MIL-HDBK-705C
29 May 1987
SUPERSEDING
MIL-HDBK-705B
26 June 1972

MILITARY HANDBOOK

GENERATOR SETS, ELECTRICAL, MEASUREMENT AND INSTRUMENTATION METHODS

FSC 6115

AMSC N/A

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited

DEPARTMENT OF DEFENSE

WASHINGTON, D.C. 20301

MIL-HDBK-705C
Generator Sets, Electrical, Measurement and Instrumentation Methods

1. This Military Handbook was developed by the US Army Troop Support Command - Belvoir Research Development and Engineering Center in accordance with MIL-STD-962 and is approved for the use of all Departments and Agencies of the U.S. Government.

2. This publication, revision "C", was approved on 29 May 1987, for printing and inclusion in the military handbook series.

3. This document provides basic and fundamental information on measurement and instrumentation methods for evaluation of electrical power generators, generator sets and related items when these items are tested in accordance with MIL-STD-705 and similar test methods.

4. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Troop Support Command - Belvoir Research Development and Engineering Center, ATTN: STRBE-DS, Fort Belvoir, VA 22060-5606, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FOREWORD

1. This handbook is intended to explain and establish conventions for terminology, instrumentation, methods of measurement and accepted procedures associated with the testing and evaluation of electric generators, generator sets, and related items. It is to be used in conjunction with MIL-STD-705 to determine capabilities, conditions and compliance with the requirements of procurement documents. The methods herein contain preparatory procedures and basic detailed requirements for general use instruments, measurements and instrumentation, while the many specific methods of test are established in MIL-STD-705, Generator Sets, Engine-Driven, Test Methods and Instructions.

2. Some test instruments illustrated herein are no longer being manufactured and their functions have been superseded by newer types of instruments; the older types, however, are still being used in some areas and are still acceptable; therefore, their inclusion in this handbook will be continued until such time as their removal will be in the Government's best interest.

3. Because this handbook is closely allied to MIL-STD-705, references from one to the other are freely used particularly from MIL-STD-705 to this document. Inspectors and testers will find need for both the handbook and standard when working with electrical power generation equipment.

4. Due to the complexity of specified requirements in procurement documents covering engine-driven electric generators and other similar types of electric machinery, military personnel will find this handbook especially helpful as a convenient source of general information on electrical instruments and their proper use. This technology has been documented from experience by government and industry engineers and technicians with the manufacturing, procurement and testing of electrical power generation equipment.

CONTENTS

REVISION STATUS OF METHODS

Method No.	Revision	Date	Replaced by (if Method deleted)
101.1 -------	b		
102.1 -------	b		
103.1 -------	b		
104.1 -------	b		
105.1 -------	b		
106.1 -------	b		
107.1 -------	b		
108.1 -------	b		
109.1 -------	b		
110.1 -------	b		
111.1 -------	b		
112.1 -------	b		
114.1 -------	b		
114.2 -------	a		
114.3 -------	a		
115.1 -------	a		
116.1 -------	b		
117.1 -------	b		
201.1 -------	b		
202.1 -------	b		
203.1 -------	b		
205.1 -------	b		
220.1 -------	b		
220.2 -------	b		
221.1 -------	a		
222.1 -------	a		

FIGURES

FIGURES (continued)

FIGURES (continued)

FIGURES (continued)

CROSS-INDEX: SUBJECT-TO-FIGURES

CROSS-INDEX: SUBJECT-TO-FIGURES (continued)

CROSS-INDEX: SUBJECT-TO-FIGURES (continued)

CROSS-INDEX: SUBJECT-TO-FIGURES (continued)

CROSS-INDEX: SUBJECT-TO-FIGURES (continued)

1. SCOPE

1.1 Coverage. This handbook covers two series of methods for measuring and determining characterstics of all electric generators and generator sets as classified by MIL-STD-1332, and associated equipment. The illustration and description of the test instruments together with instruction for their use are included as applicable under each method. As noted in the foreword of this handbook, some of the older types of instruments are no longer manufactured.

1.2 Numbering systems used in this handbook. Text herein is identified in accordance with MIL-STD-962 and the sample formats shown therein. Method and method figure numbering is additionally significant as follows:

1.2.1 Methods numbered in the 100 series. These methods pertain to basic instruments and measurements.

1.2.2 Methods numbered in the 200 series. These methods pertain to basic instrumentation procedures and applications.

1.2.3 Revisions to methods - identification. Lower case alphabetic characters are suffixed to the method numbers to identify revisions to methods.

1.2.4 Figure numbering within methods. The beginning digits of any figure number are the same as the method number that figure pertains to. A hyphen is used to separate the first and second portions of the figure numbers. The digits used in the second portions of figure numbers establish the order of figures within each method; where groups of alternate or multi-page figures occur, such as when depicting several types or manufacturers' models of instruments used for the same purpose, the second portion of the figure number is suffixed with a decimal on each of the second and subsequent figures involved. The decimals establish the order of the subsequent figures within that group.

Certain of the figures depict multi-purpose instruments; therefore there are several instances where the pictorial content of figures is identical, and is used twice or more, but the figure numbers and titles differ, depending upon the category or method where the figure occurs.

2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following specifications and standards of the issue in effect on date of invitation for bids or request for proposal, unless a different issue is specified in the procurement documents, form a part of this handbook to the extent specified herein.

STANDARDS

MILITARY

MIL-STD-705	- Generator Sets, Engine Driven Test Methods and Instructions.
MIL-STD-1332	- Definitions of Tactical, Prime, Precise, and Utility Terminologies for Classification of the DOD Mobile Electric Power Engine Generator Set Family.
MIL-STD-1474	- Noise Limits for Army Materiel.

(Copies of specifications and standards required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer. Copies for other purposes may be obtained from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.)

2.2 Other publications. The following publications of the issue in effect on date of invitation for bids or request for proposal, unless a different issue is specified in the procurement documents, form a part of this handbook to the extent specified herein.

AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI C2 - National Electrical Safety Code.
ANSI C50.10 thru C50.41 Series - Rotating Electrical Machinery.
ANSI/ASHRAE 41.6 - Standard Method for Measurement of Moist Air Properties.
ANSI/IEEE 100 - Standard Dictionary of Electrical and Electronics Terms.
ANSI/NEMA MG1 - Motors and Generators.
ANSI/NEMA MG2 - Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators.
ANSI/NFPA 70 - National Electrical Code.

(included as general references)

(Copies may be obtained from the American National Standards Institute, 1430 Broadway, New York, NY 10018. Microform or copies are also maintained at many libraries.)

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR CONDITIONING ENGINEERS (ASHRAE).

ASHRAE Handbook 1981 Fundamentals, Chapter 5, Psychrometrics, and Chapter 6, Psychrometric Tables.

ASHRAE Brochure on Psychrometry.

(Copies may be obtained from ASHRAE, Inc., 1791 Tullie Circle NE, Atlanta, GA 30329. Microform or copies are also maintained at many libraries.)

2.3 Textbooks. The following textbooks are listed for information purposes and are not to be considered as a part of this handbook:

Electrical Engineers' Handbook, Pender and Del Mar, Vol. 1, 4th Ed., Wiley Brothers.

IEEE Standard Dictionary of Electrical and Electronics Terms, IEEE 100 Wilby - Interscience.

Standard Handbook for Electrical Engineers, Fink and Beaty, 11th Ed., McGraw-Hill Book Co.

Chamber's Dictionary of Science and Technology (1978), Hippocrene Books.

(Copies may be obtained from bookstores, or from the publishers listed; copies are also maintained at many libraries.)

3. DEFINITIONS

3.1 Extent and sources of definitions. Consult the ANSI/IEEE 100 Standard Dictionary of Electrical and Electronics Terms, and other reference documents of section 2 herein.

4. GENERAL REQUIREMENTS

4.1 Physical standards, conventions and calibration traceability. Primary and secondary standards, conventions, and values for calculations, computations, conversions, and calibration of instruments, shall be those recognized by the International Electrotechnical Commission (IEC), International Organization for Standardization (ISO) and the United States National Bureau of Standards (NBS). The IEC and ISO are both located in Geneva, Switzerland. In the U.S.A., information regarding all these standards and conventions may be obtained from NBS, Washingtion D.C., 20234.

4.2 Recycled, virgin and reclaimed materials. Reclaimed, recycled and recovered materials shall be used, where appropriate, to the maximum extent possible. This handbook does not contain any requirements that items be manufactured from virgin materials, so long as the intended use of any item is not jeopardized thereby.

5. DETAILED REQUIREMENTS

5.1 Instruments and Measurements - 100 Series.

METHOD 101.1b

MEASUREMENT OF POTENTIAL

101.1.1 GENERAL. The terms "voltage", "electromotive force", and "potential" are considered synonomous herein.

101.1.2 INDICATING VOLTMETERS.

101.1.2.1 DC VOLTAGE. Two types of instruments are recommended for measuring dc voltage - D'Arsonval voltmeters and digital electronic voltmeters (figure 101.1-1). Digital electronic types should not be used to measure dc voltage which also contains an ac component of any significance because such an ac component can prevent these types from obtaining a steady reading. Both D'Arsonval and digital voltmeters are available as high-resistance Voltmeters having full-scale readings at values in the microvolt, and are also available as full-scale, self-contained units ranging as high as 750 volts.

Voltmeter ranges can be further extended, even beyond 50,000 volts, by conjunctive use with externally-attached multiplying devices (figure 101.1-2). Such devices, commonly referred to as "series resistance multipliers" and "series multipliers", are precision-made, wire-wound resisters. They are carefully manufactured and calibrated to be electrically stable within specific tolerances over ranges of temperature and periods of time.

Voltmeters, especially millivoltmeters, should not be connected into circuits having voltages higher than the rating of the instrument. To measure voltages higher than the rating of a relatively low resistance instrument, a "series resistance multiplier" must be used with it (figure 101.1-2). In this case, the correct voltage is obtained by solving the following equation:

$$E = \frac{V_r(R_v+R_m)}{R_v}$$

where:

E is the voltage to be measured.

V_r is the reading of the voltmeter.

R_V is the resistance of the voltmeter. (This may be found on the voltmeter dial or on the voltmeter cover.)

R_m is the resistance of the series multiplier. (This value is usually stated on the exterior of the series multiplier housing.) This formula, solved for R_m, can be used for selecting a series multiplier to be used if the approximate value of E is known.

Because of the high-inductive-voltage surge which may bend the pointer on D'arsonval analog type meters, dc voltmeters should be disconnected from a field circuit before the field switch is opened. Because of high alternating voltages developed by transformer action in the field windings during starting, dc voltmeters also should be disconnected from synchronous motors or synchronous condenser fields before the machines are started from the ac line.

101.1.2.2 AC VOLTAGE. Two type of (RMS) sensing and indicating voltmeters are used to measure ac voltage. These type are dynamometer (figure 101.1-3) and digital (figure 101.1-3.1 and 101-3.2) type volt meters. Dynamometer type voltmeter ranges usually are from 7-1/2 to 750 volts full scale. Dynamometer-type voltmeters should not be used outside their rated frequency range. Digital type voltmeters usually have wider ranges and in many cases are autoranging.

101.1.3 RECORDING VOLTMETERS. Recording voltmeters are used to measure transients or time-varying voltages. Figure 101.1-4 shows an acceptable type of recording voltmeter. This type of instrument, Texas Instruments Model PDRHXFHXVA-A16-XT, or Gould Model 2108-2202-005542, shall be used throughout the generator tests given in MIL-STD-705, unless the requirements of the procurement document specifically state otherwise.

101.1.4 POTENTIAL TRANSFORMERS. Potential transformers (figure 101.1-5) are used for two purposes: to isolate the testing instruments from the line voltage, and to act as multiplying devices for the instruments.

To obtain satisfactory accuracy when using a potential transformer, it should be used under conditions of voltage, frequency, and volt-ampere burden that the manufacturer rated it for.

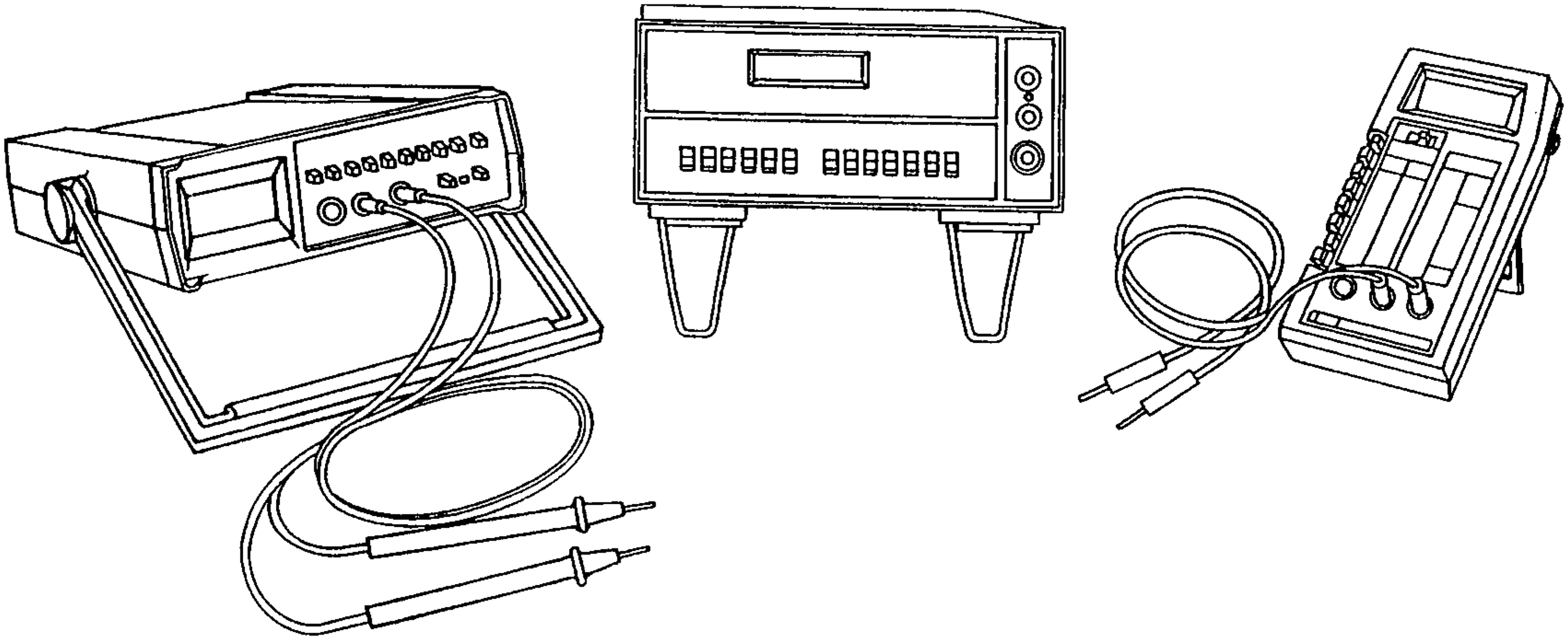


FIGURE 101.1-1. Representative types of meters suitable for measurement of dc volts.

X-4165A

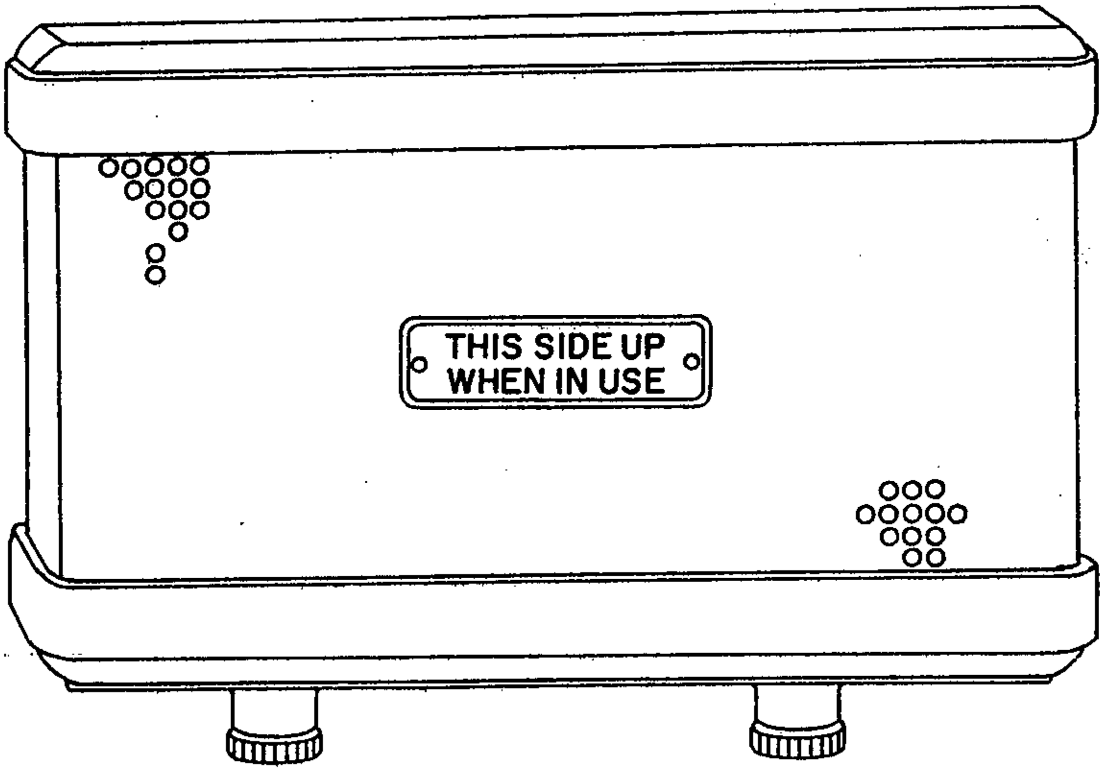


FIGURE 101.1-2. Series resistance multiplier.

