limits				
Factors Relating to Physical Size								
Case size reference			inches mm	1.5 38	2.0 51	3.0 76	5.0 127	8.0 203
Voltage, rated circuit-to-ground			V peak	350	350	350	1100	1100
Current loading and resistance	micam and mam	5.40	Ω max	$\frac{1100}{I_{fs}}$†	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$	$\frac{1100}{I_{fs}}$
	vm > 10 V (pref nom value)	5.4	Ω/V ± 5%	1000	1000	1000	1000	1000
Overshoot		5.38	% max	25	40	40	40	40
Response time		5.41	seconds max	2.0	2.0	2.0	3.0	5.0
Dielectric test voltage		5.5	V rms	1500	1500	1500	2600	2600
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20	20
Scale length	see accuracy class requirements	5.42	inches min mm min	1.0 25	1.6 41	2.5 64	4.0 102	6.3 160
Self-contained ranges			A max	20	20	20	20	20
			V max	150	300	300	300	300
Dimensions and drill plans (Fig. 9)								
Front zero adjuster required				no	no	yes	yes	yes
Normal operating position			dial	vertical	vertical	vertical	vertical	vertical

*See Section 3 for an alphabetical listing of definitions of terms used.

†I_{fs} = full-scale current of instrument in milliamperes.

Plate 7
Rectangular Switchboard Instruments (90- and 250-Degree Nominal)
Ammeters, Milliammeters, Voltmeters, Millivoltmeters, Kilovoltmeters
Accuracy Class: 1
Application or Use: Direct Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				1.0	1.0	1.0	1.0
Case size	conventional identification		inches mm	4.5 114	4.5 114	6.0 152	8.75 222
Scale angle	nominal		degrees	90	250	90	250
			Factors Relating to Accuracy Class				
Intrinsic accuracy		5.2	% fiducial	1.0	1.0	1.0	1.0
Scale length		5.42	inches min mm min	3.2 81	6.8 172	5.0 127	13.6 345
Repeatability	< 1.0 mA ⩾ 1.0 mA	5.39	% fid max % fid max	1.0 0.5	1.0 0.5	1.0 0.5	1.0 0.5
Balance		5.3	% scale length max	1.0	1.0	1.0	1.0
			Influences				
External magnetic field		5.20	% fid max	0.5	0.5	0.5	0.5
External temperature (Note 3)	amm	5.21	% fid max	1.0	1.0	1.0	1.0
	mam ⩾ 10 mA	5.21	% fid max	1.0	1.0	1.0	1.0
	mam < 10 mA	5.21	% fid max	0.5	0.5	0.5	0.5
	mvm ⩾ 50 mV	5.21	% fid max	1.0	1.0	1.0	1.0
	vm	5.21	% fid max	0.5	0.5	0.5	0.5
	kvm	5.21	% fid max	0.5	0.5	0.5	0.5
Extreme temperature		5.22	% fid max	5 X external temperature influence			
Position (Note 1)		5.28	% fid max	1.0	1.0	1.0	1.0
Sustained operation		5.27	% fid max	1.0	1.0	1.0	1.0
Voltage, rated circuit-to-ground		5.18	% scale length max	1.0	1.0	1.0	1.0
			Effects				
Extreme temperature		5.6	% fid max	1.0	1.0	1.0	1.0
Usage		5.12	% fid max	1.0	1.0	1.0	1.0
Momentary overload	permanent change	5.8	% fid max	1.0	1.0	1.0	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.5	0.5	0.5	0.5
Shock	permanent change	5.9	% fid max	1.0	1.0	1.0	1.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	2.0	2.0	2.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	4.0

Plate 7 (*continued*)

Item*	Comments	Test	Unit	Limits			
			Factors Relating to Physical Size				
Voltage, rated circuit-to-ground			V peak	920	920	920	920
Overshoot		5.38	max	10	10	10	10
Response time		5.41	seconds max	2.5	2.5	2.5	3.5
Dielectric test voltage		5.5	V rms max	2300	2300	2300	2300
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Normal operating position			dial	vertical	vertical	vertical	vertical
Self-contained ratings (Notes 4 and 5)	end-scale value: amm		A max	50	50	50	50
	vm		V max	800	800	800	800
Dimensions and drill plans				Fig. 11	11	10	11
Current loading, voltage drop, or ohms per volt	mam	5.51	mV max	300	300	300	300
	amm, self-contained	5.51	mV max	100	100	100	100
	amm, external shunt	5.51	mV ± 1%	50	50	50	50
	mvm	5.4	mA max	10	10	10	10
	vm	5.4	Ω/V min	200	200	200	200
	kvm (Note 2)	5.4	mA ± 1%	1.0	1.0	1.0	1.0

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: Limits do not apply to instruments with the reference position marked in accordance with symbols D-1 through D-7 in Table F1, Appendix F.

NOTE 2: When lower current is required, the preferred value is 200 μA ± 1.0%.

NOTE 3: Millivoltmeters having a full-scale value of less than 5 mV are not limited in temperature influence.

NOTE 4: For higher ranges, or where otherwise required, a 50-mV external shunt is used.

NOTE 5: For higher ranges an instrument with a full-scale current of 1 mA, in accordance with the above detailed requirements, is used with an appropriate external resistor.

Plate 8
Rectangular Switchboard Instruments (90- and 250-Degree Nominal)
Ammeters, Voltmeters, Milliammeters
Accuracy Class: 1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				1.0	1.0	1.0	1.0
Case size	conventional identification		inches mm	4.5 114	4.5 114	6.0 152	8.75 222
Scale angle	nominal		degrees	90	250	90	250
Factors Relating to Accuracy Class							
Intrinsic accuracy		5.2	% fiducial	1.0	1.0	1.0	1.0
Scale length		5.42	inches min mm min	3.2 81	6.8 172	5.0 127	13.6 345
Repeatability		5.39	% fid max	0.5	0.5	0.5	0.5
Balance		5.3	% scale length max	1.0	1.0	1.0	1.0
Influences							
External magnetic field		5.20	% fid max	3.0	3.0	3.0	3.0
External temperature	vm	5.21	% fid max	0.75	0.75	0.75	0.75
	mam	5.21	% fid max	0.5	0.5	0.5	0.5
	amm	5.21	% fid max	0.5	0.5	0.5	0.5
Extreme temperature	vm	5.22	% fid max	3.75	3.75	3.75	3.75
	amm and mam	5.22	% fid max	2.5	2.5	2.5	2.5
Frequency	at ±10% from rated frequency	5.23	% fid max	0.5	0.5	0.5	0.5
Position (Note 1)		5.28	% fid max	1.0	1.0	1.0	1.0
Sustained operation		5.27	% fid max	1.0	1.0	1.0	1.0
Waveform	at rated frequency	5.34	% fid max	0.5	0.5	0.5	0.5
Voltage, rated circuit-to-ground		5.18	% scale length max	1.0	1.0	1.0	1.0
Effects							
Extreme temperature		5.6	% fid max	1.0	1.0	1.0	1.0
Usage		5.12	% fid max	1.0	1.0	1.0	1.0
Momentary overload	permanent change	5.8	% fid max	1.0	1.0	1.0	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.5	0.5	0.5	0.5
Shock		5.9	% fid max	1.0	1.0	1.0	1.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	2.0	2.0	2.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	4.0

Plate 8 (*continued*)

Item*	Comments	Test	Unit	Limits			
Factors Relating to Physical Size							
Voltage, rated circuit-to-ground			V peak	920	920	920	920
Overshoot		5.38	V peak max	10.0	10.0	10.0	25.0
Response time		5.41	seconds max	2.5	2.5	2.5	3.5
Dielectric test voltage		5.5	V rms	2300	2300	2300	2300
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Normal operating position			dial	vertical	vertical	vertical	vertical
Self-contained ratings	potential ranges may all be external		V max	650	650	650	650
			A max	20	20	30	20
Dimensions and drill plans				Fig. 11	11	10	11
Apparent power loading	vm	5.37	VA max	10.0	10.0	10.0	10.0
	amm and mam	5.36	VA max	5.0	5.0	5.0	5.0

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: Limits do not apply to instruments with the reference position marked in accordance with symbols D-1 through D-7 in Table F1, Appendix F.