X-4166A

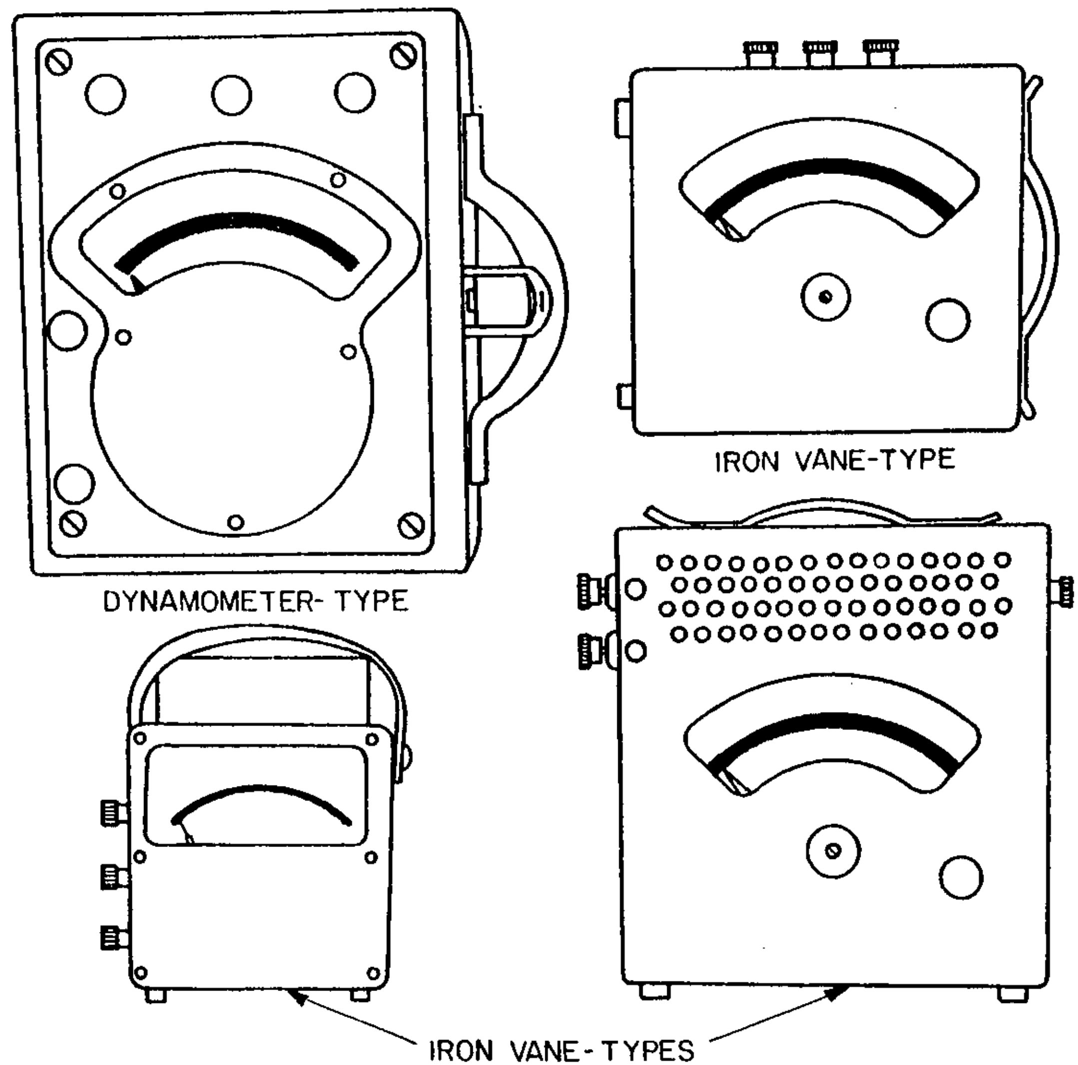


FIGURE 101.1-3. Representative types of ac voltmeters.

X-4167A

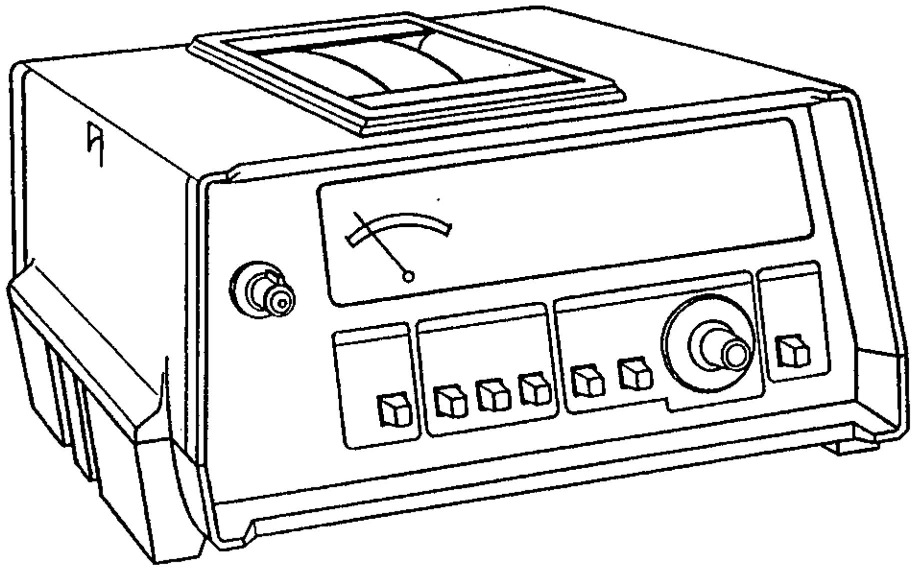


FIGURE 101.1-3.1. Representative type of meter suitable for measurement of ac volts.

X-4680

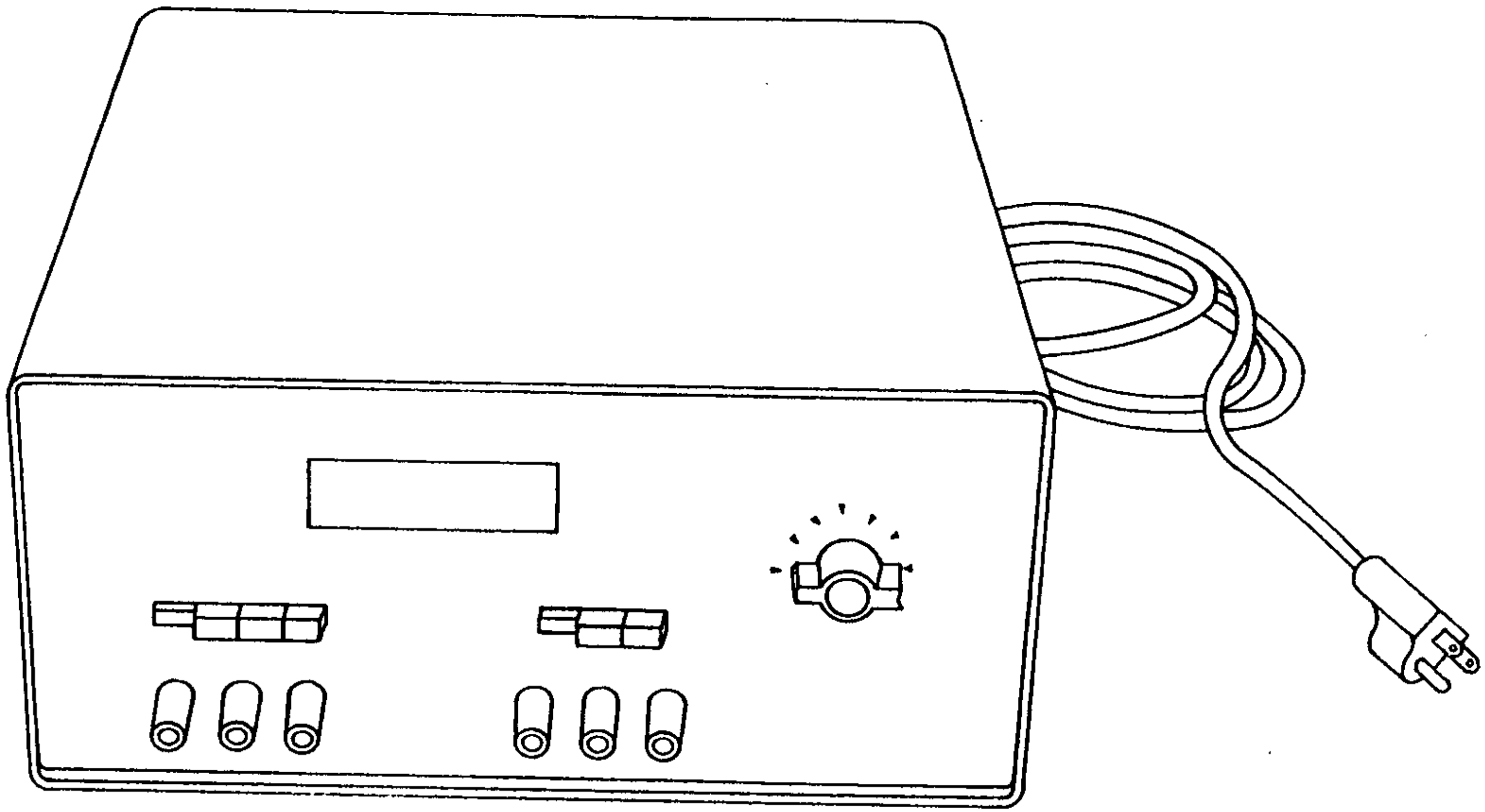


FIGURE 101.1-3.2. Representative type of meter suitable for measurement of ac volts.

X-4169A

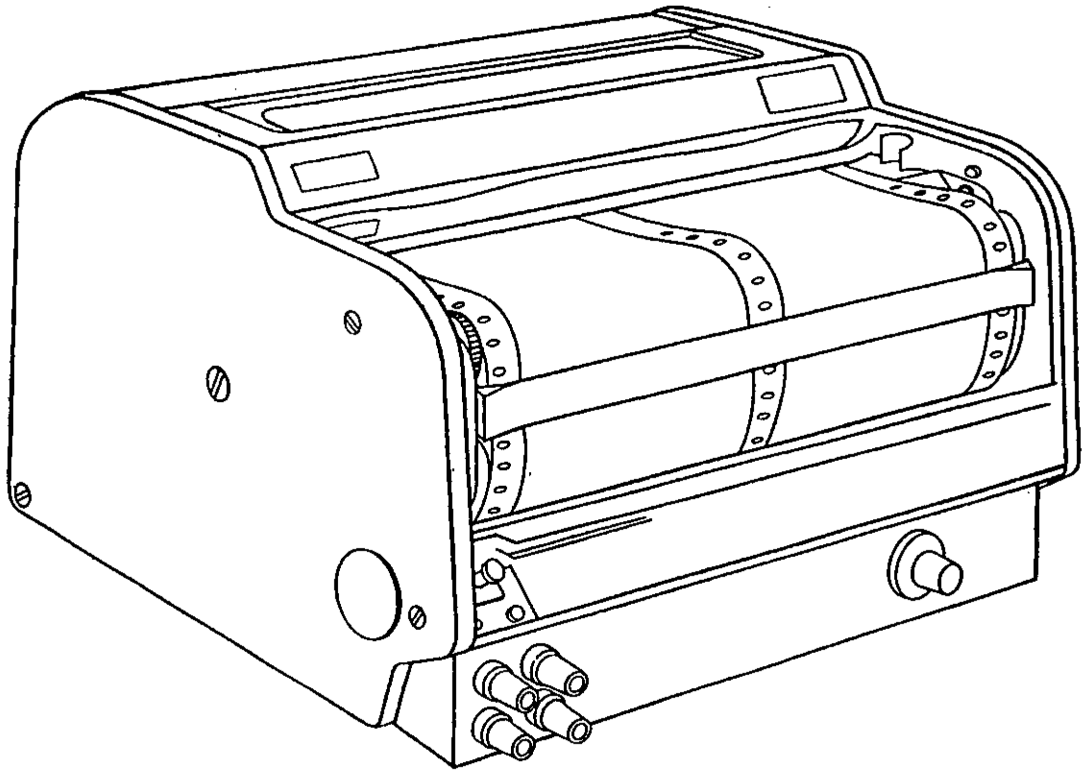


FIGURE 101.1-4. Acceptable type of recording voltmeter.

X-4172A

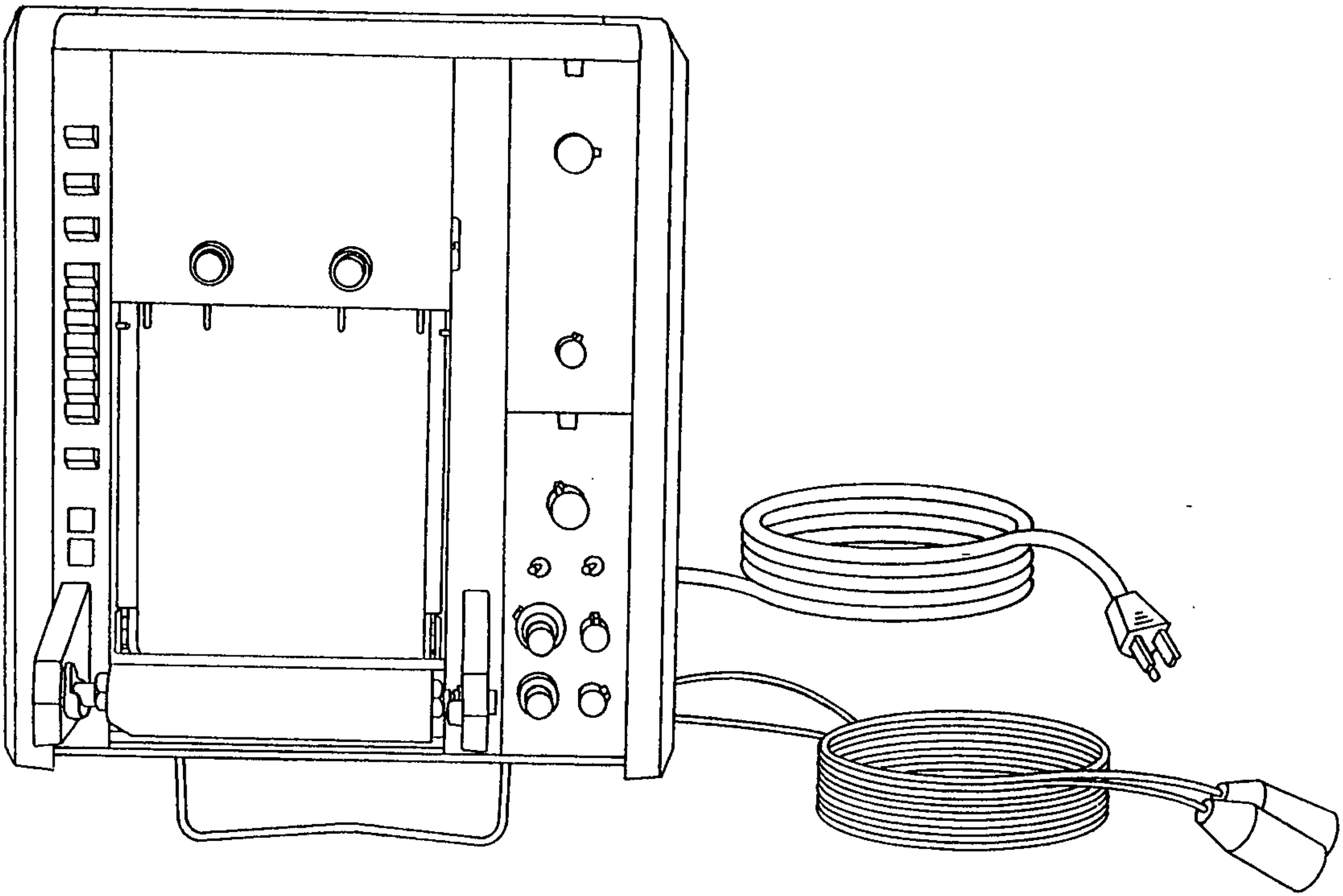


FIGURE 101.1-4.1. Acceptable type of recording voltmeter.

X-4173A

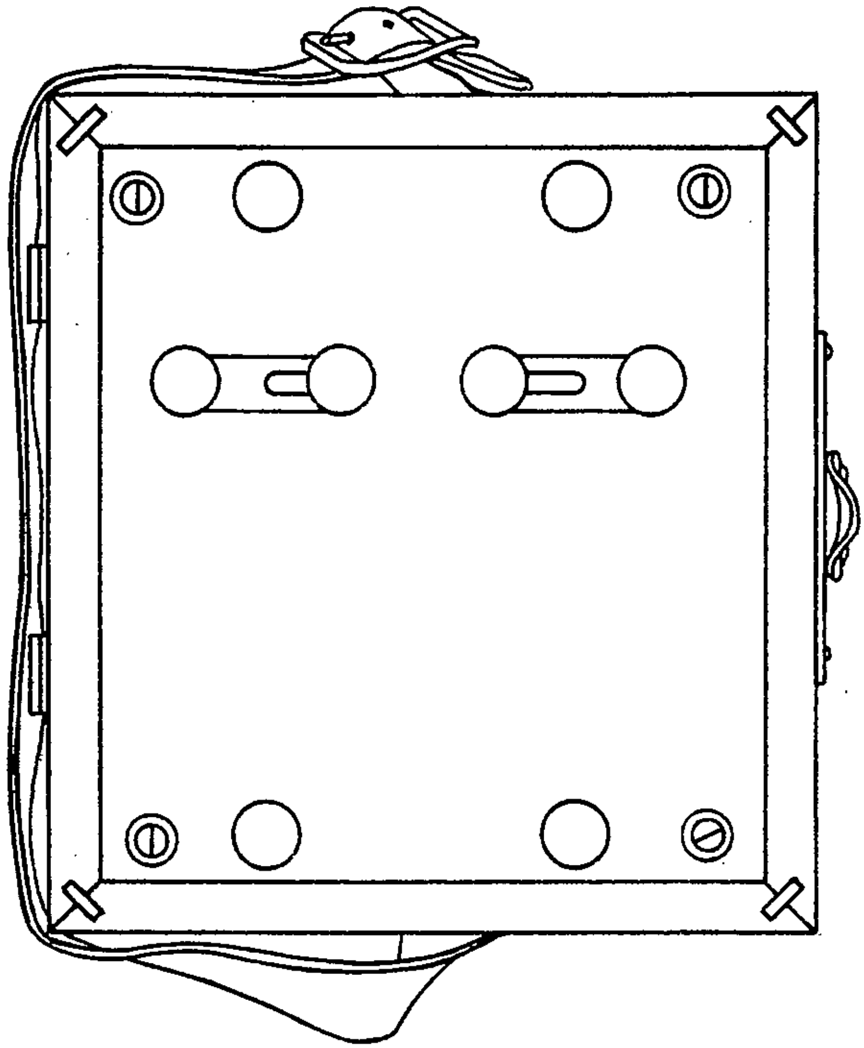


FIGURE 101.1-5. Potential transformer.

X-4174A

METHOD 102.1b

MEASUREMENT OF CURRENT

102.1.1 GENERAL. Current is obtained from the formula

$$I = \frac{E}{R}$$

where I is the current in amperes, E is the potential reading in volts, and R is the resistance in ohms.

102.1.2 INDICATING AMMETERS. When any ammeter is used in a circuit having cyclic or varying current levels, such as exciter fields, it must be recognized that the accuracy of the instrument is compromised by these fluctuations, often by an amount that renders the instrument useless for the intended measurement. Filtering devices are available for minimizing the effects of these fluctuations.

102.1.2.1 DIRECT CURRENT. For the measurement of direct current, analog D'Arsonval-type or digital ammeters are used. Self-contained instruments of these types are available with full-scale readings from 20 microamperes up to 30 amperes (figure 102.1-1).

Digital ammeters are actually digital voltmeters used in conjunction with an internal shunt to display the measured current as a set of numerals.

For measuring current beyond the capacity of the instrument at hand, shunts are used to extend the range of the meters (figure 102.1-2). Shunts are precision four-terminal resistors used to measure current by measuring the voltage drop between the voltage terminals with the current introduced at the current terminals. Shunts are normally calibrated for a specific millivolt drop at a specific known current. When D'Arsonval millivoltmeters are used in connection with shunts, (as in an ammeter system), the millivolt rating of the meter should be the same as that of the shunt at rated current utilizing calibrated leads.

102.1.2.2 ALTERNATING CURRENT. For the measurement of alternating currents (RMS) sensing and indicationg meters such as dynamometers, iron-vane type analog instruments, and digital meters (figures 102.1-3) normally are used. By combining these instruments with appropriate current transformers, any ac current measurements having practical significance can be made. Because of the nonlinear characteristics of most analog ac ammeter scales, they should not be used in the lower portion of their ranges.

102.1.3 CURRENT TRANSFORMERS. Current transformers (figure 102.1-4) are used for two purposes; to isolate the instrument from the line voltage, and to act as a multiplying device for the instruments.

It is desirable to use three current transformers with three ammeters (or one ammeter and a suitable transfer switch) to measure the three line currents on three-phase, three-wire circuits (figure 205.1-12). The use of less than three current transformers is usually not cost-effective, due to time consumed changing test connections, and may not provide the desired level of confidence for acceptance testing.

CAUTION: ALLOWING DIRECT CURRENT TO FLOW IN EITHER WINDING, MAY CAUSE THE TRANSFORMER CORE TO BECOME MAGNETIZED AND IMPAIR THE ACCURACY OF THE INSTRUMENT. IN ADDITION, DANGEROUSLY HIGH VOLTAGES MAY BE INDUCED IN THE SECONDARY WINDING (PRIMARY OR SECONDARY), CAUSING POSSIBLE INJURY TO THE OPERATOR AND BREAKDOWN OF THE WINDING INSULATION. IF MAGNETIZATION IS SUSPECTED OR IF THE CALIBRATION IS NOT EVIDENT, THE TRANSFORMER SHOULD BE SUBMITTED TO A PROPER CALIBRATION FACILITY FOR CERTIFICATION. IN ORDER TO OBTAIN MAXIMUM SAFETY FOR OPERATORS AND APPARATUS, ONE SECONDARY TERMINAL MUST BE GROUNDED; THE METAL CASE OR CORE, IF ACCESSIBLE, MUST BE GROUNDED; CONNECTIONS MUST NOT BE MADE OR CHANGED WITH VOLTAGE ON; THE PRIMARY OF THE TRANSFORMER MUST BE CONNECTED IN THE LINE AND THE SECONDARY TO THE INSTRUMENTS, AND NOT VICE VERSA; AND THE SECONDARY OF THE TRANSFORMER MUST NOT BE OPENED WITH THE CURRENT FLOWING IN THE PRIMARY. A SHORTING SWITCH ACROSS THE SECONDARY WILL BE PROVIDED. THIS SWITCH WILL BE OPENED ONLY WHEN TAKING METER READINGS. THIS SWITCH NORMALLY WILL BE A PART OF THE CURRENT TRANSFORMER.

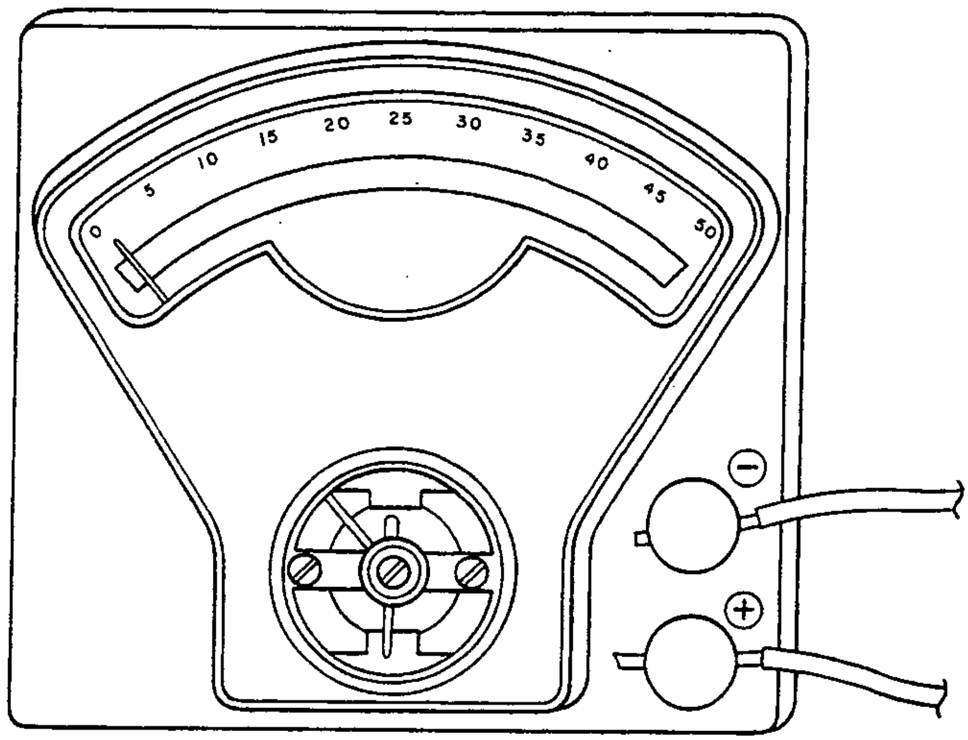


FIGURE 102. 1-1. Acceptable type of self-contained dc ammeter.

X-4175A

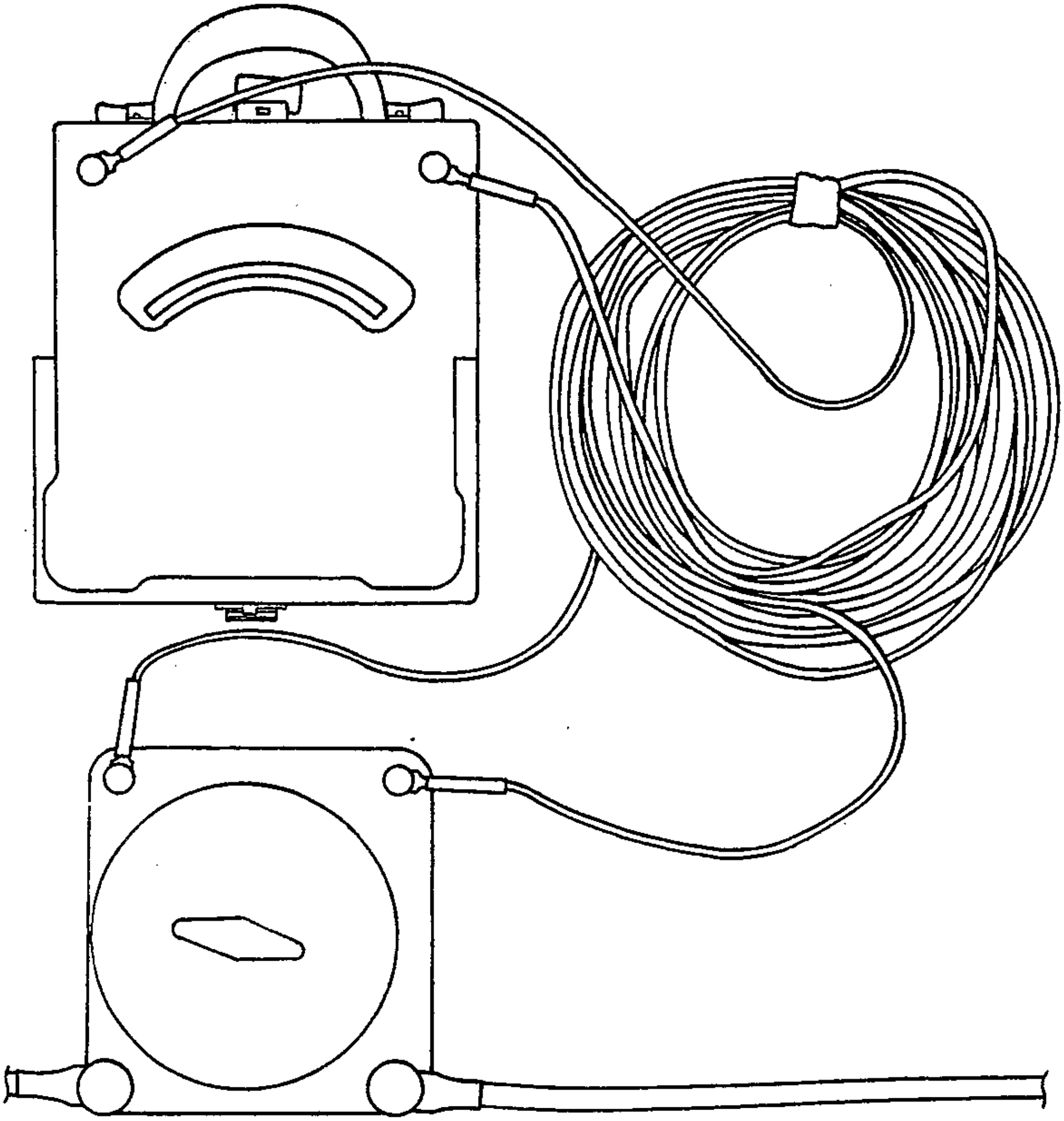


FIGURE 102.1-2. Dc ammeter with rotary shunt.

X-4176A

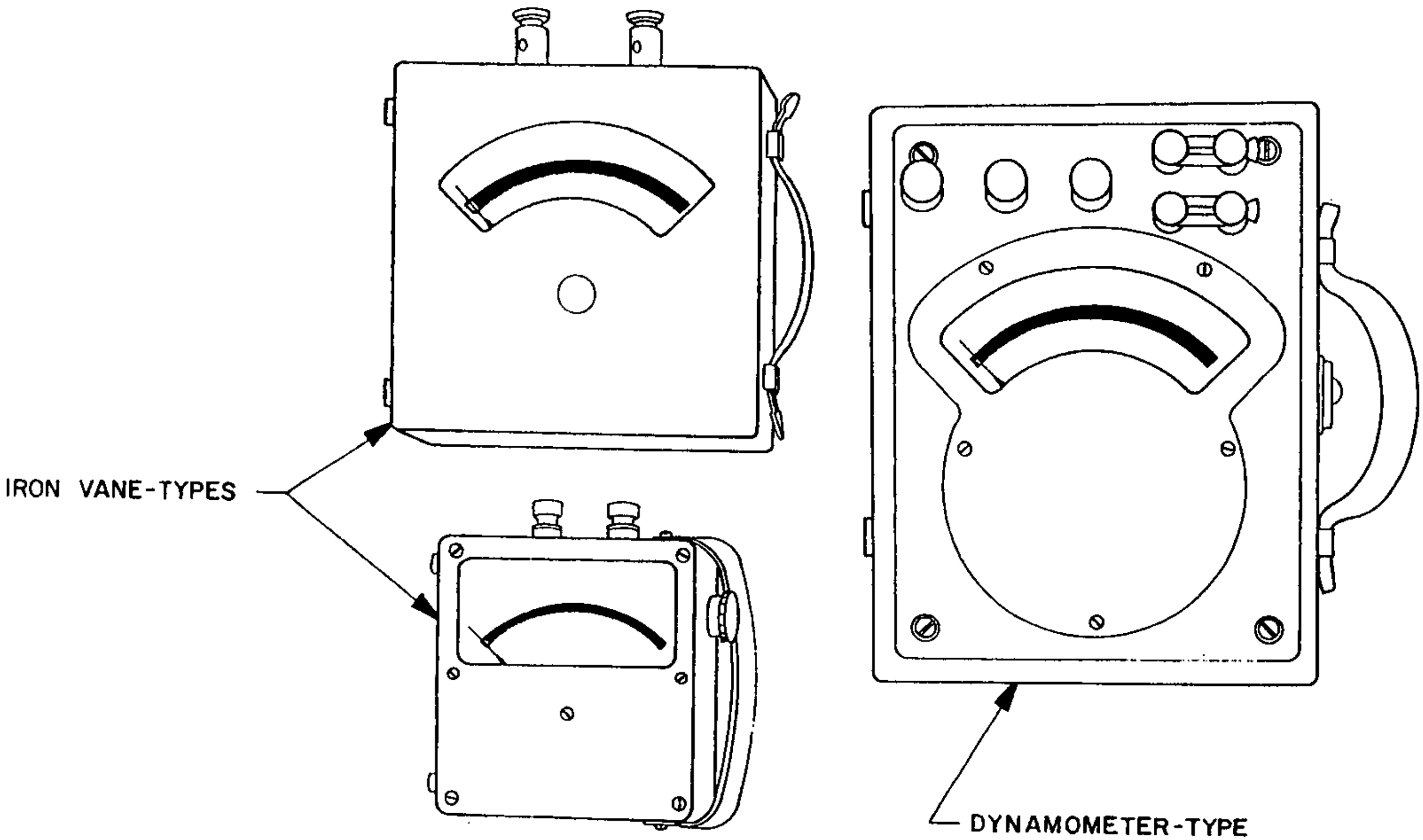


FIGURE 102.1-3. Representative meters suitable to measure ac current.

X-4177A

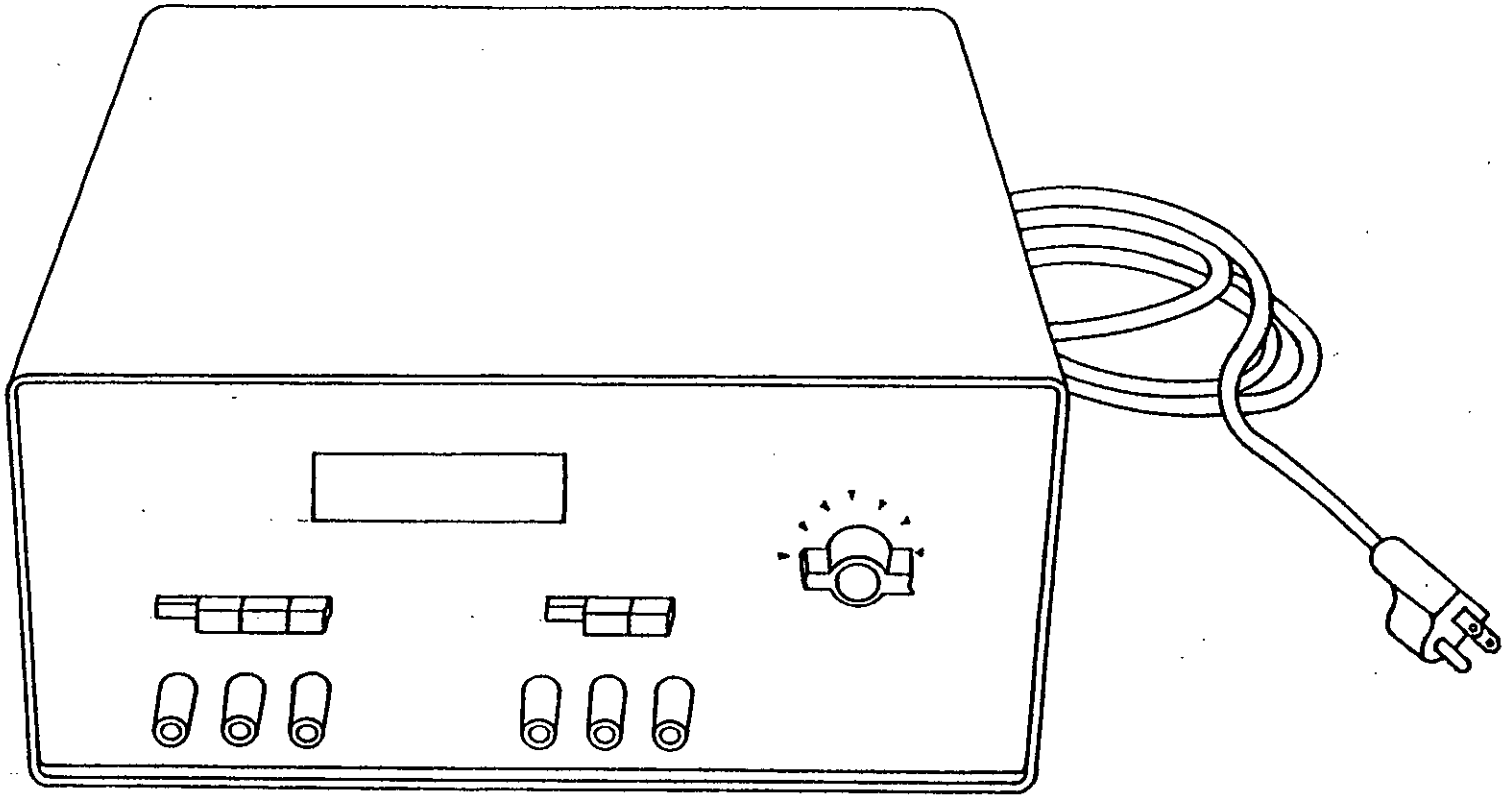


FIGURE 102.1-3.1. Representative meter suitable for measurement of ac current.

X-4178A

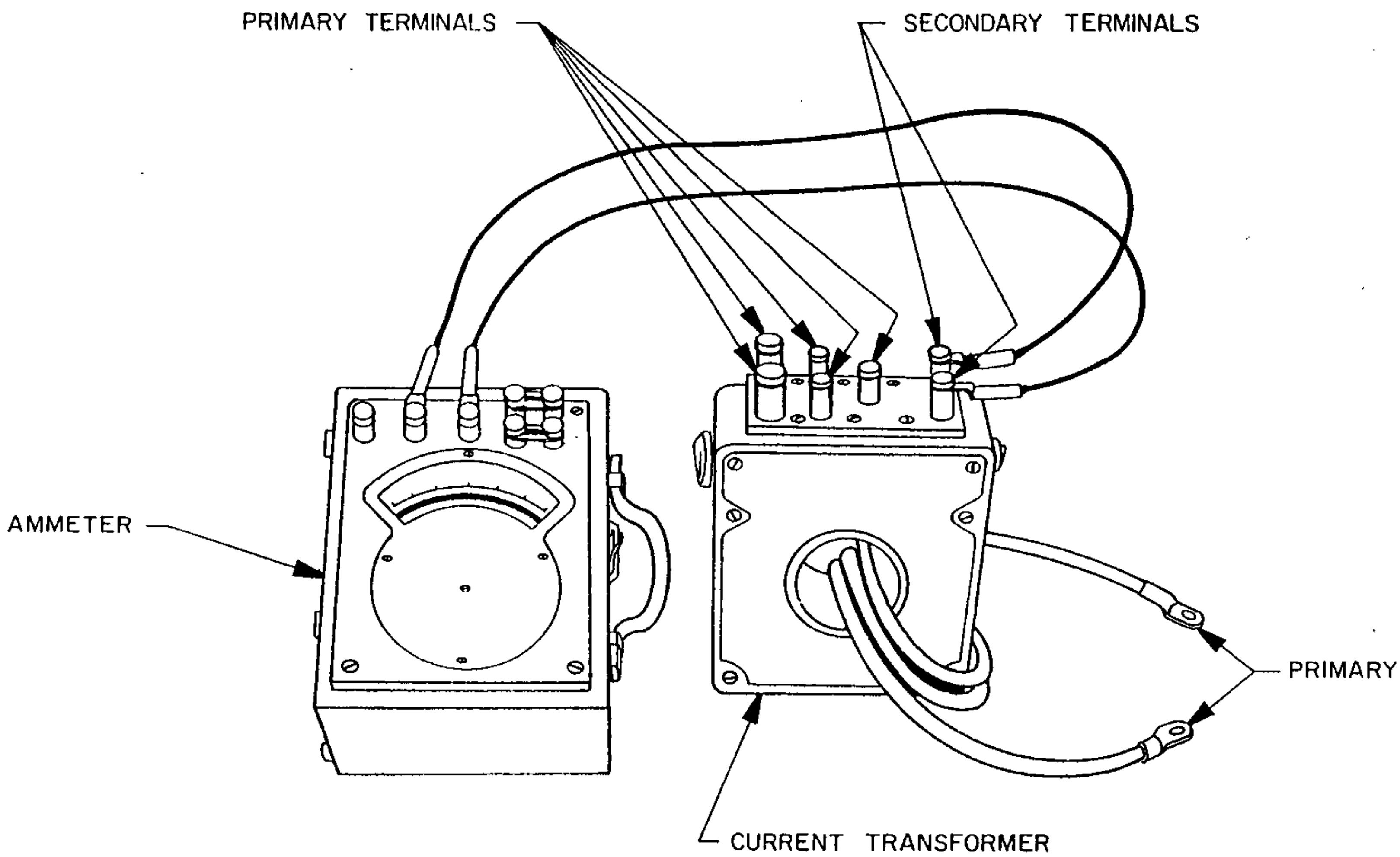


FIGURE 102.1-4. Ac ammeter with current transformer.