Plate 9
Rectangular Switchboard Instruments (90- and 250-Degree Nominal)
One and Two Element Wattmeters (Note 1)
Accuracy Class: 1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				1.0	1.0	1.0	1.0
Case size	conventional identification		inches mm	4.5 114	4.5 114	6.0 152	8.75 222
Scale angle	nominal		degrees	90	250	90	250
Factors Relating to Accuracy Class							
Intrinsic accuracy		5.2	% fiducial	1.0	1.0	1.0	1.0
Scale length		5.42	inches min mm min	3.2 81	6.8 172	5.0 127	13.6 345
Repeatability		5.39	% fid max	0.5	0.5	0.5	0.5
Balance		5.3	% scale length max	1.0	1.0	1.0	1.0
Influences							
Combined current and voltage		5.17	% fid max	1.0	1.0	1.0	1.0
External magnetic field		5.20	% fid max	3.0	1.0	3.0	1.0
External temperature		5.21	% fid max	0.5	0.5	0.5	0.5
Extreme temperature		5.22	% fid max	2.5	2.5	2.5	2.5
Frequency (Note 6)	any power factor 0.5–1.0 with ±10% deviation from rated frequency	5.23	% fid max	0.5	0.5	0.5	0.5
Interelement		5.26	% fid max	0.5	0.5	0.5	0.5
Position (Note 5)		5.28	% fid max	1.0	1.0	1.0	1.0
Sustained operation		5.27	% fid max	1.0	1.0	1.0	1.0
Power factor	1.0–0.5 leading or lagging power factor at rated frequency	5.29	% fid max	1.0	1.0	1.0	1.0
Waveform	at rated frequency	5.34	% fid max	0.5	0.5	0.5	0.5
Voltage, rated circuit-to-ground		5.18	% scale length max	1.0	1.0	1.0	1.0
Unbalanced current		5.31	% fid max	1.0	1.0	1.0	1.0
Voltage (at zero)		5.32		1.0	1.0	1.0	1.0
Effects							
Extreme temperature		5.6	% fid max	1.0	1.0	1.0	1.0
Usage		5.12	% fid max	1.0	1.0	1.0	1.0
Momentary overload		5.8	% fid max	1.0	1.0	1.0	1.0

Plate 9 (*continued*)

Item*	Comments	Test	Unit	Limits			
			Effects (*continued*)				
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.5	0.5	0.5	0.5
Shock		5.9	% fid max	1.0	1.0	1.0	1.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	% fid max	2.0	2.0	2.0	2.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	4.0
			Factors Relating to Physical Size				
Voltage, rated circuit-to-ground			V peak	920	920	920	920
Overshoot		5.38	% max	20	20	20	25
Response time		5.41	seconds max	2.5	2.5	2.5	3.5
Dielectric test voltage	live parts to face and panel	5.5	V rms	2300	2300	2300	2300
	between independent circuits	5.5	V rms	1500	1500	1500	1500
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Maximum voltage rating			V max	20% greater than rated			
Maximum current rating			A max	20% greater than rated			
Self-contained ratings (Note 4)			amperes max	20	20	20	20
			volts max	650	650	650	650
Dimensions and drill plans				Fig. 11	11	10	11
Apparent power loading (Notes 2 and 3)	potential system (rated voltage)	5.37	VA per element, max	7.5	7.5	7.5	7.5
	current system	5.36	VA per element, max	2.5	2.5	2.5	2.5

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: These requirements include two-element wattmeters and varmeters with three current circuits; sometimes called 2-1/2-element instruments (see Plate 13).

NOTE 2: At 120 volts for nominal 120-volt rating. For higher nominal voltage ratings, the maximum volt-amperes shall be increased proportionately.

NOTE 3: With current applied in phase with the potential to produce full-scale deflection while the potential system is energized at rated voltage and rated frequency. In a two-element system this is determined with all current coils similarly energized.

NOTE 4: Potential ranges may all be external.

NOTE 5: Limits do not apply to instruments with the reference position marked in accordance with symbols D1 through D7 in Table F1, Appendix F.

NOTE 6: On single phase varmeters, max frequency deviation = ±0.5% of rated frequency.

Plate 10
Rectangular Switchboard Instruments (90-, 180-, and 250-Degree Nominal)
Single-Phase and Polyphase Power-Factor Meters
Accuracy Class: 1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits				
Accuracy class				1.0	1.0	1.0	1.0	1.0
Case size	conventional identification		inches mm	4.5 114	4.5 114	4.5 114	6.0 152	8.75 222
Scale angle	nominal		degrees	90	180	250	90	180
			Factors Relating to Accuracy Class					
Intrinsic accuracy	40% to 120% rated current	5.2	% fid max	1.0	1.0	1.0	1.0	1.0
	20% to 40% rated current	5.2	% fid max	2.0	2.0	2.0	2.0	2.0
Scale length		5.42	inches min mm min	3.2 81	4.9 124	6.8 172	5.0 127	9.4 238
Repeatability		5.39	% fid max	1.0	1.0	1.0	1.0	1.0
Balance	with mechanical restoring torque	5.3	% scale length max	1.0	1.0	1.0	1.0	1.0
	without mechanical restoring torque energized					(See Note 4)		
			Influences					
External magnetic field (Note 2)		5.20	% fid max	3.0	3.0	3.0	3.0	3.0
External temperature (Note 2)		5.21	% fid max	0.5	0.5	0.5	0.5	0.5
Extreme temperature (Note 2)		5.22	% fid max	2.5	2.5	2.5	2.5	2.5
Frequency (Note 2)	polyphase ±10% deviation from rated frequency	5.23	% fid max	1.0	1.0	1.0	1.0	1.0
	single phase ±1.7% from rated frequency	5.23	% fid max	1.0	1.0	1.0	1.0	1.0
Position (Notes 2 and 5)		5.28	% fid max	1.0	1.0	1.0	1.0	1.0
Sustained operation		5.27	% fid max	1.0	1.0	1.0	1.0	1.0
Voltage	±10% variation from nominal	5.33	% fid max	0.5	0.5	0.5	0.5	0.5
	±20% variation from nominal	5.33	% fid max	2.0	2.0	2.0	2.0	2.0
Voltage, rated circuit-to-ground	(Note 4)	5.18	% scale length max	1.0	1.0	1.0	1.0	1.0
			Effects					
Extreme temperature (Note 2)		5.6	% fid max	1.0	1.0	1.0	1.0	1.0
Usage (Note 2)		5.12	% fid max	1.0	1.0	1.0	1.0	1.0

Plate 10 (*continued*)