X-4179A

METHOD 103.1b

MEASUREMENT OF POWER

103.1.1 GENERAL. Mechanical power most commonly is expressed in horsepower. Electrical power ordinarily is expressed in watts.

There is no practical primary standard of electric power, the watt being derived from the volt and ampere. However, expressed in terms of work performed, one kilowatt (1,000) is equal to 1.34 horsepower.

Horsepower is the equivalent of the amount of work performed in a given time. One horsepower is the rate of work performed equivalent to raising 33,000 pounds 1 foot in 1 minute.

103.1.2 DC MEASUREMENT. DC power is usually found by computing the product of the voltage and amperage in the circuit. This is represented by the formula $W = EI$ where W is in watts. Wattmeters ordinarily are not used for measuring power in dc circuits.

103.1.3 AC MEASUREMENTS. Wattmeters (figure 103.1-1) for measuring ac power may be designed for use in single-phase or polyphase circuits. The formula for power in a single-phase circuit is $W = EI \cos \theta$, where E is the line voltage, I is the line current, and $\cos \theta$ is the power factor (see Method 107.1). For balanced three-phase circuits the power formula is $W = \sqrt{3}\, EI \cos \theta$, where E is the line-to-line voltage, I is the line current, and $\cos \theta$ is the power factor.

Wattmeters are generally available with potential circuits rated from 10 to 600 volts, and current circuits rated from 1.5 to 200 amperes. Full scale readings for such instruments range from 15 to 120,000 watts. There are also special wattmeters designed for use at low power factors.

Transducers are available to convert real power (watts) to a dc voltage with the dc voltage directly proportional to the power. These transducers may be used during the performance of the tests contained in MIL-STD-705 providing the accuracy of the system (transducer and voltmeter) meets the instrumentation accuracy required in Method 201.1 and the normal instrumentation calibration requirements are met.

AC digital wattmeters are available for measurement of power and may be used interchangeably with analog instruments.

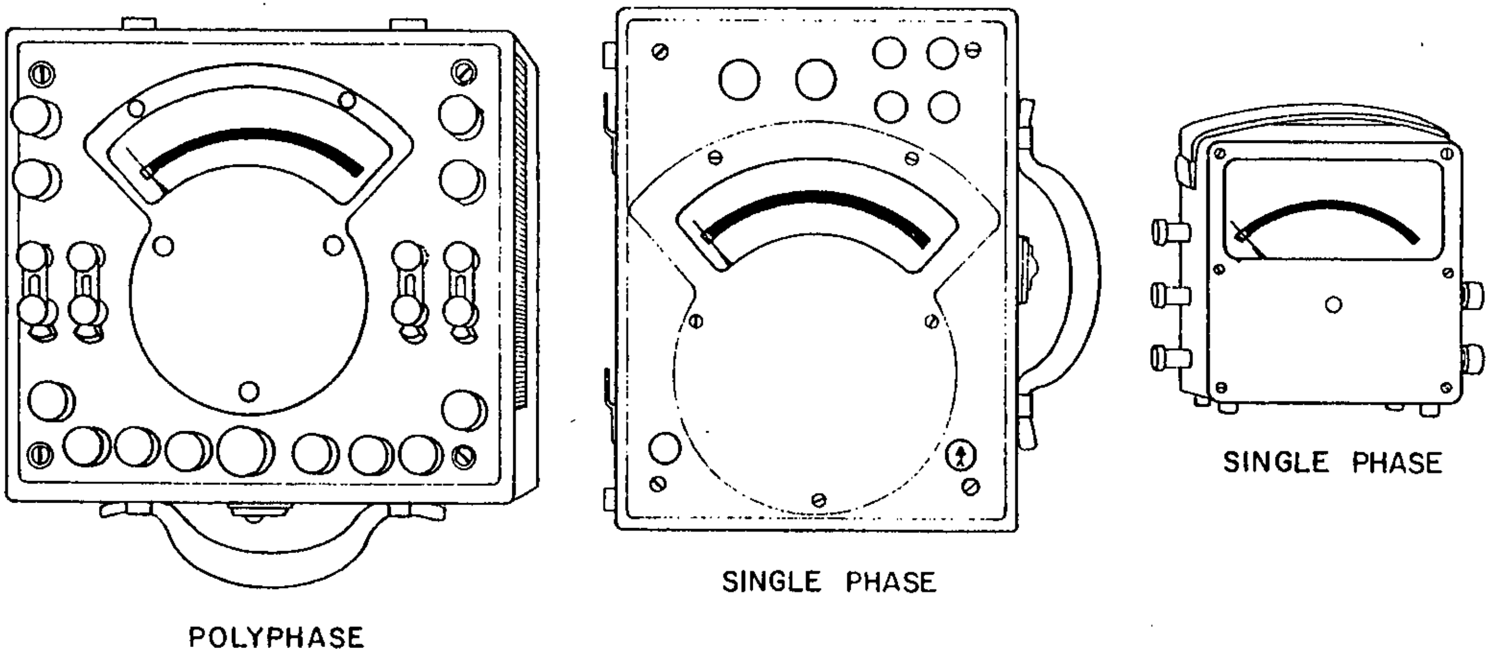


FIGURE 103.1-1. Acceptable types of wattmeters.

X-4180A

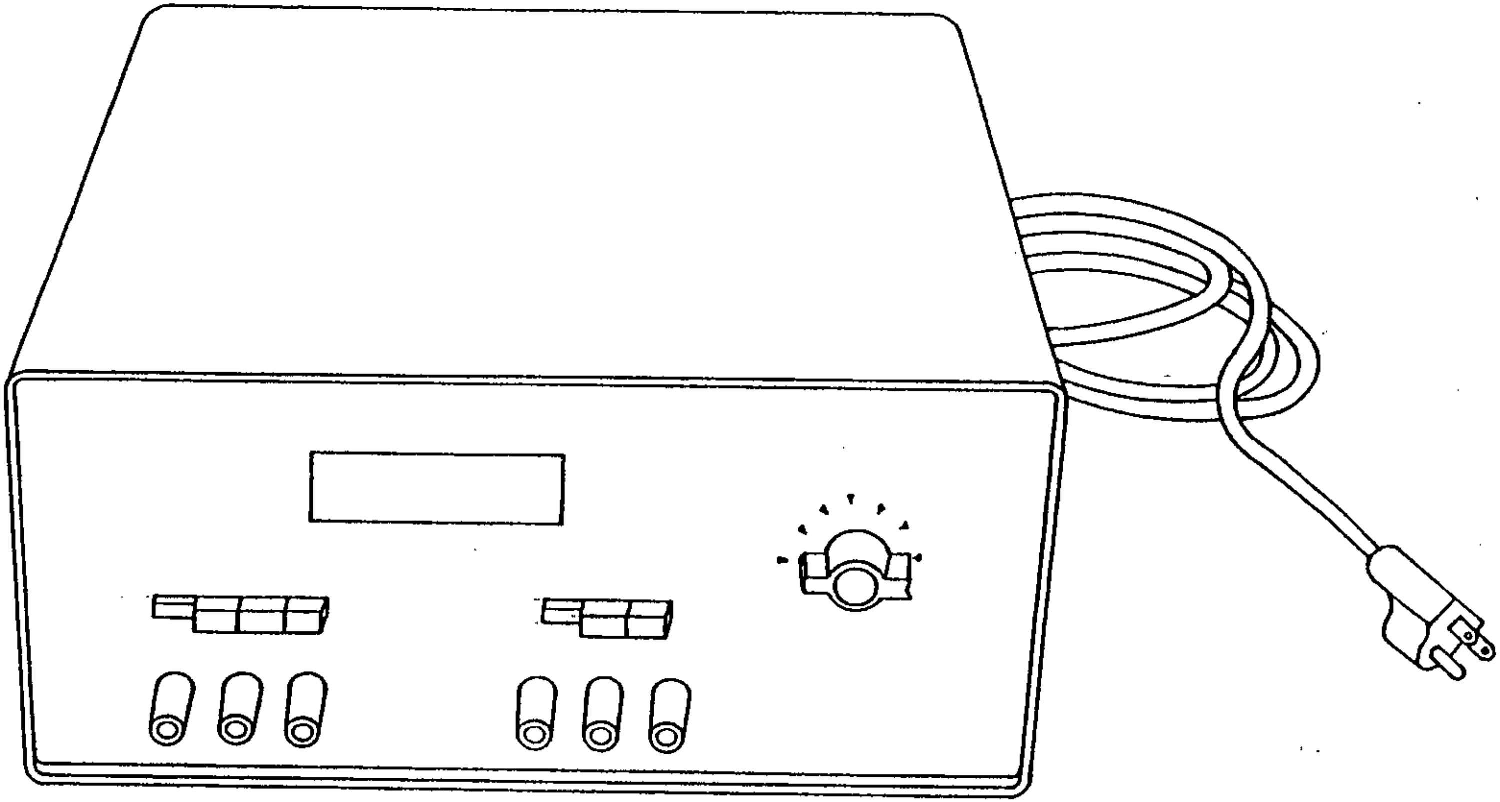


FIGURE 103.1-1.1. Representative meter suitable to measure power in watts.

X-4181A

METHOD 104.1b

MEASUREMENT OF FREQUENCY

104.1.1 GENERAL. Frequency is defined as the number of recurrences of a cyclic quantity per unit of time. For ac circuits, frequency normally is expressed in Hertz.

The primary standard of frequency is maintained at the National Bureau of Standards in the form of quartz-crystal oscillators maintained under carefully controlled conditions, at constant pressure. The oscillators control various standard frequencies ranging from 440 Hertz to 15 megaHertz. Some of these are broadcast continuously.

104.1.2 INDICATING FREQUENCY METERS. There are two types of indicating frequency meters. They are the type constructed on the resonant-circuit principle (figure 104.1-1) and the digital frequency meter (figure 104.1-2). The first type usually makes use of two or more resonant circuits and a differential-type measuring instrument. Thus, if one circuit resonates at a frequency slightly below the other, the ratio of the currents in the two circuits is a measure of the impressed frequency. Indicating frequency meters of this type have no springs to return the pointer to the end of the scale; therefore, the pointer will take no particular position when the instrument is not connected in a circuit.

These instruments will operate with satisfactory accuracy on voltages within 10 percent of their rating and generally are unaffected by voltage changes within this range.

Digital frequency meters are also available for these measurements and may be used interchangeably with analog instruments, providing the frequency is not cyclic or varying.

104.1.3 RECORDING FREQUENCY METERS. Recording frequency meters are used to measure the transient change in speed of a generator set due to a sudden change in load and the steady state stability of a generator set under constant conditions. The use of a recording frequency meter is especially convenient for alternating current generators, and has the important advantage of giving a graphical record of frequency variation. However, because of the effects of inertia and damping, the response of the instrument is never instantaneous, consequently the measured frequency variation is subject to dynamic errors which may sometimes be very large. In addition, due to the differences in construction or adjustment, the torque and response characteristics of different instruments (even of the same make) may be different so that their results are not necessarily comparable. Finally, because the torque and response characteristics of a given instrument may be affected by environmental and operating conditions, it is sometimes difficult even to compare readings from the same instrument.

Only through a large number of tests utilizing many different instruments of the same make and model can resolution of the above difficulties be assured. It has been found that with adjustments to the manufacturer's specifications the Texas Instruments Model PDRHXFHXVA-A16-XT or Gould Model 2108-2202-005542 (figures 104.1-3) recording voltage and frequency meter will give satisfactory results when this type of instrument is called for in MIL-STD-705. The requirements of the procurement document must state the instrument to be used if other than as specified herein.

The chart speeds will be specified in the specific test methods. The transducer power supplies and chart drives shall, when possible, be powered independently from the set under test.

104.1.4 VIBRATION FREQUENCY METERS. Vibration-type frequency meters employ mechanical response to obtain a frequency indication. These instruments are rugged and dependable and retain their calibration for long periods of time. They are not affected by small changes in signal voltage. However, this type of instrument ordinarily is not used in performing precision tests because of the difficulty in reading exact frequencies to a close enough accuracy and, in addition, they are almost useless in the measurement of frequency transients.

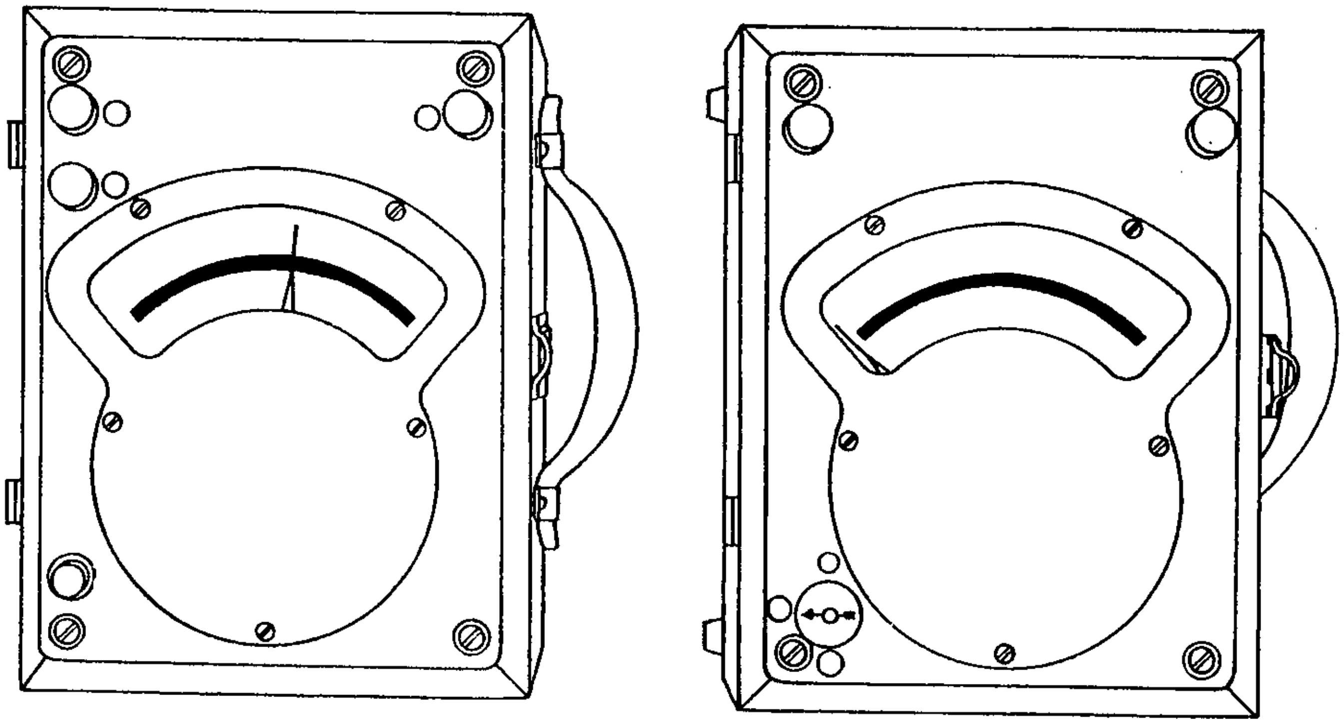


FIGURE 104.1-1. Representative meters suitable for measurement of frequency.

X-4182A

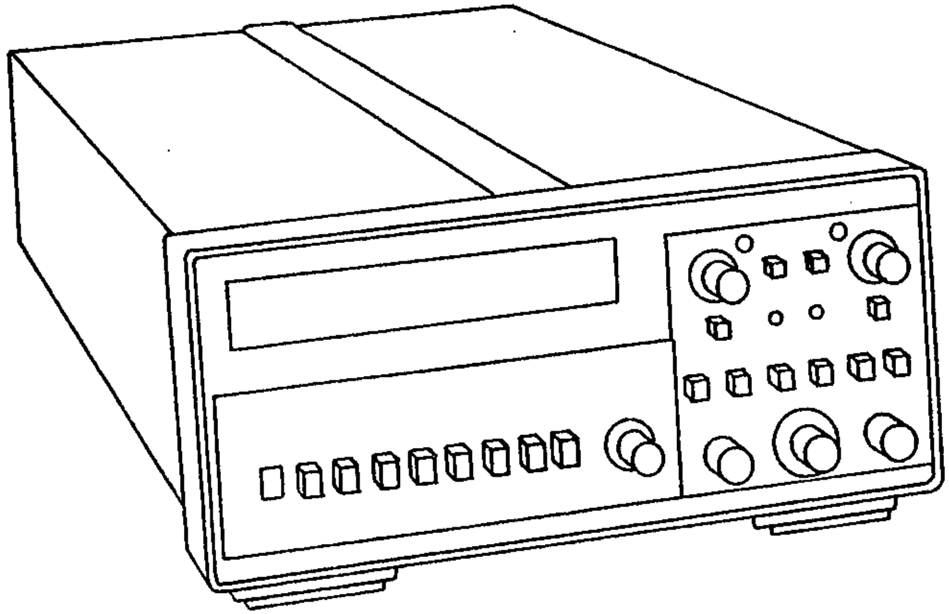


FIGURE 104.1-2. Representative meter suitable for measurement of frequency.

X-4681

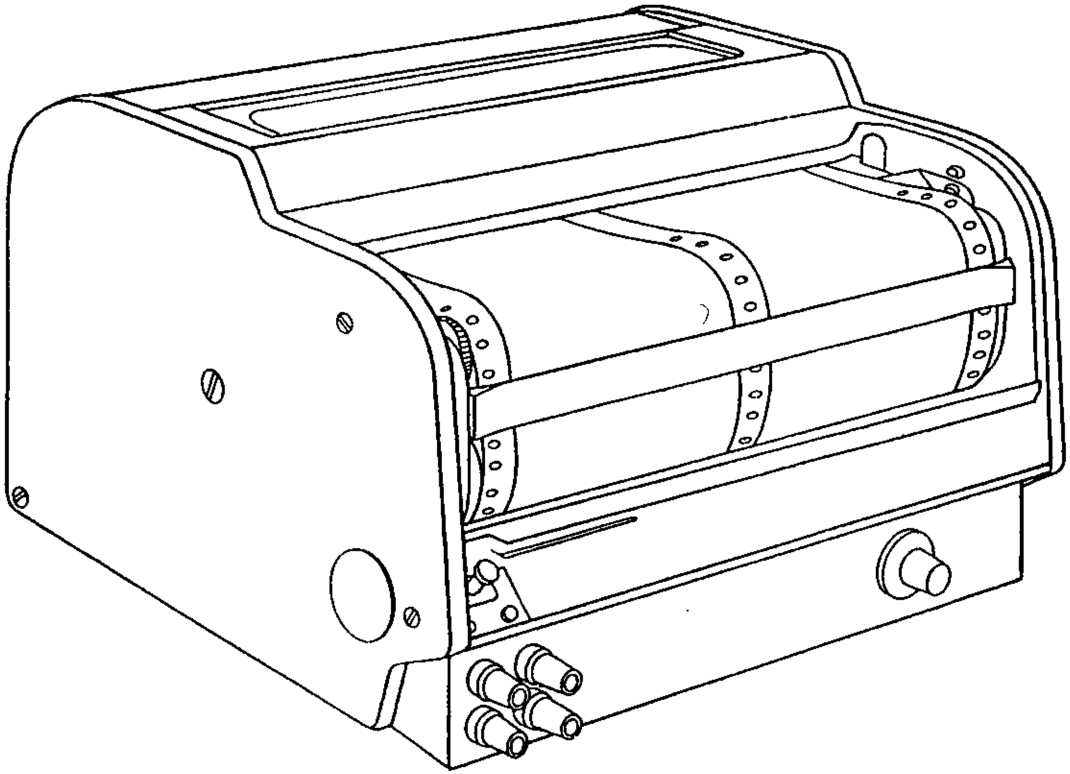


FIGURE 104.1-3. Acceptable type of recording frequency meter.