Item*	Comments	Test	Unit	Limits				
			Effects (*continued*)					
Momentary overload		5.8	% fid max	1.0	1.0	1.0	1.0	1.0
Sustained overload	temporary zero shift (Note 4)	5.11	% scale length max	1.0	1.0	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.5	0.5	0.5	0.5	0.5
Shock (Note 2)		5.9	% fid max	1.0	1.0	1.0	1.0	1.0
Humidity (Note 2)		5.7	% scale length max	3.0	3.0	3.0	3.0	3.0
Vibration (Note 2)	accuracy	5.13	% fid max	2.0	2.0	2.0	2.0	2.0
	repeatability after vibration	5.39	% fid max	4.0	4.0	4.0	4.0	4.0
			Factors Relating to Physical Size					
Voltage, rated circuit-to-ground			V peak	920	920	920	920	920
Overshoot	(Note 2)	5.38	% max	33	33	33	33	33
Response time	(Note 2)	5.41	seconds max	2.5	2.5	2.5	2.5	3.5
Dielectric test voltage (Note 3)	live parts to panel	5.5	V rms	2300	2300	2300	2300	2300
	between independent circuits	5.5	V rms	1500	1500	1500	1500	1500
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20	20
Maximum voltage rating				20% greater than rated				
Maximum current rating				20% greater than rated				
Normal operating position			dial	vertical	vertical	vertical	vertical	vertical
Self-contained ratings (Note 3)	end-scale values		amperes max	20	20	20	20	20
			voltage max	650	650	650	650	650
Dimensions and drill plans				Fig. 11	11	11	10	11
Apparent power loading (Note 1)	potential system at rated voltage and frequency	5.37	VA per element, max	7.5	7.5	7.5	7.5	7.5
	current system at rated current	5.36	VA per element, max	4.5	4.5	4.5	4.5	4.5

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: At 120 volts for nominal 120-volt rating. For higher nominal ratings, the maximum volt-amperes shall be increased proportionately.

NOTE 2: With rated voltage and two-thirds of rated current.

NOTE 3: Potential ranges may be external.

NOTE 4: Does not apply to instruments without mechanical restoring torque.

NOTE 5: Limits do not apply to instruments with the reference position marked in accordance with symbols D-1 through D-7 in Table F1, Appendix F.

Plate 11
Rectangular Switchboard Instruments (90- and 250-Degree Nominal)
Frequency Meters
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits			
Accuracy class				see intrinsic accuracy			
Case size	conventional identification		inches mm	4.5 114	4.5 114	6.0 152	8.75 222
Scale angle	nominal		degrees	90	250	90	250
			Factors Relating to Accuracy Class				
Intrinsic accuracy	accuracy depends upon range		Range, Hz	Class	Accuracy, Hz		
			45–65	0.5	0.325		
			50–70	0.5	0.35		
			55–65	0.3	0.195		
		5.2	58–62	0.15	0.093		
			59–61	0.1	0.061		
			350–450	0.5	2.25		
			380–420	0.2	0.84		
			390–410	0.12	0.492		
Scale length		5.42	inches min mm min	3.2 81	6.8 172	5.0 127	13.6 345
Repeatability		5.39	times accuracy	0.5	0.5	0.5	0.5
Balance	with mechanical restoring force	5.3	% scale length max	0.6	0.6	0.6	0.6
	without mechanical restoring force		(See Note 3)				
			Influences				
External magnetic field (Note 1)		5.20	times accuracy max	2.0	2.0	2.0	2.0
External temperature (Note 1)		5.21	times accuracy max	0.6	0.6	0.6	0.6
Extreme temperature		5.22	times accuracy max	3.0	3.0	3.0	3.0
Position (Note 2)		5.28	times accuracy max	0.6	0.6	0.6	0.6
Sustained operation (Note 1)		5.27	times accuracy max	0.5	0.5	0.5	0.5
Voltage	with ±10% variation	5.33	times accuracy max	0.6	0.6	0.6	0.6
	with ±20% variation	5.33	times accuracy max	1.25	1.25	1.25	1.25
Waveform (Note 1)		5.34	times accuracy max	1.0	1.0	1.0	1.0
Voltage, rated circuit-to-ground		5.18	Hz	equal to intrinsic accuracy			

Plate 11 (*continued*)

Item*	Comments	Test	Unit	Limits			
			Effects				
Extreme temperature		5.6	times accuracy max	0.6	0.6	0.6	0.6
Usage		5.12	times accuracy max	0.6	0.6	0.6	0.6
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0	1.0
	(Note 3) accuracy	5.11	times accuracy max	0.5	0.5	0.5	0.5
Shock		5.9	times accuracy max	1.0	1.0	1.0	1.0
Humidity		5.7	% scale length max	3.0	3.0	3.0	3.0
Vibration	accuracy	5.13	times accuracy max	1.25	1.25	1.25	1.25
	repeatability after vibration	5.39	times accuracy max	2.5	2.5	2.5	2.5
			Factors Relating to Physical Size				
Voltage, rated circuit-to-ground			V peak	920	920	920	920
Overshoot		5.38	% max	33	33	33	33
Response time	at rated voltage	5.41	seconds max	3.0	3.0	3.0	3.5
Dielectric test voltage		5.5	V rms	2300	2300	2300	2300
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20	20
Normal operating position			dial	vertical	vertical	vertical	vertical
Self-contained ratings	all ratings may have external transducers or impedors						
Dimensions and drill plans				Fig. 11	11	10	11
Apparent power loading	(Note 1)	5.37	VA max	6.0	6.0	6.0	6.0

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: At midscale.

NOTE 2: Limits do not apply to instruments with the reference position marked in accordance with symbols D-1 through D-7 of Table F1, Appendix F.

NOTE 3: Limits do not apply to instruments without mechanical restoring torque.

Plate 12
Rectangular Switchboard Instruments
Synchroscopes
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits		
Accuracy class				1	1	1
Case size	conventional identification		inches mm	4.5 114	6.0 152	8.75 222
Factors Relating to Accuracy Class						
Intrinsic accuracy			% fid max	1.0	1.0	1.0
Sensitivity	Note 1	5.43	electrical degrees max	3.0	3.0	3.0
Scale length	for 360°	5.42	inches min mm min	10.0 254	11.5 292	20 508
Frequency, pull-in, differential		5.15	Hz min	1.5	1.5	1.5
Frequency, dropout, differential (with rated voltage ±10%)		5.14	Hz min	3.0	3.0	3.0
Balance pointer position	unenergized without tapping, degrees from 12 o'clock		mechanical degrees min	45	45	45
Influences						
External magnetic field		5.20	% fid max	3.0	3.0	3.0
External temperature		5.21	% fid max	0.5	0.5	0.5
Sustained operation		5.27	% fid max	1.0	1.0	1.0
Extreme temperature		5.22	% fid max	2.5	2.5	2.5
Effects						
Extreme temperature		5.6	% full scale max	0.5	0.5	0.5
Usage		5.12	% full scale max	1.0	1.0	1.0
Sustained overload	accuracy	5.11	% fiducial max	0.5	0.5	0.5
Shock		5.9	% full scale max	1.0	1.0	1.0
Humidity		5.7	% scale length max	3.0	3.0	3.0
Vibration	accuracy	5.13	% full scale max	2.0	2.0	2.0
	repeatability after vibration	5.39	% full scale max	4.0	4.0	4.0
Other Factors						
Voltage, rated circuit-to-ground			V peak	920	920	920
Overshoot		5.38	% max	33	33	33
Response time (Note 1)	for 180° deflection	5.41	seconds max	3.0	3.0	3.0
Dielectric test voltage	live parts to face of panel	5.5	V rms	2300	2300	2300
	between circuits	5.5	V rms	1500	1500	1500

Plate 12 (*continued*)

Item*	Comments	Test	Unit	Limits		
Other Factors (*continued*)						
Leakage current	at 800 V, 60 Hz	5.35	μA max	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20
Normal operating position			dial	vertical	vertical	vertical
Self-contained ratings	all ratings may have external impedors					
Dimensions and drill plans				Fig. 11	10	11
Apparent power loading	(Note 1) each circuit	5.37	VA max	6.0	6.0	6.0

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: With rated voltage and frequency.

Plate 13
Rectangular Switchboard Instruments (90- and 250-Degree Nominal)
One- and Two-Element Single and Polyphase Varmeters
Accuracy Class: 1
Application or Use: Alternating Current

Polyphase varmeters are essentially polyphase wattmeters with an arrangement for potential excitation in quadrature. They are tested and have the same characteristics and detailed requirements as polyphase wattmeters of equivalent ratings. (See detailed requirement sheets for corresponding wattmeters.) Where the quadrature relation of the voltage is obtained by a phase-shifting means, however, the burden of the voltage system may differ.

Single-phase varmeters require a phase-shifting means that alters their characteristics as a wattmeter and causes them to have a higher frequency-influence characteristic. Except, however, for loss and frequency influences, the requirements for wattmeters of equivalent rating apply. (See detailed requirement sheets for corresponding wattmeters.)

The scales of varmeters should be marked with the title "VARS," "KILOVARS," or "MEGAVARS" as required with sublegends indicating the direction of var flow. The preferred standard marking on zero-center varmeters will be "IN" (left) and "OUT" (right). Other sublegends may be used as applicable to a specific set of conditions or location.

Plate 14
Portable Instruments
Ammeters, Milliammeters, Voltmeters, Millivoltmeters
Accuracy Class: 0.25–1
Application or Use: Direct Current

Item*	Comments	Test	Unit	Limits		
Accuracy class				0.25	0.5	1.0
Factors Relating to Accuracy Class						
Intrinsic accuracy (Note 1)		5.2	% fiducial	0.25	0.5	1.0
Scale length			inches min mm min	5.0 127	3.2 81	2.5 64
Influences						
External magnetic field		5.20	% fid max	1.0	1.0	1.0
External temperature	vm; mam < 10 mA	5.21	% fid max	0.25	0.5	0.5
	amm; mvm ⩾ 50 mV	5.21	% fid max	0.5	1.0	1.0
	mam ⩾ 10 mA	5.21	% fid max	0.5	1.0	1.0
Ferrous platform		5.25	% fid max	0.1	0.15	0.25
	short-time single-range	5.27	% fid max	0.1	0.15	0.25
Operation	short-time multirange	5.27	% fid max	0.15	0.2	0.35
	sustained	5.27	% fid max	0.2	0.3	0.5
Position	6° deviation from horizontal		% fid max	0.3	0.2	0.1
Shunt and millivoltmeter lead resistance	Note 3		ohms	0.026 ± 0.005	0.026 ± 0.005	0.065 ± 0.01
Voltage, rated circuit-to-ground		5.18	% scale length max	0.25	0.5	1.0
Effects						
Momentary overload		5.8	% fid max	0.25	0.5	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.125	0.25	0.5
Extreme temperature		5.6	% fid max	0.25	0.5	1.0
Usage		5.12	% fid max	0.25	0.5	1.0

Plate 14 (*continued*)

Item*	Comments	Test	Unit	Limits		
		Other Factors				
Voltage, rated circuit-to-ground			V peak	1100	1100	1100
Mirror scale				yes	yes	no
Knife-edge pointer				yes	yes	yes
Overshoot		5.38	% max	20	20	45
Response time		5.41	seconds max	3.5	3.0	2.5
Dielectric test voltage	(Note 2)	5.5	V rms	2600	2600	2600
Leakage current	at 800 V	5.35	μA max	100	100	100
	at 120 V	5.35	μA max	20	20	20
Normal operating position			dial	horizontal	horizontal	horizontal
Self-contained ranges	vm		V max	800	800	800
	amm		A max	20	50	50
Current loading or voltage drop	mvm ⩾ 50 mV	5.4	Ω/V min	33	50	50
	vm ⩾ 1 V	5.4	Ω/V min	50	50	50
	mam ⩾ 5 mA	5.51	mV max	500	250	150
	amm self-contained ⩾ 1 A	5.51	mV max	250	100	100
	amm external shunt (+ drop in leads)	5.4	mV nom Ω/V min	50 or 100 33	50 50	50 50

*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: The limits for accuracy of ammeters used with external shunts apply to the combined accuracy of millivoltmeter and shunt.

NOTE 2: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts.

NOTE 3: Unless otherwise specified by the manufacturer.

Plate 15
Portable Instruments
Voltmeters
Accuracy Class: 0.25-1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits		
Accuracy class				0.25	0.5	1.0
Factors Relating to Accuracy Class						
Intrinsic accuracy		5.2	% fiducial	0.25	0.5	1.0
Scale length		5.42	inches min mm min	5.0 127	3.2 81	2.5 64
Influences						
External magnetic field		5.20	% fid max	0.5	2.0	5.0
	single range ⩾ 75 V	5.21	% fid max	0.15	0.3	0.3
External temperature	single range < 75 V	5.21	% fid max	0.25	0.5	0.5
	multirange ratio ⩽ 5:1	5.21	% fid max	0.25	0.5	0.5
Frequency	54 to 66 Hz inclusive for 60-Hz instruments	5.23	% fid max	0.1	0.2	0.5
Leads	for low-resistance voltmeters (Note 2)		ohms	0.026	0.026	0.026
Ferrous platform		5.25	% fid max	0.125	0.25	0.5
Operation	short-time single range	5.27	% fid max	0.1	0.15	0.25
	short-time multirange	5.27	% fid max	0.15	0.2	0.35
	sustained single range ⩾ 75 V	5.27	% fid max	0.2	0.3	0.5
	sustained single range < 75 V	5.27	% fid max	0.3	0.45	0.75
	sustained multirange ⩾ 75 V with range ratio ⩽ 4:1	5.27	% fid max	0.4	0.6	1.0
Position	6° deviation from horizontal		% fid max	0.3	0.3	0.25
Waveform		5.34	% fid max	0.125	0.25	0.5
Voltage, rated circuit-to-ground		5.18	% scale length max	0.25	0.5	1.0
Effects						
Extreme temperature		5.6	% fid max	0.25	0.5	1.0
Usage		5.12	% fid max	0.25	0.5	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.125	0.25	0.5
Apparent power loading	single range ⩽ 150 V single range > 150 V	5.37	VA max VA max	10 25	10 20	10 15

Plate 15 (*continued*)

Item*	Comments	Test	Unit	Limits		
Other Factors						
Voltage, rated circuit-to-ground			V peak	1100	1100	1100
Mirror scale				yes	yes	no
Knife-edge pointer				yes	yes	yes
Overshoot		5.38	% max	33	33	50
Response time		5.41	seconds max	5	5	2.5
Dielectric test voltage	(Note 1)	5.5	V rms	2600	2600	2600
Leakage current	at 800 V	5.35	μA max	100	100	100
	at 120 V	5.35	μA max	20	20	20
Normal operating position			dial	horizontal	horizontal	horizontal
Self-contained ranges			V max V min	800 15	800 3	800 1.5
Differences between readings on 60 Hz and mean of reversed dc values			% max	0.15	†	†

*See Section 3 for an alphabetical listing of definitions of terms used.

†It is not required that these instruments be operable on direct current.

NOTE 1: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts.

NOTE 2: Unless otherwise specified by the manufacturer.