X-4183A

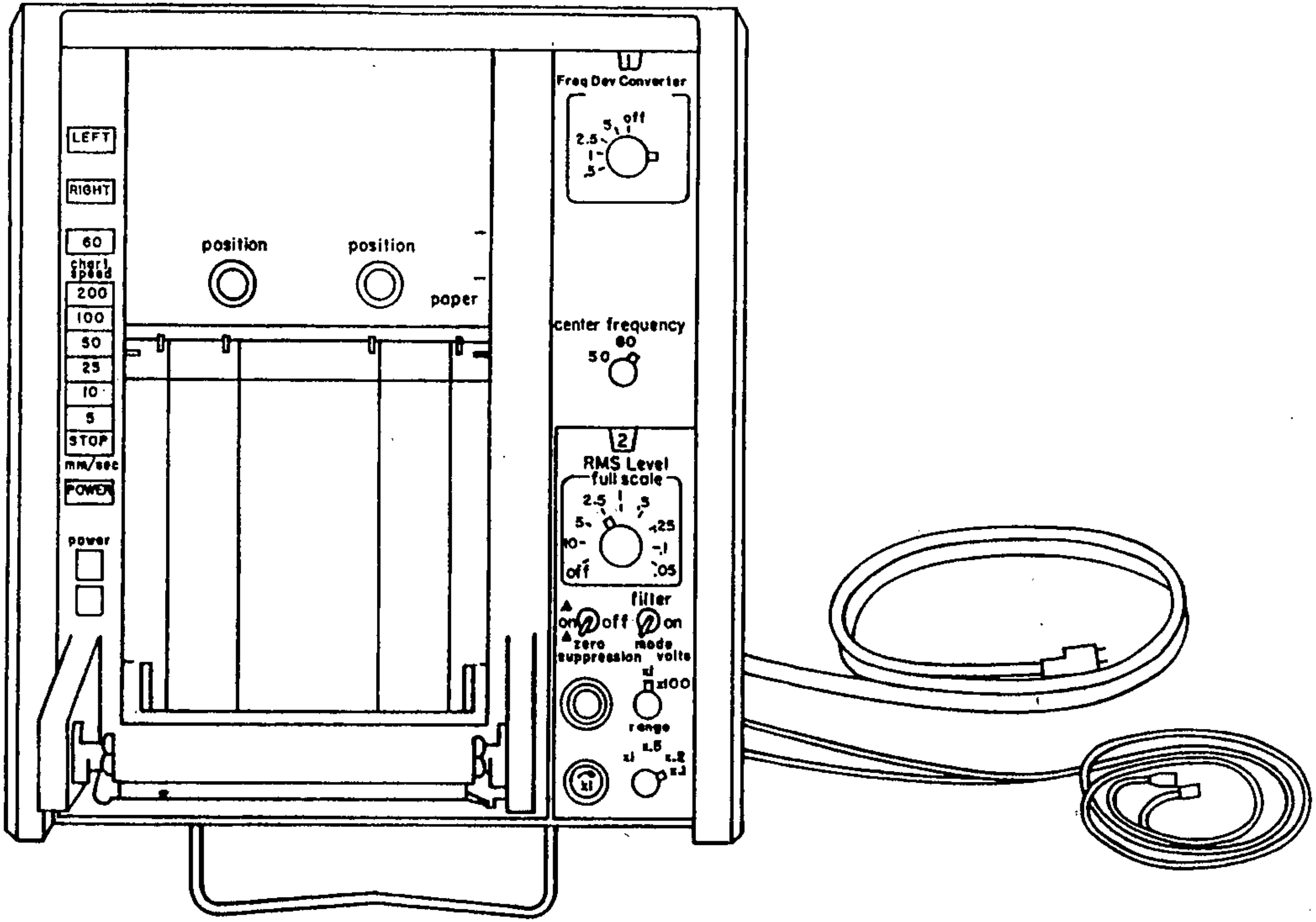


FIGURE 104.1-3.1. Acceptable type of recording frequency meter.

X-4184

METHOD 105.1b

MEASUREMENT OF RESISTANCE

105.1.1 GENERAL. The primary standard of resistance is the ABSOLUTE ohm, which is derived from the fundamental units of length, mass, and time. The National Bureau of Standards maintains the primary standards of resistance in the form of 1-ohm resistors, which are kept at constant temperature when in use.

The importance of accuracy in measuring resistance cannot be overemphasized. These measurements are used to calculate the efficiency of a generator, and to determine the temperature rise of the windings. Both of these are critical factors in design. These measurements also are employed to determine the correctness of the internal connections of the generator, and, at times, tc ascertain whether a sample test generator is the same as the production model.

The leads of the winding to be measured must be clean. The terminal lugs should be cleaned with emery cloth to make sure that all foreign matter, paint, varnish, or oxide coating is removed and only bright, bare metal remains exposed for contact with the Kelvin or Wheatstone bridge leads. The bridge leads shall be secured firmly to assure positive contact with the terminal lugs. Care must be taken to compensate for lead resistance to the test instrument if such resistance is of a significant value compared to the resistance being measured (105.1.3.1).

105.1.2 CLASSES OF RESISTANCE MEASUREMENTS. There are three general classes into which resistance measurements are divided. These are: LOW resistances, covering a range below 1 ohm; MEDIUM resistance, covering a range between 1 and 100,000 ohms; and HIGH resistances, covering a range above 50,000 ohms. These will be discussed in detail in the following paragraphs.

Circuits whose resistance is to be measured often are highly inductive, and damage to the galvanometer or detector may result unless the following precautions are excerised: Close the battery or supply switch first, wait a few seconds for the current to build up, then close the detector switch. After obtaining the setting or reading, open the detector switch first, then open the supply switch.

105.1.3 LOW RESISTANCE MEASUREMENTS. To measure resistance of less than one ohm, one of the following three methods usually should be used: the Double-Bridge Method, the Drop-in-Potential Method, or the Comparison Method.

105.1.3.1 Double-Bridge Method. The so-called "Kelvin Double Bridge" (figure 105.1-1) is a modification of the "Wheatstone Bridge" and is so arranged that the resistance of the instrument leads and contacts is not included in the measured resistance. It is, therefore, adaptable to the measurement of very small resistances, of which the lead and contact resistance would otherwise form a large and indeterminate part.

The isolation of the resistance to be measured from the lead and contact resistances is achieved by the use of separate pairs of leads for current and potential. Therefore, to secure accurate results the current and potential leads must be attached separately to the measured resistance: The potential leads must be paralleled with the resistance to be measured and the current leads attached such that the current leads allow the current to become evenly distributed before reaching the potential leads. If the current and potential leads are connected together, the advantage of the double bridge circuit will be reduced.

These bridges are supplied with special calibrated leads and, when other leads are used, they should have a resistance within about 20 percent of the resistance of the regular bridge leads.

The double bridge is a null-balance instrument usually containing a ratio dial, a resistance dial, and a galvanometer. Adjust the ratio and resistance dials until the galvanometer indicates balance, then calculate the resistance by multiplying the two dial settings.

When the double bridge is used on inductive circuits, the galvanometer may swing violently when the key is depressed. This is due to the inductive transient and may be ignored. The final, steady position of the galvanometer is the significant indication in all cases.

105.1.3.2 Drop-in-Potential Method. A resistance may be calculated by means of ohm's law, $R = \frac{E}{I}$ if the voltage across the resistance and the amperage through it are known. Thus, to measure a resistance by the drop-in-potential method, connect the unknown resistance in series with an ammeter and a source of constant direct current. Connect a voltmeter across the resistance. Then, calculate the resistance by dividing the voltmeter reading by the ammeter reading (figure 105.1-2).

The ammeter and voltmeter should be chosen so that the deflections obtained are reasonably large in order to avoid the large percentage errors which may occur in the lower part of the instrument scales.

The current used should be great enough to give good instrument readings without heating the unknown resistance, which would change its value. If the current used is unsteady, simultaneous instrument readings should be taken by two observers. A series of such readings, when averaged, will give reasonably accurate results although the individual readings are in error.

The ratio of the voltmeter resistance to the unknown resistance affects the accuracy of the measurement because the voltmeter current flows through the ammeter. The fractional error is equal to the reciprocal of this ratio (the unknown resistance divided by the voltmeter resistance). If the ratio is 1,000 or less, the ammeter reading should be corrected accordingly.

For very precise work, the voltmeter should be replaced with a potentiometer, and the ammeter with a potentiometer and calibrated shunt.

105.1.3.3 Comparison Method. The comparison method of measuring resistance is an adaptation of the drop-in-potential method described above. However, the results obtained are independent of the current measurement.

In this method, connect the unknown resistance in series with a known resistance and a source of direct current (figure 105.1-3). Measure the voltage across both resistances and calculate the unknown resistance by the following formula:

$$X = \frac{R\ E_x}{E_r}$$

where:

X is the unknown resistance.
E_x is the voltage across X.
E_r is the voltage across R.
R is the known resistance.

Maximum accuracy is obtained when R and X are equal.

The current source should be steady and the voltmeter should have a resistance 100 or more times the resistance of either R or X.

This method is especially applicable to a wide variety of measurements in which the actual value of each of a series of resistances is relatively unimportant, but in which all of the elements should be equal, such as the windings of a dc generator, or the field coils of an alternator. In this case, connect the elements to be measured in series and measure the drop across each one. If the resistance of one element is used as a standard, the calculations are the same as previously described.

105.1.4 MEDIUM RESISTANCE MEASUREMENTS. Resistances which fall between approximately 1 ohm and 100,000 ohms are measured by either the "Wheatstone Bridge Method" or with an ohmmeter.

105.1.4.1 Wheatstone Bridge. When the wheatstone bridge (figure 105.1-4) is used, ratios should be selected so that the bridge resistances correspond as closely as possible to the resistance being measured.

So that the galvanometer will not be subjected to an inductive voltage surge, use the instrument shunt key to complete the current circuit before the galvanometer circuit is closed. Reverse the sequence when the circuit is opened.

The bridge measures total resistance of the circuit between its binding posts; that is, resistance of the leads (or probes) connecting the bridge with the winding is included with the resistance of the winding itself.

Resistance of the winding is the difference between resistance as measured and resistance of connecting leads, assuming that connections between leads and windings have been properly made. If not, contact resistance also influences the measurement (see 105.1.1).

For wheatstone bridges, unless they are self-contained, a current-limiting resistor of about 50 ohms per volt of battery supply should be connected in series with the battery to protect the bridge coils from damage at low resistance settings.

For ordinary bridge measurements, the temperature coefficient of the bridge itself can be neglected. The temperature coefficient of material being measured, however, must always be considered, and an allowance for it should be made, when necessary, to assure accuracy (see Method 221.1).

105.1.4.2 Ohmmeter. Ohmmeters are available with full-scale ratings from 1 ohm to 1,000,000 ohms. They are applicable where portability and automatic readings are important factors, but where highly accurate readings are required, the methods described above should be employed.

105.1.5 HIGH RESISTANCE MEASUREMENTS. Resistances of 50,000 ohms and more may be measured by either of the following methods:

105.1.5.1 DC Voltmeter Method. A dc voltmeter with a resistance of approximately 100 ohms per volt, and a source of constant potential, usually about 500 volts, are employed in this method.

Connect the voltmeter directly across the source and note the reading. Insert the unknown resistance in series with the voltmeter and source and again note the reading.

Calculate the unknown resistance from the following formula:

$$X = R_v \frac{E - V_r}{V_r}$$

where:

X is the unknown resistance.
E is the supply voltage.
V_r is the voltmeter reading in series with X.
R_v is the voltmeter resistance.

This method should be used only when the supply voltage is steady. When the voltage is unsteady, simultaneous readings of E and V_r should be taken with two voltmeters. In this case, R_v is the resistance of the voltmeter in series with X.

Caution must be exercised in the use of this method because of the high voltage supply.

105.1.5.2 Megger Method. A "megger", or insulation resistance tester, is a self-contained direct-reading instrument, consisting of a small magnetic generator, battery, or electronic power supply, standard resistances; and a differential-current milliammeter.

The electomotive force of the generator is impressed upon the unknown resistance and the standard resistance, in parallel. The two currents are compared in the differential-type instrument so that the instrument reading depends only upon the value of the unknown resistance and is independent of the applied emf.

A slip-clutch is used to obtain constant speed on the hand-driven type instruments (figure 105.1-5) in order to avoid the erratic efforts which would otherwise appear as a result of the charging currents caused by variable voltage being applied to circuits having appreciable electrostatic capacity, such as the armatures of large generators. While these instruments are being used, the crank must be turned at a speed sufficiently high to keep the clutch slipping.

The megger always should be operated until the indication is steady and constant before a reading is taken.

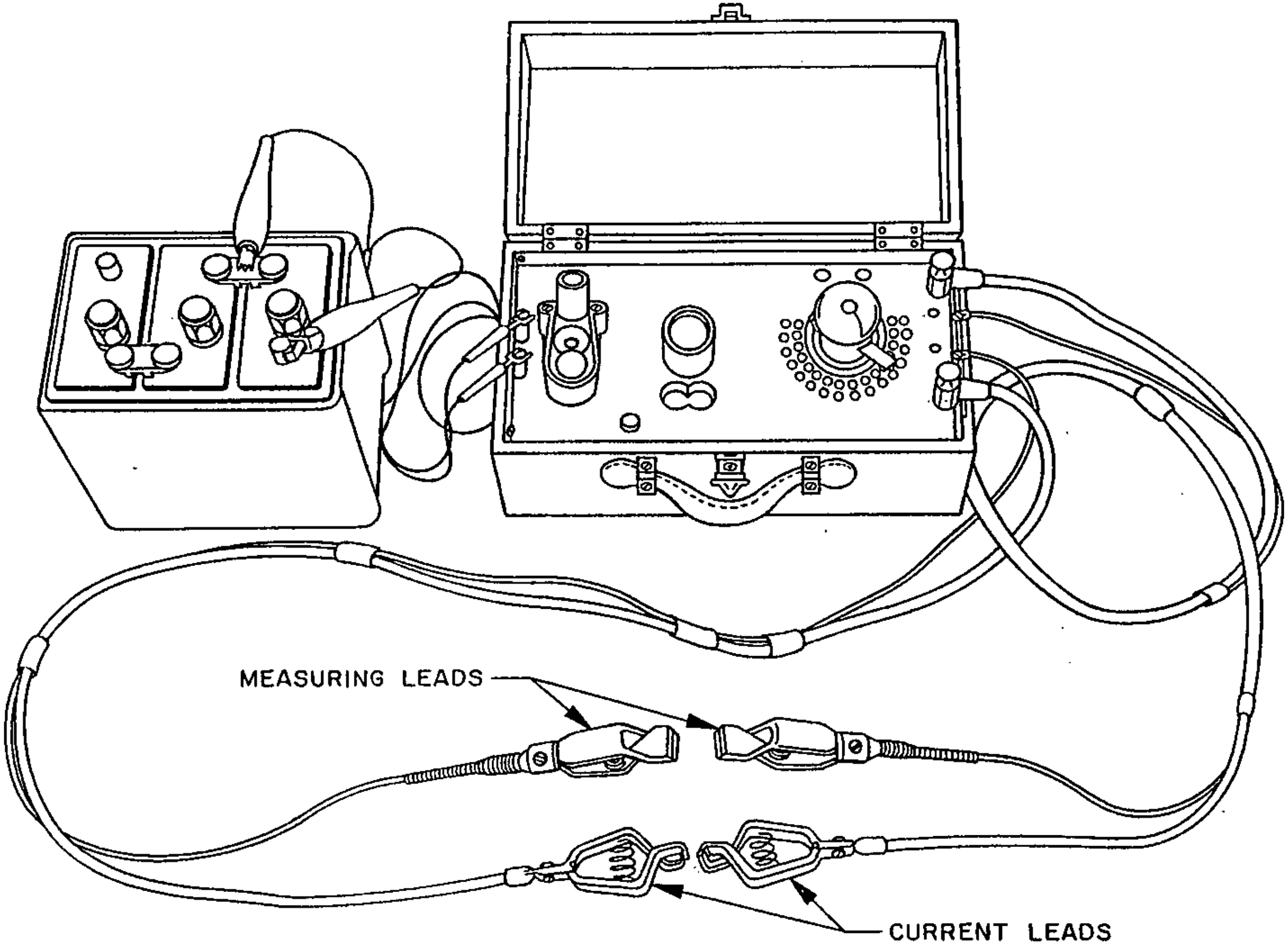


FIGURE 105.1-1. Kelvin bridge for measuring low resistance.

X-4185A

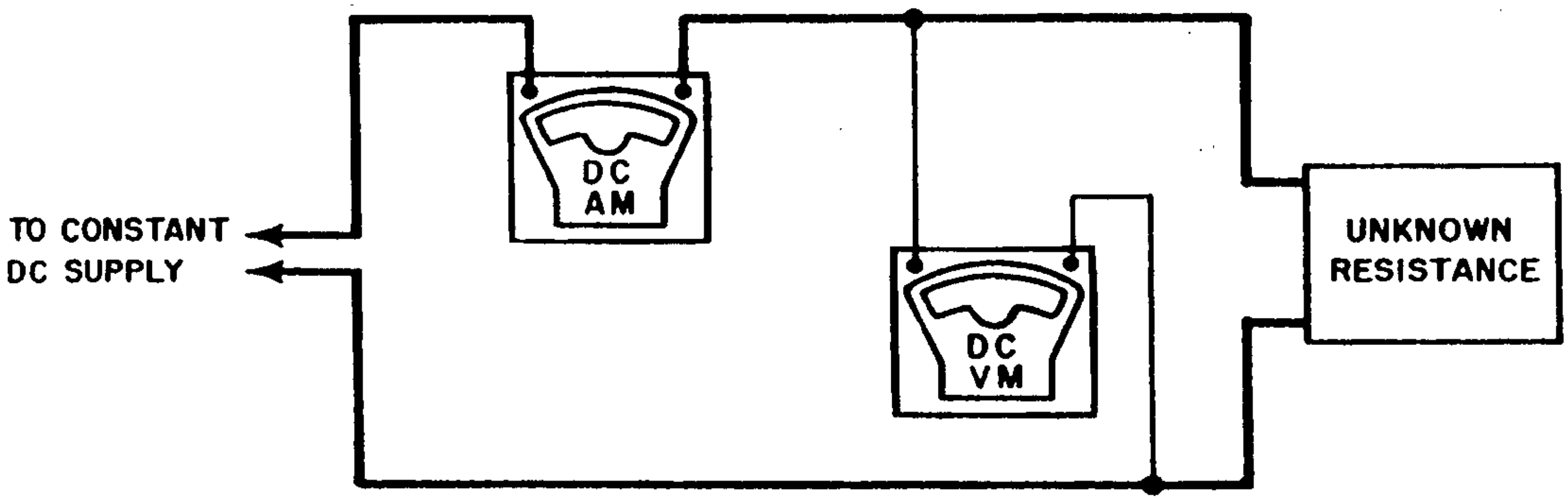


FIGURE 105.1-2. Drop-in-potential test connections.