Plate 16
Portable Instruments
Ammeters, Milliammeters (Single- and Multiple-Range)
Accuracy Class: 0.25–1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits		
Accuracy class				0.25	0.5	1.0
Factors Relating to Accuracy Class						
Intrinsic accuracy		5.2	% fiducial	0.25	0.5	1.0
Scale length		5.42	inches min mm min	5.0 127	3.2 81	2.5 64
Influences						
External magnetic field		5.20	% fid max	0.5	2.0	5.0
External temperature		5.21	% fid max	0.25	0.5	0.5
Frequency	54–66 Hz inclusive for 60-Hz instruments	5.23	% fid max	0.1	0.2	0.5
Ferrous platform		5.25	% fid max	0.125	0.25	0.5
Operation	short-time single range ⩽ 5 A	5.27	% fid max	0.1	0.15	0.25
	short-time multirange	5.27	% fid max	0.15	0.2	0.35
	sustained single range ⩽ 5 A	5.27	% fid max	0.2	0.3	0.5
	sustained multirange	5.27	% fid max	0.4	0.6	1.0
Position	6° deviation from horizontal		% fid max	0.3	0.3	0.25
Waveform		5.34	% fid max	0.125	0.25	0.5
Voltage, rated circuit-to-ground		5.18	% scale length max	0.25	0.5	1.0
Effects						
Extreme temperature		5.6	% fid max	0.25	0.5	1.0
Usage		5.12	% fid max	0.25	0.5	1.0
Momentary overload		5.8	% fid max	0.25	0.5	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.125	0.25	0.5

Plate 16 (*continued*)

Item*	Comments	Test	Unit	Limits		
Other Factors						
Voltage, rated circuit-to-ground			V peak	1100	1100	1100
Mirror scale				yes	yes	no
Knife-edge pointer				yes	yes	no
Overshoot		5.38	% max	33	33	50
Response time		5.41	seconds max	5.0	5.0	2.5
Dielectric test voltage	(Note 1)	5.5	V rms	2600	2600	2600
Leakage	at 800 V, 60 Hz	5.35	μA max	100	100	100
	at 120 V, 60 Hz	5.35	μA max	20	20	20
Normal operating position			dial	horizontal	horizontal	horizontal
Self-contained ranges			A max	20	50	50
			mA min	15	10	10
Difference between readings on 60 Hz and mean of reversed dc values			% fid max	0.15	†	†
Apparent power loading (at 60 Hz)	amm, 5 A full scale	5.36	VA max	5.0	2.0	1.0
	amm, any other range	5.36	VA max	1.5	5.0	5.0

*See Section 3 for an alphabetical listing of definitions of terms used.

†It is not required that these instruments be operable on direct current.

NOTE 1: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts.

Plate 17
Portable Instruments
Wattmeters, Single-Element (Single- and Multiple-Range)
Accuracy Class: 0.25–1
Application or Use: Alternating Current

Item*	Comments	Test	Unit	Limits		
Accuracy class				0.25	0.5	1.0
Factors Relating to Accuracy Class						
Intrinsic accuracy		5.2	% fiducial	0.25	0.5	1.0
Scale length			inches min mm min	5.0 127	3.2 81	2.5 64
Influences						
External magnetic field		5.20	% fid max	0.75	2.0	5.0
External temperature		5.21	% fid max	0.25	0.5	0.5
Frequency	54–66 Hz inclusive for 60-Hz instruments	5.23	% fid max	0.1	0.2	0.5
Ferrous platform		5.25	% fid max	0.125	0.25	0.5
Operation	short-time single range ⩾ 75 V	5.27	% fid max	0.1	0.15	0.25
	short-time multirange	5.27	% fid max	0.15	0.2	0.35
	sustained single range ⩾ 75 V	5.27	% fid max	0.2	0.3	0.5
	sustained single range < 75 V	5.27	% fid max	0.3	0.45	0.75
	sustained multirange ⩾ 75 V with range ratio ⩽ 4:1	5.27	% fid max	0.4	0.6	1.0
Position	6° deviation from horizontal		% fid max	0.3	0.3	0.25
Power factor	from 1.0–0.5 leading or lagging power factor at 60 Hz	5.29	% fid max	0.25	0.5	1.0
Combined current and voltage		5.17	% fid max	0.25	0.5	1.0
Waveform		5.34	% fid max	0.125	0.25	0.5
Voltage, rated circuit-to-ground		5.18	% scale length max	0.25	0.5	1.0
Effects						
Extreme temperature		5.6	% fid max	0.25	0.5	1.0
Usage		5.12	% fid max	0.25	0.5	1.0
Momentary overload		5.8	% fid max	0.25	0.5	1.0
Sustained overload	temporary zero shift	5.11	% scale length max	1.0	1.0	1.0
	accuracy	5.11	% fid max	0.125	0.25	0.5

Plate 17 (*continued*)

Item*	Comments	Test	Unit	Limits		
Other Factors						
Voltage, rated circuit-to-ground			V peak	1100	1100	1100
Mirror scale				yes	yes	no
Knife-edge pointer				yes	yes	no
Overshoot		5.33	% max	33	20	50
Response time		5.36	seconds max	5.0	5.0	2.5
Dielectric test voltage (Note 1)	live parts to panel including zero adjuster	5.5	V rms	2600	2600	2600
	between any independent circuits	5.5	V rms	1500	1500	1500
Leakage current	at 800 V	5.35	μA max	100	100	100
	at 120 V	5.35	μA max	20	20	20
Normal operating position			dial	horizontal	horizontal	horizontal
Self-contained ranges	highest range		A	20	50	50
			V	300	300	300
Apparent power loading at 60 Hz	100–150-V rating at 120 V	5.37	VA max	5.0	5.0	5.0
	200–300-V rating at 240 V	5.37	VA max	10.0	10.0	10.0
	< 100-V rating at 80% of rating	5.37	VA max	5.0	5.0	5.0
	10 amperes or less	5.36	VA max	2.0	2.0	2.0
	10 amperes or more	5.36	VA max	4.0	5.0	5.0

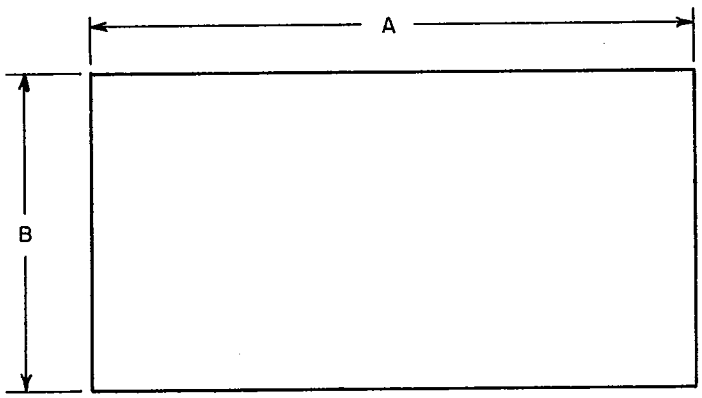
*See Section 3 for an alphabetical listing of definitions of terms used.

NOTE 1: For 651–1000-volt service, it is recommended that the dielectric test voltage be 3000 volts.

Appendixes

(These Appendixes are not a part of American National Standard Requirements for Electrical Analog Indicating Instruments, ANSI C39.1-1981, but are included for information purposes only.)

Appendix A
Guide for the User: Panel Cutouts



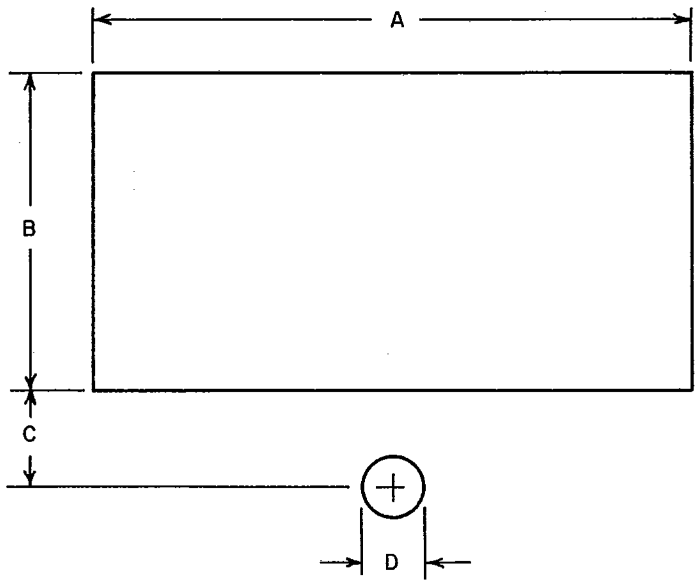
Case Size Reference	Min Scale Length	A	B
1.5	1.00 (25.4)	1.71 (43.4)	0.53 (13.5)
3	2.50 (63.5)	3.45 (87.6)	1.42 (36.1)
5	4.00 (101.6)	5.77 (146.6)	1.80 (45.7)

NOTE 1: These are panel cutouts of maximum size to accept the majority of present designs as a guide to the user.

NOTE 2: All dimensions are in inches (millimeters) and are nominal only.

CAUTION: Contact the manufacturer for exact dimensions.

Fig. A1
Dimensions of Edgewise Panel Cutouts
(Guide for the User: Existing Designs)



Case Size Reference	A	B	C*	D* Hole Size
2.5	3.000 (76.2)	1.609 (40.9)		0.312 (7.9)
3.5	3.718 (94.4)	2.156 (54.8)		0.312 (7.9)
4.5	4.812 (122.2)	2.750 (69.9)		0.312 (7.9)
5.5	5.906 (150)	3.156 (80.2)		0.312 (7.9)

*Consult manufacturer for dimensions. In some instances hole "D" is not required.

NOTE 1: These are panel cutouts of maximum size to accept the majority of present designs as a guide to the user.

NOTE 2: All dimensions are in inches (millimeters) and are nominal only.

CAUTION: Consult the manufacturer for exact dimensions.

Fig. A2
Dimensions of Cutouts for Back-of-Panel Mounted Panel Cutouts, Panel Instruments

Appendix B

Minimum Torque Values and Test Procedure for Testing Mounting of Terminals

B1. Test Condition

B1.1 Direction and Application of Torque. The torque shall be applied clockwise and then counterclockwise in a plane perpendicular to the axis of the terminal, as shown in Fig. B1.

B1.2 Duration of Applied Force. The force shall be applied gradually to the terminal and then maintained for a period of 5 to 15 seconds.

B1.3 Screw Thread Terminals. When testing screw thread terminals, the torque, in accordance with the terminal size, shall be applied to the centerline of the terminal assembly, as follows:

Screw-Thread Terminals	Torque (Pound-Inches)
No. 4	3.0
No. 6	5.0
No. 8	11.0
No. 10	15.0
No. 12	24.0
1/4 inch	32.0

B1.4 Other Nonwire Rigid-Type Terminals. When testing other nonwire rigid-type terminals, the applied torque is dependent on the equivalent diameter of the external portion of the terminal assembly. The equivalent diameter is defined as being equal to twice the distance from the terminal axis to the point of normal wire connection. The torque shall be applied in accordance with the equivalent diameter, as follows:

Equivalent Diameter (Inch)	Torque (Ounce Inches)
< 1/16	0
> 1/16 to 1/8, inclusive	8
> 1/8 to 3/16, inclusive	18
> 3/16 to 5/16, inclusive	40
> 5/16 to 1/2, inclusive	80
> 1/2	In accordance with the individual specification

B2. Measurements

Measurements to be made before and after the test, as applicable, shall be as specified in the individual specification.

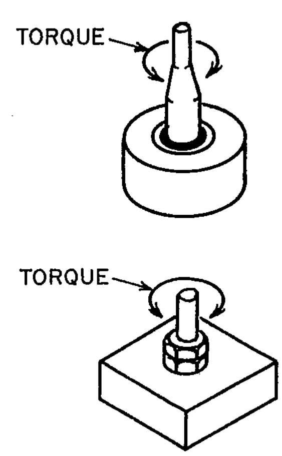


Fig. B1
Direction and Application of Torque

Appendix C

Preferred End-Scale Values for Self-Contained Instruments where Zero Is at the Left

The preferred end-scale values shall be as shown by the asterisks in Table C1 or shall be decimal multiples of these values.

Table C1
End-Scale Values

End-Scale Value	DC Volt-meters	DC Ammeters	AC Volt-meters	AC Ammeters	Wattmeters
1.0	*	*	†	*	*
1.2	–	–	–	–	†
1.5	*	†	*	†	*
2.0	*	*	–	*	*
2.5	–	†	–	–	*
3.0	*	*	*	*	*
4.0	–	–	–	*	†
5.0	*	*	–	*	*
6.0	–	†	†	*	*
7.5	*	†	*	–	–
8.0‡	*	†	*	†	*

*Preferred end-scale value.

†End-scale value used but not preferred.

‡The end-scale value of 8.0 is preferred over the 7.5 value for instruments with small panels where a 75-division scale would tend to be crowded.

NOTE 1: For values above 1000 amperes or 1000 volts, any of the end-scale values listed may be used in place of the preferred values.

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

Appendix D
Unit Designation of Quantity Measured

The unit designation of the quantity measured is determined by the end-scale value and should, preferably, be in accordance with Table D1.

Table D1
Unit Designations

Quantity Measured	Unit Designations*
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
Kilowatts	1–999
Megawatts	Above 999 kilowatts
Vars	1–999
Kilovars	1–999
Megavars	Above 999 kilovars
Hertz	1–999
Kilohertz	1–999
Megahertz	Above 999 kilohertz

*Although the units used over the various ranges are preferably those given in the above table, end-scale values of 1000, 1500, 2000, etc, are considered satisfactory and may be used.

Appendix E
Abbreviations and Unit Symbols Used in This Standard

amm	ammeter	micam	microammeter
A	ampere	min	minimum
ac	alternating current	mm	millimeters
dc	direct current	mV	millivolt
dia	diameter	mvm	millivoltmeter
EMF	electromotive force	μA	microampere
fid	fiducial	nom	nominal
Hz	hertz	pref	preferred
kV	kilovolt	rad	radius
kvm	kilovoltmeter	rms	root-mean-square
mA	milliampere	V	volt
mam	milliammeter	VA	voltampere
max	maximum	vm	voltmeter

Appendix F

Markings and Symbols for Electrical Indicating Instruments

NOTE: The material in this Appendix is adapted from IEC (International Electrotechnical Commission) Recommendations for Indicating Electrical Measuring Instruments and Their Accessories, Publication 51 (1973). It is included here for reference purposes.

F1. Markings and Symbols for Measuring Instruments

Instruments should bear on the dial, or on one of the external surfaces, the markings listed below.

The majority of these markings are made using the symbols given in Table F1. When the size of the instrument is insufficient (for example, diameter or side of the case is equal to or less than 2-1/2 inches) it is permissible to give only the essential markings and to include the other information in a certificate supplied with the instrument.