X-4186

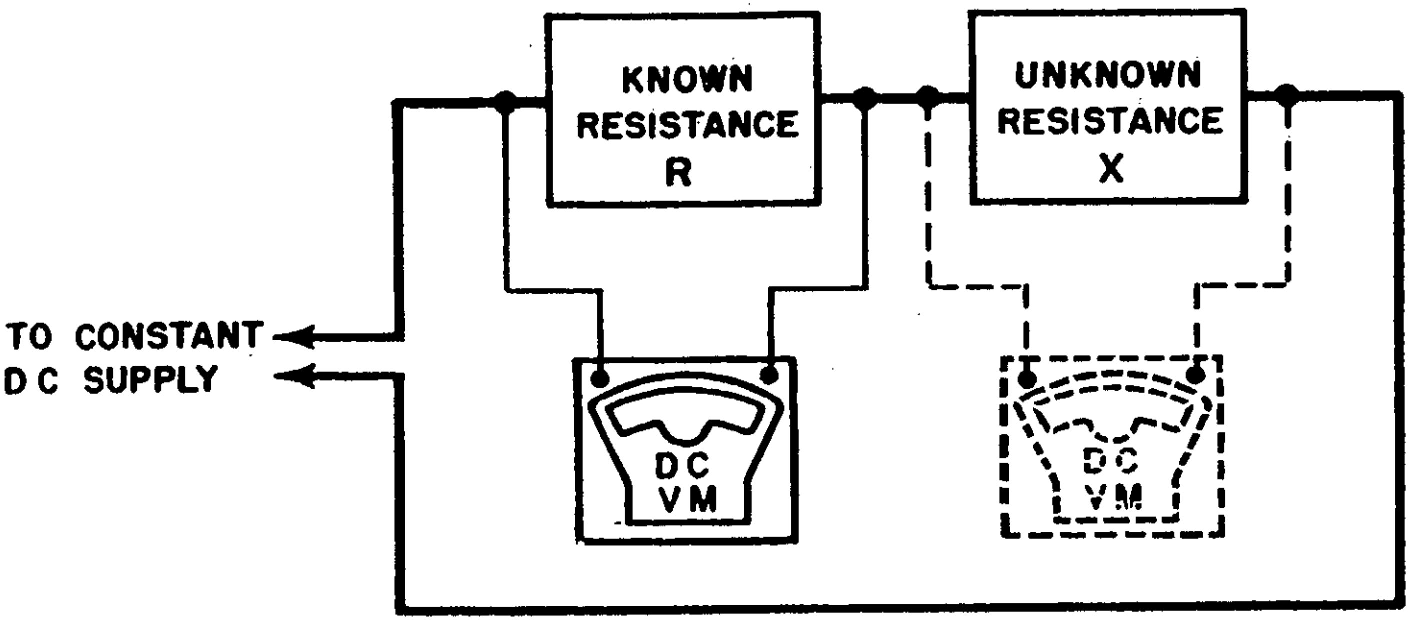


FIGURE 105.1-3. Comparison method test connections.

X-4187

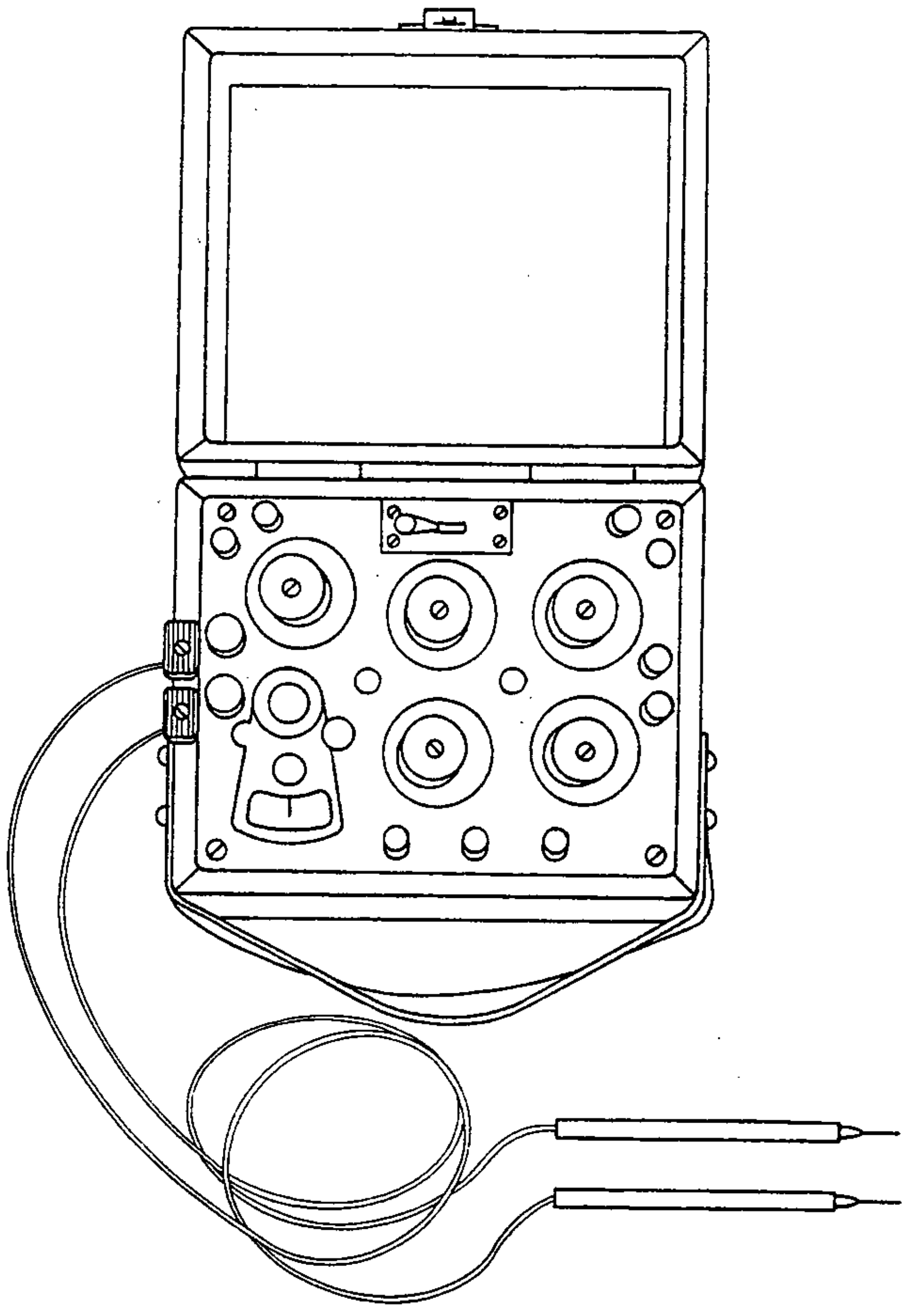


FIGURE 105.1-4. Wheatstone bridge for measuring resistances.

X-4188A

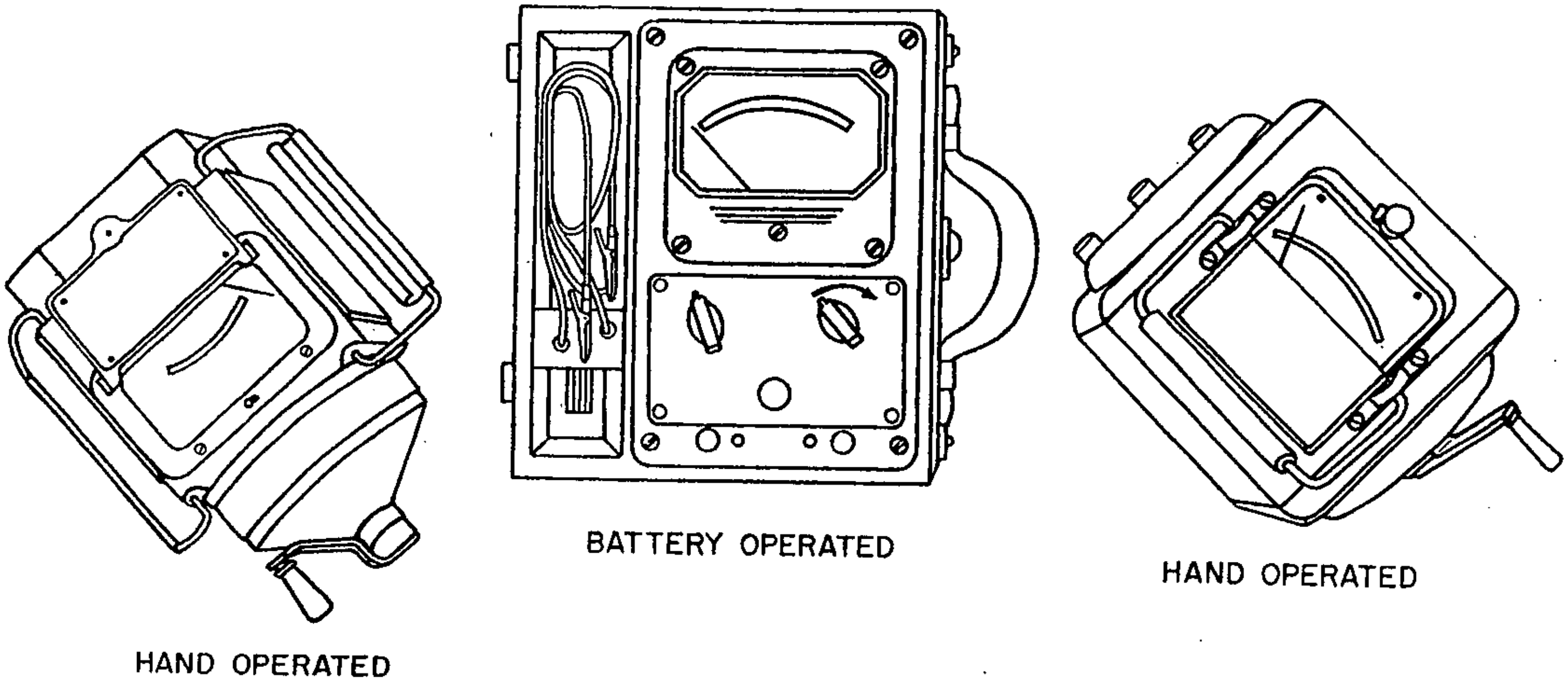


FIGURE 105.1-5. Acceptable types of megohm meters.

X-4189A

Method 106.1b

MEASUREMENTS OF TRANSIENTS AND WAVEFORM

106.1.1 GENERAL. Electrical transients and waveform may be observed by connecting an oscilloscope or an oscillograph to the circuit in question. Waveform cannot be determined by using a harmonic analyzer to measure the magnitude, or relative value, of the component frequencies, and plotting the waveform from these values, since the phase angle differences of the various harmonics would not be known. However, harmonic analyzers may be used to determine a measure of deviation of an unknown wave from a sine wave.

106.1.2 OSCILLOSCOPE. Oscilloscopes are extremely versatile instruments which are procurable in single-beam and multi-beam models.

Oscilloscopes use two different kinds of storage - digital and cathode-ray-tube (CRT) type. Digital scopes store data representing waveforms in a digital memory; CRT storage scopes store waveforms within the CRT; either on a mesh or special phosphor. CRT storage oscilloscopes have been used for years, digital storage scopes are relatively new.

A digital oscilloscope (figure 106.1-1) is an instrument that digitizes, stores, and displays a digital representation of analog signals. It can permanently display the analog trace of a transient signal. Digital scopes have fast analog-to-digital converters. These converters can sample and digitize information at rates from one data point every 200 seconds to 2 million data points per second. They can store 16,000 points of data internally and unlimited amounts using external accessories. Voltage resolution of 1 part in 4,000 is possible. Time and voltage may be displayed in Alpha numerics on the CRT. Digital storage requires digitizing and conversion processes. "Digitizing" consists of "sampling" and "quantizing". Sampling is the process of obtaining the value of an input signal at a discrete point in time; quantizing is the transformation of that value into a binary number by the analog-to-digital (A/D) converter. The time base determines how often digitizing occurs. The time base uses a digital clock to time the A/D conversion and to store the data in memory. The rate at which this happens is the digitizing (or sampling) rate. Once the data is stored in the digital memory, it can be recalled for displaying or further waveform processing.

The oscilloscope is used for the observation of waveform and transients, by connecting the signal under observation to the Y, or vertical-axis, input terminals. The internal sweep, which supplies a sawtooth signal, with a magnitude linearly proportional to time, is then applied to the X, or horizontal-axis, input terminals and synchronized to the signal being studied. The resulting screen image shows the waveform of the unknown signal as time progresses.

A camera attachment is used to obtain a permanent record of waveform.

The following precautions should be observed when using an oscilloscope:

CAUTION: Care must be exercised when observing line to line voltage since the scope may be grounded through the bench power cord. If measurement is above ground potential, isolate scope prior to use. Due to the internal high voltage hazard, the equipment should not be operated with the case removed.

(1) A small spot or highly intensified line should not be kept stationary on the screen since such spots or lines will cause the screen to burn or become discolored.

(2) To preclude spurious deflections, the instrument should be kept as far as possible from magnets, power transformers, reactors, or busses carrying current.

(3) If extremely large power line voltage fluctuations are present, it may be necessary to employ a regulated power supply. However, precautions against spurious magnetic fields should be observed (2 above).

(4) The image must be kept on the plane portion of the screen. If the image is extended to the edge of the screen, it will be distorted, due to the curvature of the tube. Moreover, the linearity of the oscilloscope amplifier is seldom satisfactory when the signal is amplified to the value necessary for full screen projection.

106.1.3 OSCILLOGRAPH. The instantaneous variations of current and voltage in a circuit can be measured by oscillographs. The basic operating principle of an oscillograph may be either: (1) that of a D'Arsonval galvanometer with attached pen. Inertia of the pen must be low enough to permit it to follow low frequency variations; or (2) that of a reflected light beam (inherently has very low inertia) employed in conjunction with electric or magnetic fields to govern the beam's deflection. In addition to tracing waveforms, oscillographs are used for measurements of transient phenomena, such as those that occur in generator characteristic evaluations.

The oscillograph galvanometer (figure 106.1-2) may have a light low-inertia coil with attached mirror or, for higher-frequency response, a pair of thin metal ribbons tightly stretched across insulating bridges and tied together by a small mirror at their midpoints, mounted in the field of a permanent magnet. A light beam from the galvanometer mirror traces its response to varying current on a moving photographic film or, by means of an intermediate rotating mirror, on a stationary viewing screen. Light beam galvanometer elements have been built with natural response frequencies as high as 8 kHz (a more common construction has a resonance frequency of about 3 kHz). If damped at about 0.7

of critical, these elements have a response to signals which is practically free from distortion up to about half their resonant frequency. At resonant frequency, the deflection sensitivity of the elements is decreased to about 70 percent of their dc sensitivity to the damping.

The following precautions should be observed when using an oscillograph:

(1) All leads connecting the circuit to be tested should be well insulated and should be the twisted double conductor type or shielded type to avoid inductive effects.

(2) The oscillograph should be protected against mechanical vibration at all times, but especially during operation.

(3) The oscillograph input signal must be conditioned in accordance with the manufacturer's recommendations to obtain proper indications and to match the galvanometer specifications.

(4) All circuit connections should be tight.

(5) The light beam should be checked for proper width and focus.

(6) The proper amplifier should be used for protection of the galvo. The maximum resistance should be included in the control circuit prior to application of the signal. The resistance may then be reduced to obtain the desired deflection. This affords maximum protection for the galvanometer.

(7) If an automatic delay circuit is not included in the oscillograph, sufficient time must be allowed for the drum holding the photo-sensitive paper to attain its operating speed before taking the event record.

(8) The galvanometer(s) must be damped in accordance with manufacturer's instructions.

106.1.4 HARMONIC ANALYZER. The harmonic analyzer (figure 106.1-3) is essentially a precise electronic voltmeter combined with a tunable band-pass filter with provisions for determining the magnitude or the relative value of voltages of different superimposed frequencies applied to its terminals.

To obtain the harmonics with a harmonic analyzer, the signal is connected to the input terminals and the magnitude or relative value of the fundamental and harmonics is determined in accordance with instructions obtained from the manufacturer of the harmonic analyzer.

CAUTION: Care must be taken to assure the analyzer is ungrounded when used on line-to-line voltages. Personnel must be aware that this above ground potential is present and must not touch the analyzer and a grounded conductor at the same time.

106.1.5 TRANSIENT WAVEFORM RECORDER. A waveform recorder (figure 106.1-4) is most simply described as an analog-to-digital converter with memory. These waveforms can then be output in various ways. The display output reconstructs the stored digital data via a digital-to-analog (D/A) converter at a repetitive cycle for a flicker-free presentation on a x-y monitor or an oscilloscope. A plot may be obtained from the D/A output for record and analysis. Digital output is also available for interface with external computer input busses. The feature facilitates incorporation of the instrument into extensive automated data collection and analysis systems. Digital oscilloscopes with storage capability are also transient waveform recorders.

Transient waveform recorders have fast analog-to-digital converters. These converters can sample and digitize information at rates to 10 million times per second and can store 4,000 points of data at this acquisition rate. Voltage resolution 1 part in 1,000 is possible.

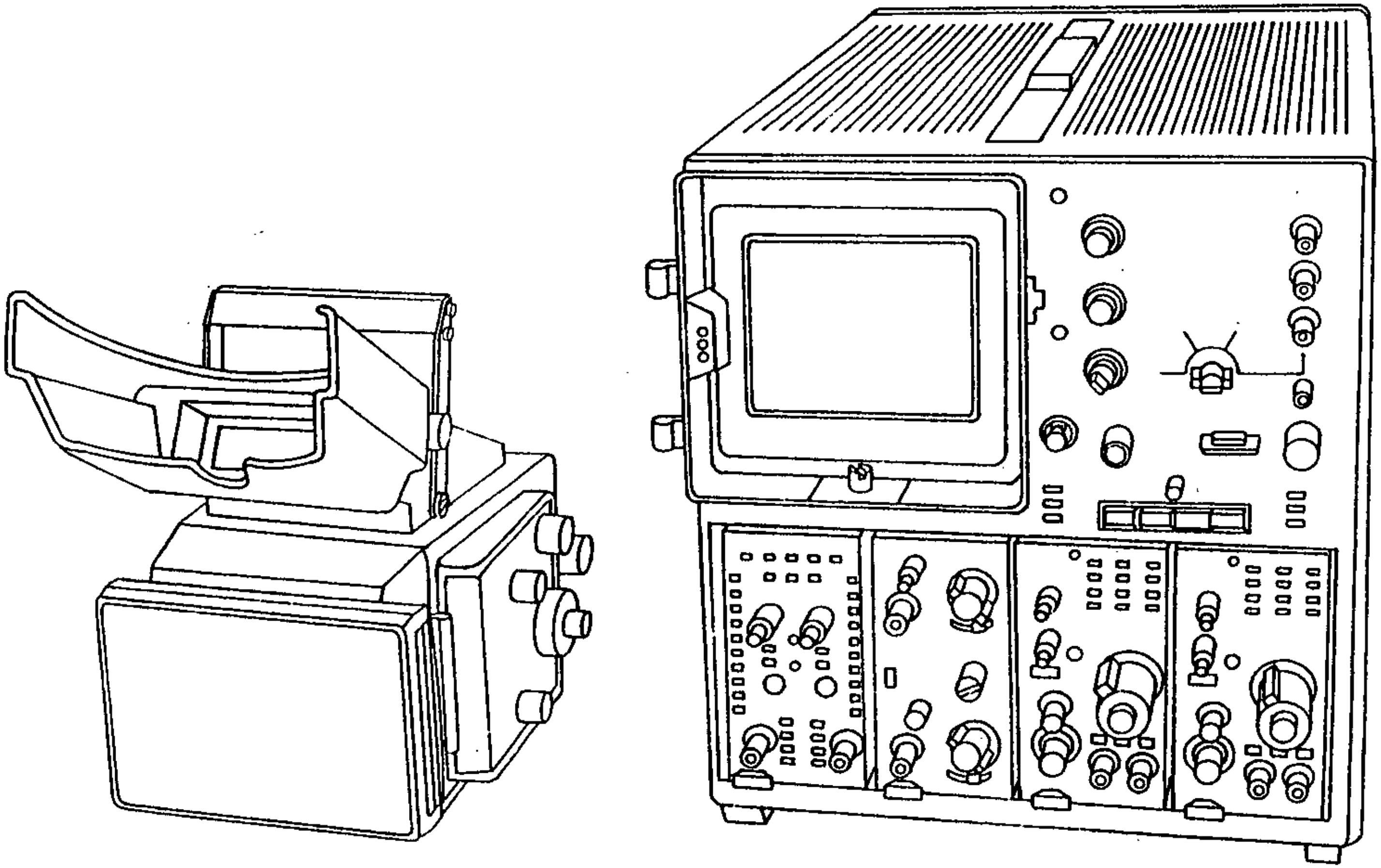


FIGURE 106.1-1. Typical oscilloscope and camera.