F2. Markings and Symbols for All Instruments

(1) The manufacturer's name or mark

(2) The symbol of the quantity measured (indicated by symbols A-1 through A-20) or, for power-factor meters, by ϕ or cos ϕ

(3) The serial number for instruments of Classes 0.1, 0.25, and 0.5

(4) The class index (symbols E-1 through E-3)

(5) The nature of the current (symbols B-1 through B-6)

(6) The dielectric test voltage (symbols C-1 through C-3); see footnote designated ‡ at end of Table F1

(7) The symbol indicating the operating method of the instrument (symbols F-1 through F-22)

F3. Markings and Symbols to Be Used on Instruments when Desired

(8) The rated values

(9) The date of manufacture or the serial number for instruments of Classes 1.0, 1.5, 2.5, and 5.0

(10) The symbol of position (symbols D-1 through D-3)

(11) The symbol for any accessory for which the instrument has been graduated (symbols F-23 through F-26)

(12) The value of any noninterchangeable accessory for which the symbol has been marked in accordance with (11) above, including the resistance of leads if relevant

(13) The ratio(s) of current (or voltage) transformers for which the instrument is graduated

(14) The values of resistance, reactance, or impedance at the rated frequency, for the current and voltage circuits of instruments of Classes 0.1, 0.25, and 0.5

(15) The indication of the external magnetic induction for which the variation corresponds to the class index (symbol F-30)

(16) The symbol showing the nature of the support for which the instrument has been calibrated

(17) The symbol showing that some essential information is given on a separate document or certificate (symbol F-33)

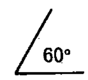
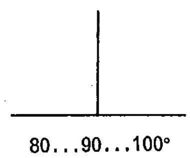
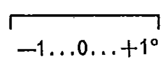
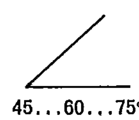
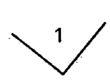
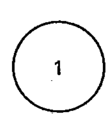
(18) The value of the source impedance when knowledge of it is necessary for the determination of the damping of the instrument

APPENDIX

Table F1
Symbols for Marking Instruments and Accessories

No.	Item	Symbol
A	**Principal units and their principal multiples and sub-multiples**	
A-1	Kiloampere	kA
A-2	Ampere	A
A-3	Milliampere	mA
A-4	Microampere	μA
A-5	Kilovolt	kV
A-6	Volt	V
A-7	Millivolt	mV
A-8	Microvolt	μV
A-9	Megawatt	MW
A-10	Kilowatt	kW
A-11	Watt	W
A-12	Megavar	Mvar
A-13	Kilovar	kvar
A-14	Var	var
A-15	Megahertz	MHz
A-16	Kilohertz	kHz
A-17	Hertz	Hz
A-18	Megohm	MΩ
A-19	Kilohm	kΩ
A-20	Ohm	Ω
A-21	Milliohm	mΩ
A-22	Tesla	T
A-23	Millitesla	mT
A-24	Degree Celsius	°C
B	**Type of supply and number of measuring elements***	
B-1	Direct current circuit	⎺ (5031)†
B-2	Alternating current circuit (single-phase)	∼ (5032)†
B-3	Direct and alternating current circuit	⎺∼ (5033)†
B-4	Three-phase alternating current circuit (general symbol)	3 ∼
B-6	One measuring element for 3-wire network	3 ∼ 1E
B-7	One measuring element for 4-wire network	3N ∼ 1E
B-8	Two measuring elements for 3-wire network with unbalanced loads	3 ∼ 2E
B-9	Two measuring elements for 4-wire network with unbalanced loads	3N ∼ 2E
B-10	Three measuring elements for 4-wire network with unbalanced loads	3N ∼ 3E
C	**Safety**	
C-1	Test voltage 500 V	☆ ‡
C-2	Test voltage above 500 V (e.g., 2 kV)	☆2 ‡
C-3	Apparatus not subjected to a voltage test	☆0 ‡
C-7	High voltage on accessory and/or on instrument	ϟ Ⓥ
D	**Position of use**	
D-1	Instrument to be used with the dial vertical	⊥
D-2	Instrument to be used with the dial horizontal	⊓

Table F1 (*Continued*)

No.	Item	Symbol
D-3	Instrument to be used with the dial inclined (e.g., 60°) from the horizontal plane	
D-4	Example for instrument to be used as D-1, nominal range of use from 80° to 100°	
D-5	Example for instrument to be used as D-2, nominal range of use from −1° to +1°	
D-6	Example for instrument to be used as D-3, nominal range of use from 45° to 75°	
E	**Accuracy class**	
E-1	Class index (e.g., 1) with errors expressed as a percentage of the fiducial value except when the latter corresponds to the span or the indicated value	1
E-2	Class index (e.g., 1) when the fiducial value corresponds to the span	
E-3	Class index (e.g., 1) when the fiducial value corresponds to the indicated value	
F	**General symbols**	
F-1	Permanent-magnet moving-coil instrument	

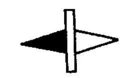
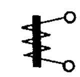
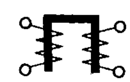
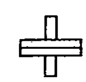
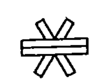
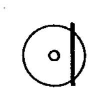
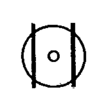
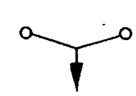
No.	Item	Symbol
F-2	Permanent-magnet ratiometer (quotientmeter)	
F-3	Moving permanent-magnet instrument	
F-4	Moving permanent-magnet ratiometer (quotientmeter)	
F-5	Moving-iron instrument	
F-6	Polarized moving-iron instrument	
F-7	Moving-iron ratiometer (quotientmeter)	
F-8	Ironless electro-dynamic instrument	
F-9	Iron-cored electro-dynamic (ferro-dynamic) instrument	
F-10	Ironless electro-dynamic ratiometer (quotientmeter)	
F-11	Iron-cored electro-dynamic (ferro-dynamic) ratiometer (quotientmeter)	
F-12	Induction instrument	
F-13	Induction ratiometer (quotientmeter)	
F-14	Thermal (hot-wire) instrument	

Table F1 (*Continued*)

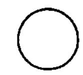
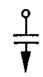
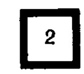
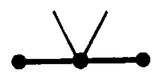
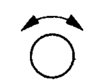
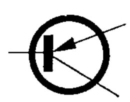
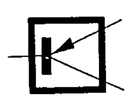
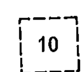
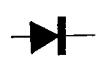
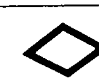
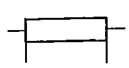
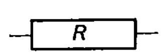
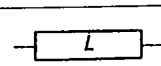
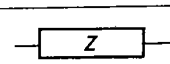
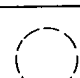
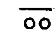
No.	Item	Symbol	No.	Item	Symbol
F-15	Bimetallic instrument		F-28	Magnetic screening	
F-16	Electrostatic instrument		F-29	Astatic instrument	ast
F-17	Vibrating-reed instrument		F-30	Magnetic field expressed in milliteslas, corresponding to the class index (e.g., 2 mT).	 (mT)
F-18	Non-insulated thermo-couple (thermal convertor) (see Note 1)		F-31	Protective earth (ground) terminal (general symbol)	 (5017)†
F-19	Insulated thermo-couple (thermal convertor) (see Note 1)		F-32	Zero adjuster	
F-20	Electronic device in a measuring circuit (see Note 1)		F-33	Refer to a separate document	
F-21	Electronic device in an auxiliary circuit		F-34	Electric field expressed in kV/m, corresponding to the class index (e.g., 10 kV/m)	
F-22	Rectifier (see Note 1)		F-35	General accessory (see Note 2)	
F-23	Shunt (see Note 3)				
F-24	Series resistor (see Note 3)		F-37	Ferrous support of a thickness of X mm	Fe X
F-25	Series inductor (see Note 3)	 or 	F-38	Ferrous support of any thickness	Fe
F-26	Series impedance		F-39	Non-ferrous support of any thickness	NFe
F-27	Electrostatic screening		F-40	Any support of any thickness	Fe NFe

Table F1 (*Continued*)

No.	Item	Symbol	No.	Item	Symbol
F-45	Signal low terminal		F-49	Overload protection device fitted	
F-48	Resistance range-setting control		F-50	Overload protection device reset control	

NOTE 1: If symbols F-18, F-19, F-20, and F-22 are combined with a symbol of an instrument, such as symbol F-1, the device is incorporated.

NOTE 2: Symbol F-35 denotes that a device is external to an instrument and shall be combined with one of the symbols F-18, F-19, F-20, or F-22.

NOTE 3: For other symbols, see IEC Publication 117, Recommended Graphical Symbols and IEC Publication 417, Graphical Symbols for Use of Equipment.

*Units of measurement and their prefixes are given in IEC Publication 27.

†Numbers in parentheses are the reference numbers of the symbols in IEC Publication 417.

‡Symbols C-1, C-2, and C-3 are not recommended for use in the United States. It is felt that these symbols may be misunderstood to be safe voltages of use rather than dielectric test voltages. It is recommended that instruments be marked in accordance with 6.18.4 for rated circuit-to-ground voltage.

Appendix G

Terminal Spacing and Size

The preferred terminal spacing and size is 1.400 inch ± 0.015 inch and 1/4-28 threads on terminals for panel instruments having a case size about 1.5 inches.

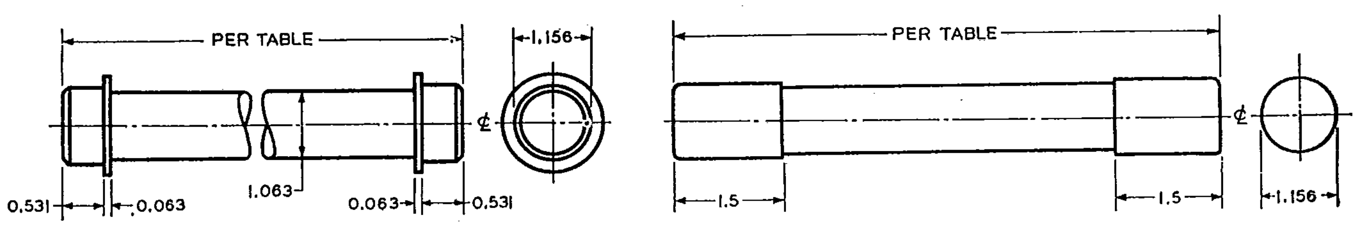
Appendix H

External Resistors and Boxes

Table H1
Tubular Resistor, Max Current Loading 1 mA

Volts, max:	2 kV	2.5 kV	3 kV	5 kV	10 kV	15 kV	20 kV
Watts, max:	2	2.5	3	5	10	15	20

Table H2
Tubular Resistor Dimensions, Inches



(a) (b)

Range, kV	Figure	Overall Length, Max
2	(a)	5.3
2.5	(a)	5.3
3	(a)	5.3
5	(a)	9.8
10	(b)	16.5
15	(b)	23.5
20	(b)	30.5

NOTES:
(1) The tubular resistor dimensions listed above are not requirements.
(2) For enclosures for external accessories, see Appendix I.

Appendix I

Enclosures for External Accessories

I1. General

This Appendix suggests optimum space utilization when enclosures are mounted at the rear of 19-inch-wide panels.

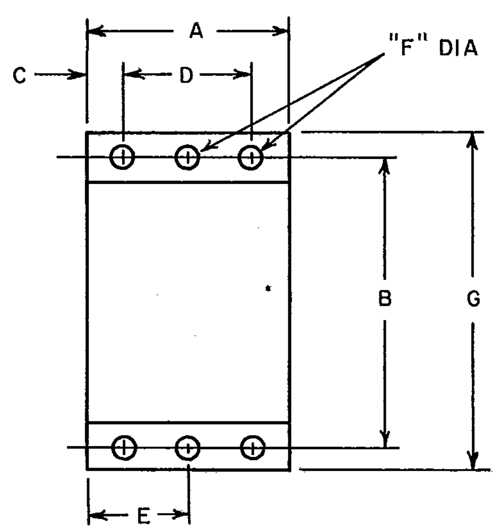
I2. Dimensions

I2.1 Width. Width is the most critical dimension and determines the maximum number of units that can be mounted in a given width of panel space. Therefore, the choice of design and arrangement should be made to utilize the minimum practical width shown in Fig. I1.

I2.2 Height. Vertical mounting height is less critical than width for optimum space utilization. Width should, therefore, always be less than height, if possible. The height determines the mounting hole location, which is fixed by the vertical spacing of the universal mounting brackets and shall be in accordance with Fig. I1.

I2.3 Depth. The horizontal depth back of the panel has not been standardized but should be kept to a minimum.

I2.4 Mounting Holes. Mounting hole location shall be in accordance with Fig. I1.



Width A	Dimension B (Choice of One)							Dimension C	D	E	F	Height G Maximum
2	2-1/4	3	4	5-1/4	5-3/4	7-1/2	9-1/4	–	–	1	9/32	3/4 inch (19 mm) more than dimension B
(50.8)	(57.15)	(76.2)	(101.6)	(133.3)	(146)	(190)	(235)	–	–	(25.4)	(7.1)	
3	–	–	4	5-1/4	5-3/4	7-1/2	9-1/4	1/2	2	–	9/32	
(76.2)	–	–	(101.6)	(133.3)	(146)	(190)	(235)	(12.7)	(50.8)	–	(7.1)	
4	–	–	–	5-1/4	5-3/4	7-1/2	9-1/4	3/4	2-1/2	–	9/32	
(101.6)	–	–	–	(133.3)	(146)	(190)	(235)	(19)	(63.5)	–	(7.1)	
5-1/2	–	–	–	–	5-3/4	7-1/2	9-1/4	1-1/2	2-1/2	–	9/32	
(139.7)	–	–	–	–	(146)	(190)	(235)	(38.1)	(63.5)	–	(7.1)	
8	–	–	–	–	–	–	9-1/4	1-1/2	5	–	9/32	
(203.2)	–	–	–	–	–	–	(235)	(38.1)	(127)	–	(7.1)	

NOTE: All dimensions are in inches (millimeters) and are nominal unless otherwise specified.

Fig. I1
Dimensions of Enclosures

American National Standards

The standard in this booklet is one of more than 10,000 standards approved to date by the American National Standards Institute.

The Standards Institute provides the machinery for creating voluntary standards. It serves to eliminate duplication of standards activities and to weld conflicting standards into single, nationally accepted standards under the designation "American National Standards."

Each standard represents general agreement among maker, seller, and user groups as to the best current practice with regard to some specific problem. Thus the completed standards cut across the whole fabric of production, distribution, and consumption of goods and services. American National Standards, by reason of Institute procedures, reflect a national consensus of manufacturers, consumers, and scientific, technical, and professional organizations, and governmental agencies. The completed standards are used widely by industry and commerce and often by municipal, state, and federal governments.

The Standards Institute, under whose auspices this work is being done, is the United States clearinghouse and coordinating body for voluntary standards activity on the national level. It is a federation of trade associations, technical societies, professional groups, and consumer organizations. Some 1000 companies are affiliated with the Institute as company members.

The American National Standards Institute is the United States member of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). Through these channels U.S. standards interests make their positions felt on the international level. American National Standards are on file in the libraries of the national standards bodies of more than 60 countries.

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