X-4190A

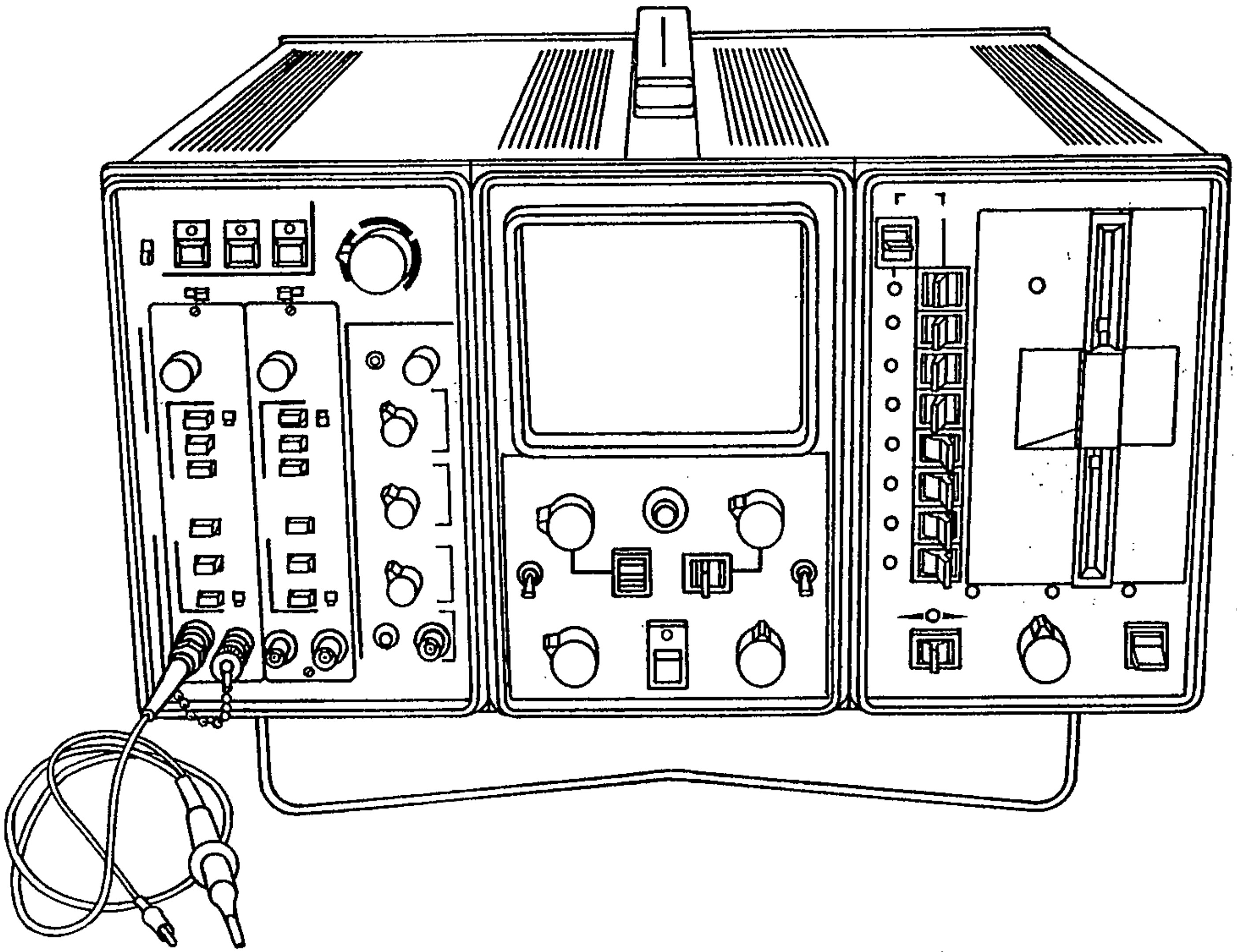


FIGURE 106.1-2. Typical digital oscilloscope.

X-4191A

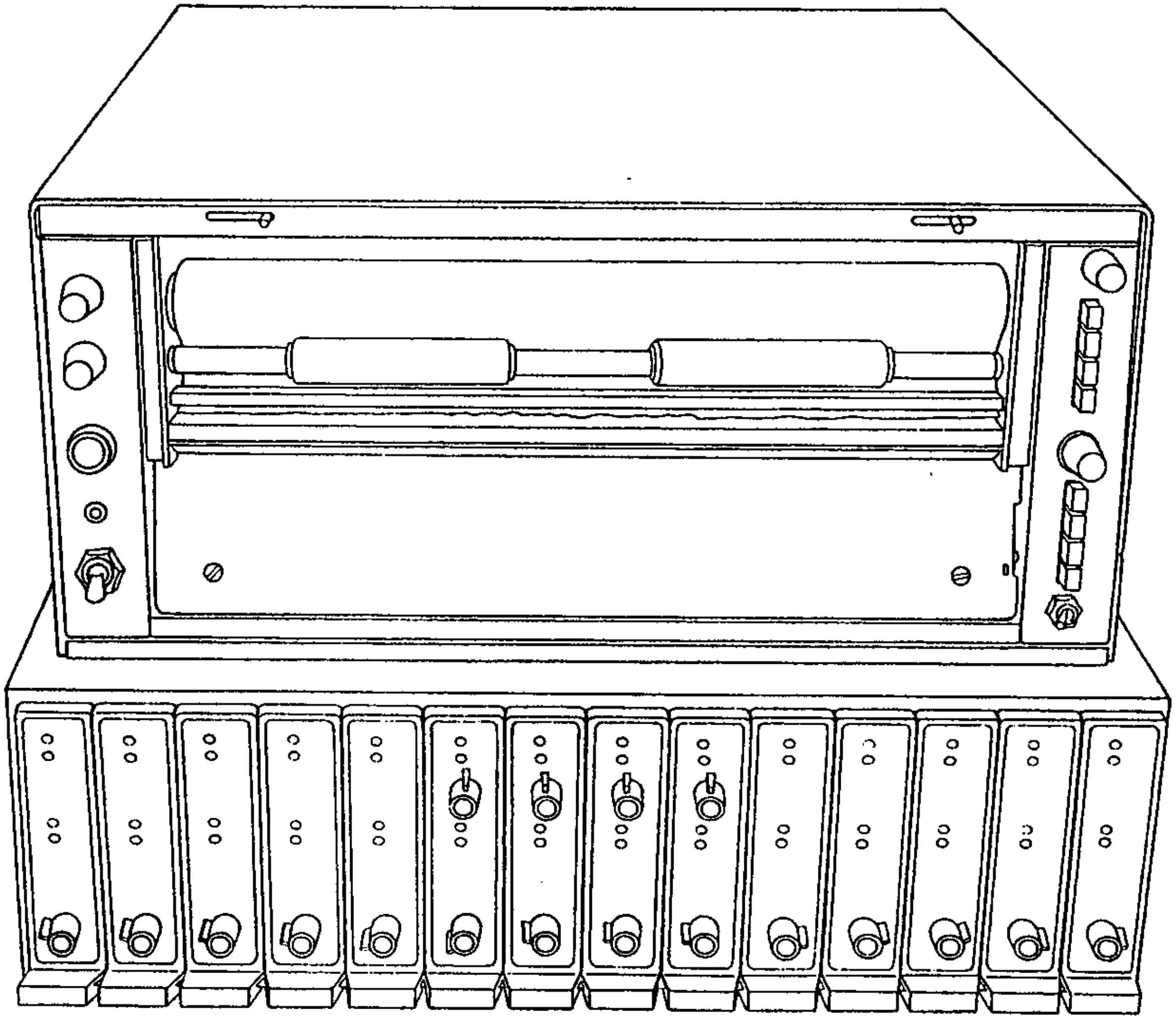


FIGURE 106.1-2.1. Typical oscillograph with galvo amplifiers.

X-4192A

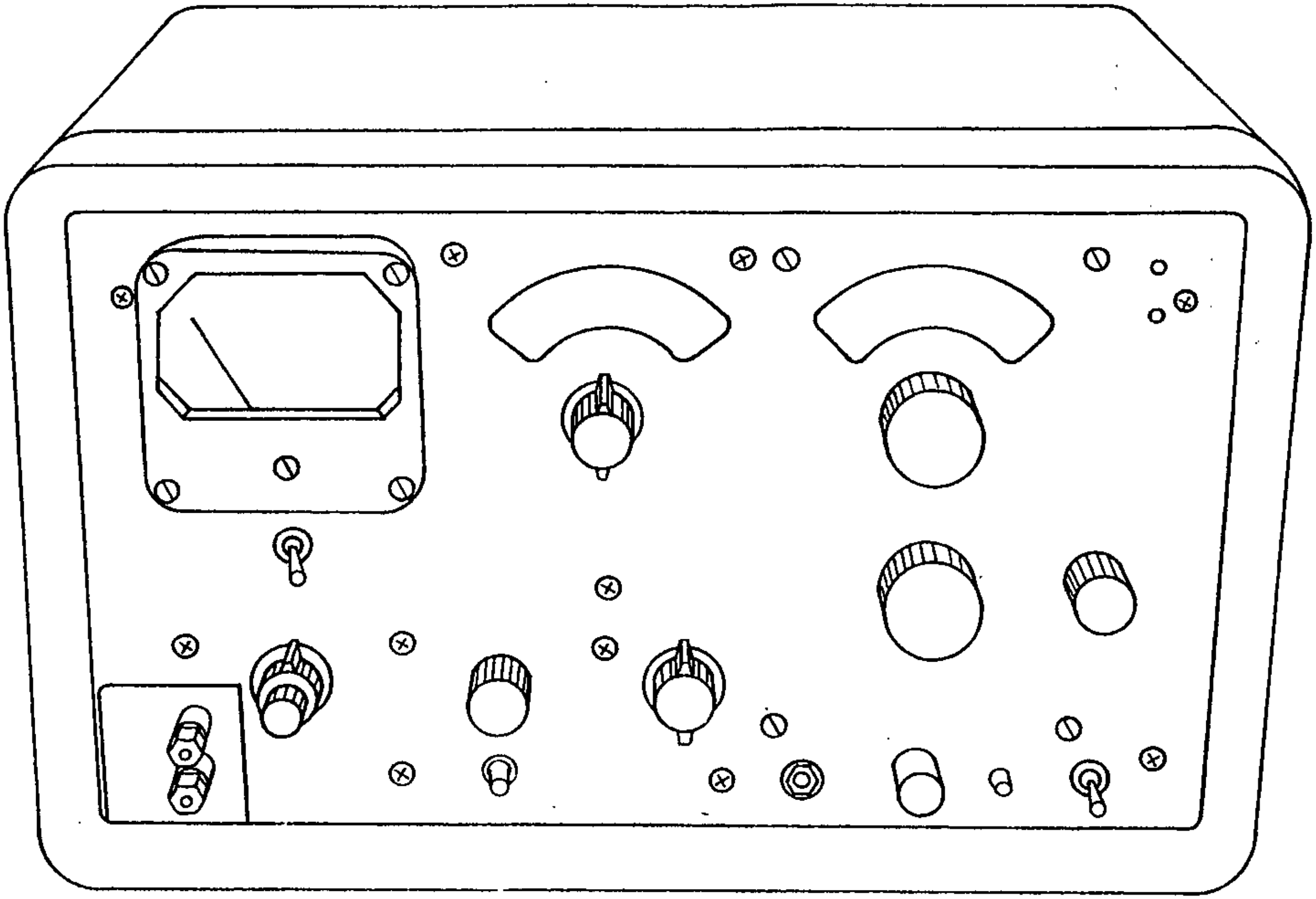


FIGURE 106.1 – 3. Typical harmonic analyzer.

X-4193A

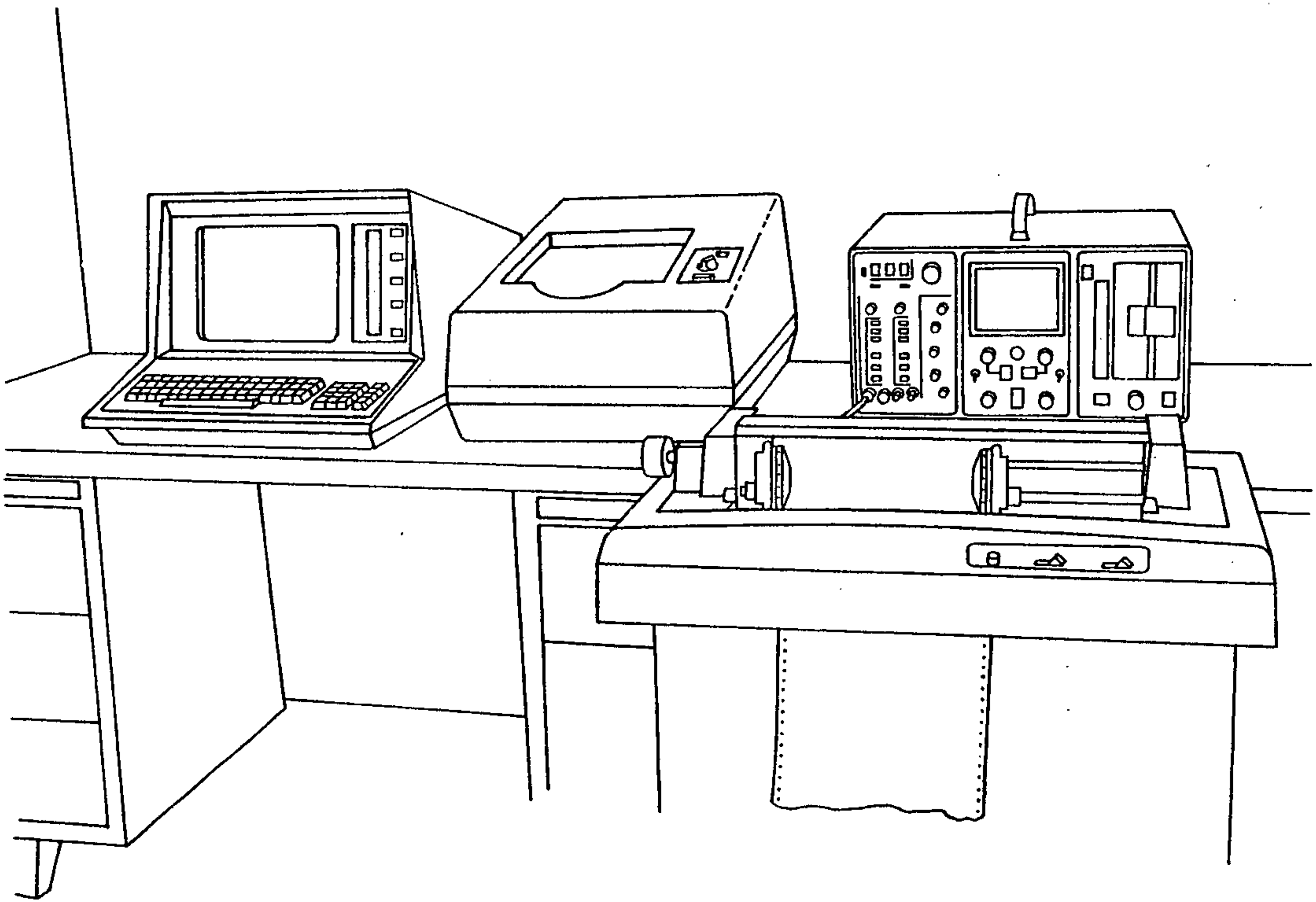


FIGURE 106.1-4. Transient waveform recorder.

X-4194A

METHOD 107.1b

MEASUREMENT OF POWER FACTOR

107.1.1 GENERAL. Power Factor is the ratio of the total power (in watts) flowing in an electric circuit to the total equivalent volt-amperes flowing in the circuit. In single-phase and balanced three-phase systems it is equal to cos θ, where θ is the phase angle between the voltage and current in a single-phase circuit, or between the phase voltage and phase current in a balanced three-phase circuit.

Reactive volt-amperes (VARS) is the product of the reactive voltage and current, or the product of the voltage and reactive current in an ac circuit.

107.1.2 INSTRUMENTS AND EQUIPMENT FOR POWER FACTOR MEASUREMENT. The dc wattage is computed by ascertaining the product of the voltage and current in a circuit (W=EI). When this same mathematical process is applied to an ac circuit, the resulting answer is not necessarily a measure of the power. It is either equal to or greater than the actual power. If this product, called "apparent power" (VA, or Volt-Amps), is divided into the actual power (W=EI cos θ) of a circuit, the resulting decimal figure (cos θ) is the POWER FACTOR of the system.

Load banks are routinely used to simulate load conditions for electrical power generator set testing and evaluation. Information on load banks is contained in Appendix A of this handbook.

When the load is entirely resistive, the power factor will be unity. If any inductance is in the circuit, the value of the power factor will be less than unity and is said to be "lagging" (current "lagging" or not in phase with the voltage). Thus, if the power actually consumed by an inductive load is 300 watts and the product of the voltage and amperage is 500 volt-amperes, the power factor is 300/500, or 0.6 lagging. If capacitance is present in the circuit, the value of the power factor will be more than unity and is said to be "leading" (current leading voltage).

When measuring a three-phase balanced system, that is, one in which the voltages are equal in the three phases and in which the currents are likewise equal, and no current in the neutral conductor, the formula for power is $W=\sqrt{3}$ EI cos θ where E and I are line voltage and current respectively. Here, again, cos θ is the power factor.

Instruments are designed which will measure the power factor in single-phase circuits, and others are designed to measure the power factor in balanced three-phase circuits (figure 107.1-1). No instruments are designed to measure power factor directly in unbalanced three-phase systems nor in systems in which the alternating current wave is greatly different from a sine wave. When it is desired to determine power factor in these cases, more rigorous methods of analysis are necessary. These are beyond the scope of this standard but are amply discussed in handbooks on electrical metering and instrumentation.

In measuring low values of power factor, care should be taken not to use a meter which is accurate only for high values of power factor.

In the following discussions, balanced polyphase systems and sinusoidal voltages and currents are assumed.

107.1.3 INSTRUMENTS FOR REACTIVE VOLT AMPERES. Power factor may be determined from the equation:

$$PF=\cos(\tan^{-1}\frac{VAR}{W})$$

where:

PF is the power factor.
VAR is the reactive volt-amperes.
W is active power.

Reactive volt-amperes may be measured on an ordinary wattmeter, providing either the voltage or current coil is excited by a signal proportional to, and vectorially in quadrature with, its normal wattmeter excitation. The two common methods of providing such excitation are described below.

107.1.3.1 Series Reactance Method. The potential coil excitation may be shifted 90 degrees by the insertion of a series reactance in the potential coil circuit. This type of instrument is connected in the same manner as a standard wattmeter and may be used in single-phase circuit, as well as in individual phases of a polyphase circuit. In order to measure VAR in a three-phase circuit, two VAR meters of this type are connected in the same manner as the wattmeters in the two-wattmeter method of measuring active power (figure 205.1-21 of Method 205.1).

107.1.3.2 Cross-Phase Method. In three-phase systems, the active component of current in one line is in quadrature with the voltage between the other two lines, while the reactive component of the same current is in phase with this voltage. Thus, an ordinary wattmeter connected with its current coil in one line and its potential coil between the other two lines indicates VAR directly. Total VAR for the system is the wattmeter reading multiplied by the square root of three.

107.1.4 PHASE ANGLE METERS. Various other instruments (one type of which is shown in figure 107.1-2), graduated in terms of either phase angle or power factor, are available for power factor measurements. These instruments may operate on any of a number of principles such as the use of phase angle itself, or the use of a mechanical comparison of the speeds of a watthour meter and

VAR-hour meter to indicate power factor directly. They should be connected in accordance with manufacturer's instructions, depending upon the type to which they belong.

107.1.5 TWO-WATTMETER METHOD. When active power is being measured by the two-wattmeter method, the power factor may be calculated from the two readings by applying the following formula:

$$PF = \cos \theta = \frac{W_1 + W_2}{2\sqrt{W_1^2 - W_1 W_2 + W_2^2}}$$

where:

PF is the power factor.
W_1 is the higher wattmeter reading, which may be either positive or negative.
W_2 is the lower wattmeter reading, which may be either positive or negative.

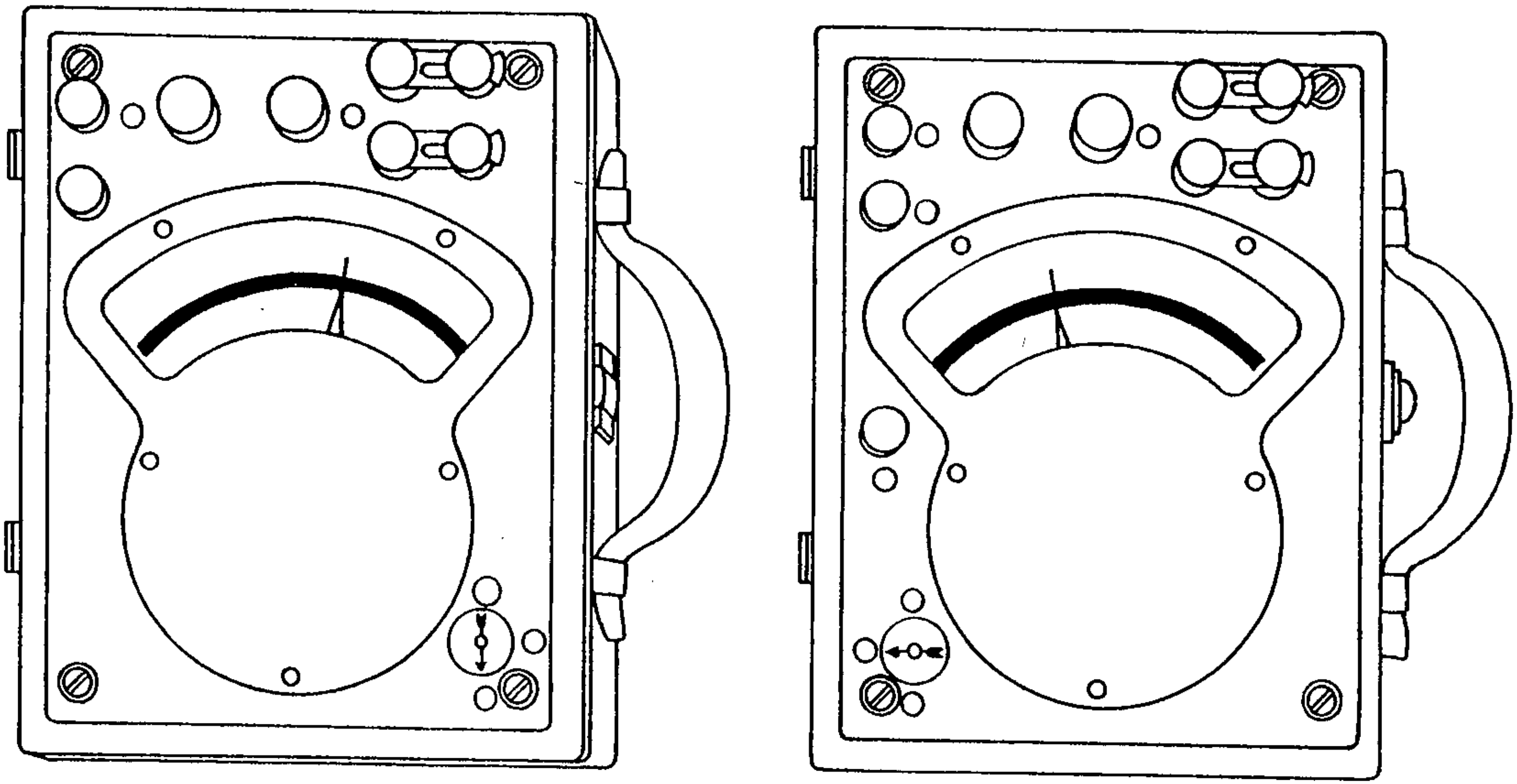


FIGURE 107.1-1. Power factor meters.

X-4195A

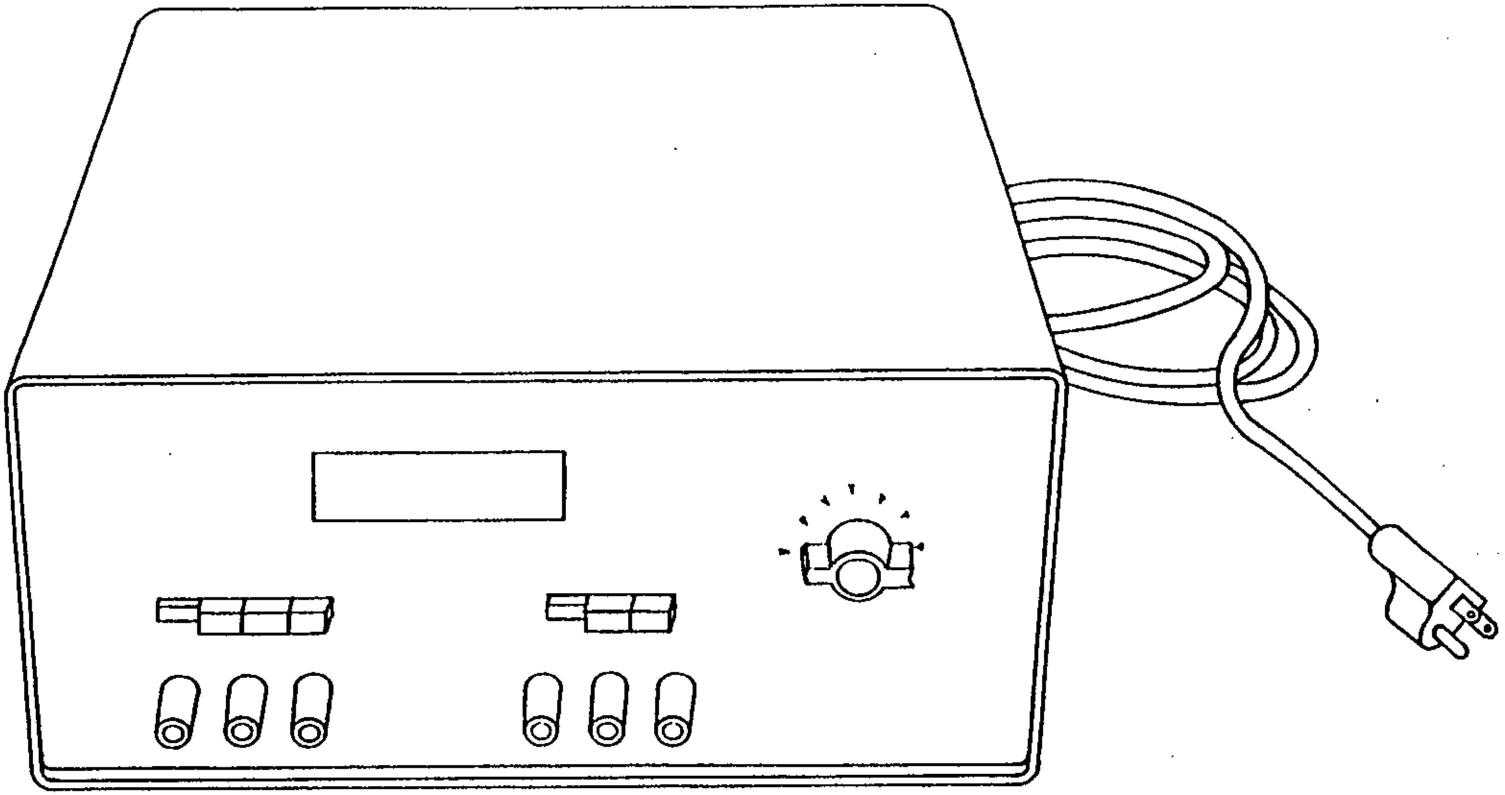


FIGURE 107.1-1.1. Power factor meters.

X-4196A

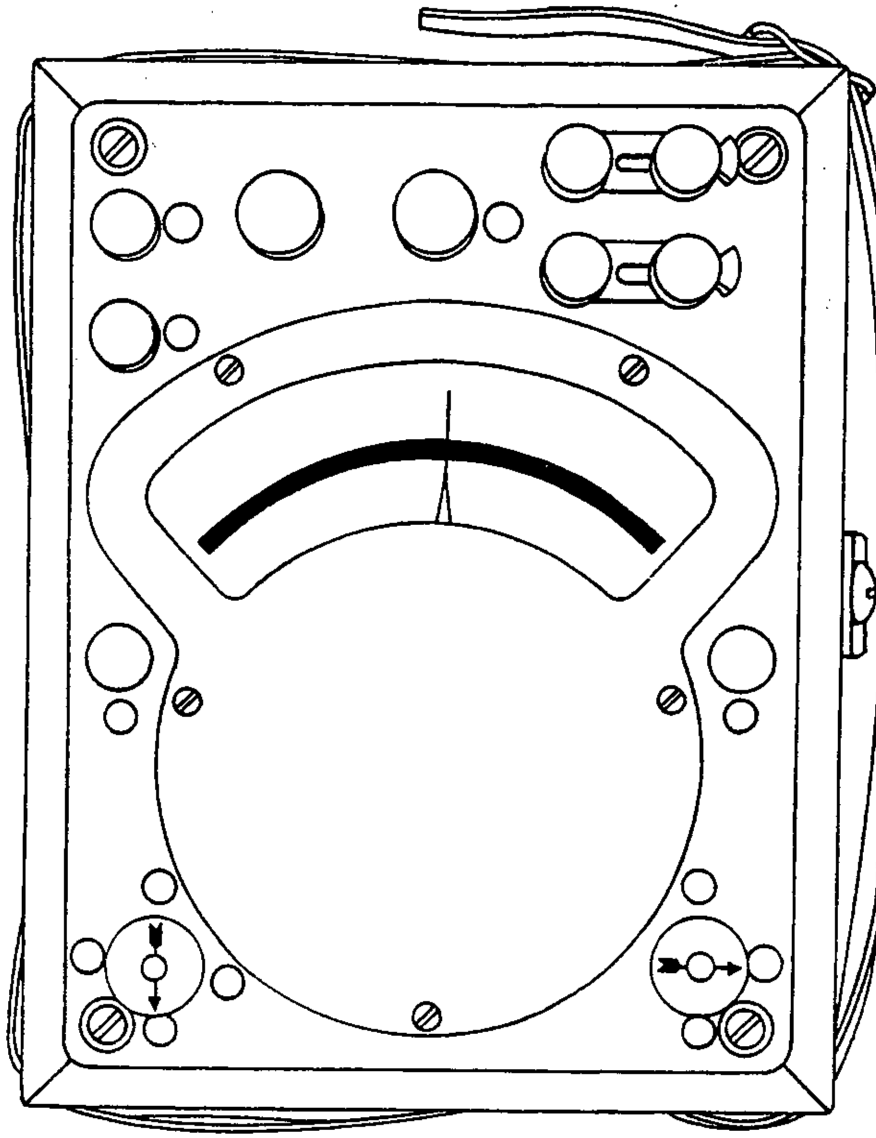


FIGURE 107.1-2. Phase angle meter.

X-4197A

METHOD 108.1b

MEASUREMENT OF TIME

108.1.1 GENERAL. The primary standard of time in the United States is based on astronomical observations made by the Naval Observatory at Washington, D.C. Time signals based on these determinations are sent out by Naval Radio Stations and by Station WWV of the National Bureau of Standards. Secondary standard clocks may be pendulum controlled or synchronous clocks driven by a constant frequency source such as a tuning fork, or crystal oscillator. These secondary standards may be checked against the Observatory time by using the radio broadcasts.

108.1.2 MECHANICAL TIMERS. Mechanical clocks for laboratory use usually are of the stop watch kind. They are specifically designed for measuring time intervals of the order of an hour or less. The start and stop mechanisms of a stop watch and clock frequently cause errors because of lag or jumping of the sweep hand when the mechanism is operated. It is frequently more accurate to start the watch at approximately 10 seconds before zero and then start the process to be timed as the hand sweeps through the zero. The percent of error of a stop watch may be minimized by making all time observations at least 1 minute long.

108.1.3 ELECTRICAL TIMERS. Several types of electrical timers are used to measure time intervals. The most common of these is the synchronous stop clock. This device operates in the same manner as the mechanical stop watches described above except that the hands are started and stopped by a small magnetic clutch engaging the hands with either a synchronous motor drive or a brake. Thus, the errors involved in starting and stopping are much less than those of the mechanical timers. Electrical timers of this type depend upon the frequency of the power source for their speed and are no more accurate than the power source to which they are connected. For this reason, they should never be driven by the power from an engine-generator set.

Digital readout stop watches or timers are commonly used during generator set testing. These devices utilize very low power drain solid state electronics and may be battery powered.

Electronic counters, utilizing controlled frequency supplies, are quite often used, especially where the required accuracy of the time interval measurement is high.

108.1.4 OSCILLOGRAM TIMING TRACES. Oscillograms (see figure 108.1-1) always require some sort of time scale if any measurements are to be made on them. The provision of such a scale is quite simple with most galvanometer types of oscillographs. A standard frequency from a crystal or tuning fork oscillator may be impressed upon the element, or a commercial power voltage may be used as a timing trace. On an oscillogram, when position is the important quantity rather than time, as in engine indicator diagrams, the timing trace may be supplied by a contactor on the engine crankshaft, or by a magnetic pickup from a slotted iron disk on the crankshaft. Oscilloscopes (figure 108.1-2) may be provided with a so-called Z-AXIS control. This acts to blank out the trace when a signal is applied. Thus, a periodic pulse may be used to dot the trace and consequently show time intervals by the distance between dots. Oscilloscopes without Z-AXIS control can be made to show a dotted trace by interrupting the signal periodically. This latter method is much more difficult to calibrate and should be avoided wherever possible.

SIMULATED DATA FOR ILLUSTRATIVE PURPOSES ONLY

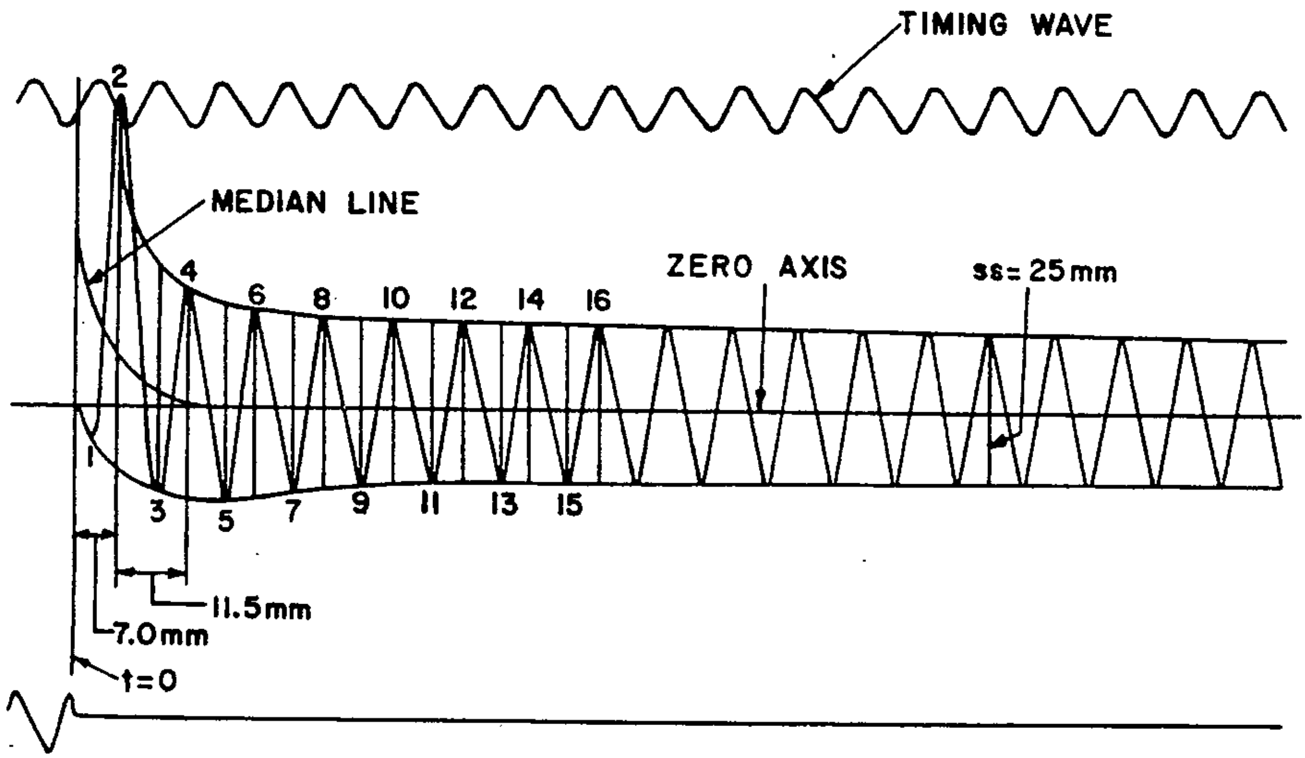


FIGURE 108.1-1 Sample oscillogram, showing median line.

X-4198

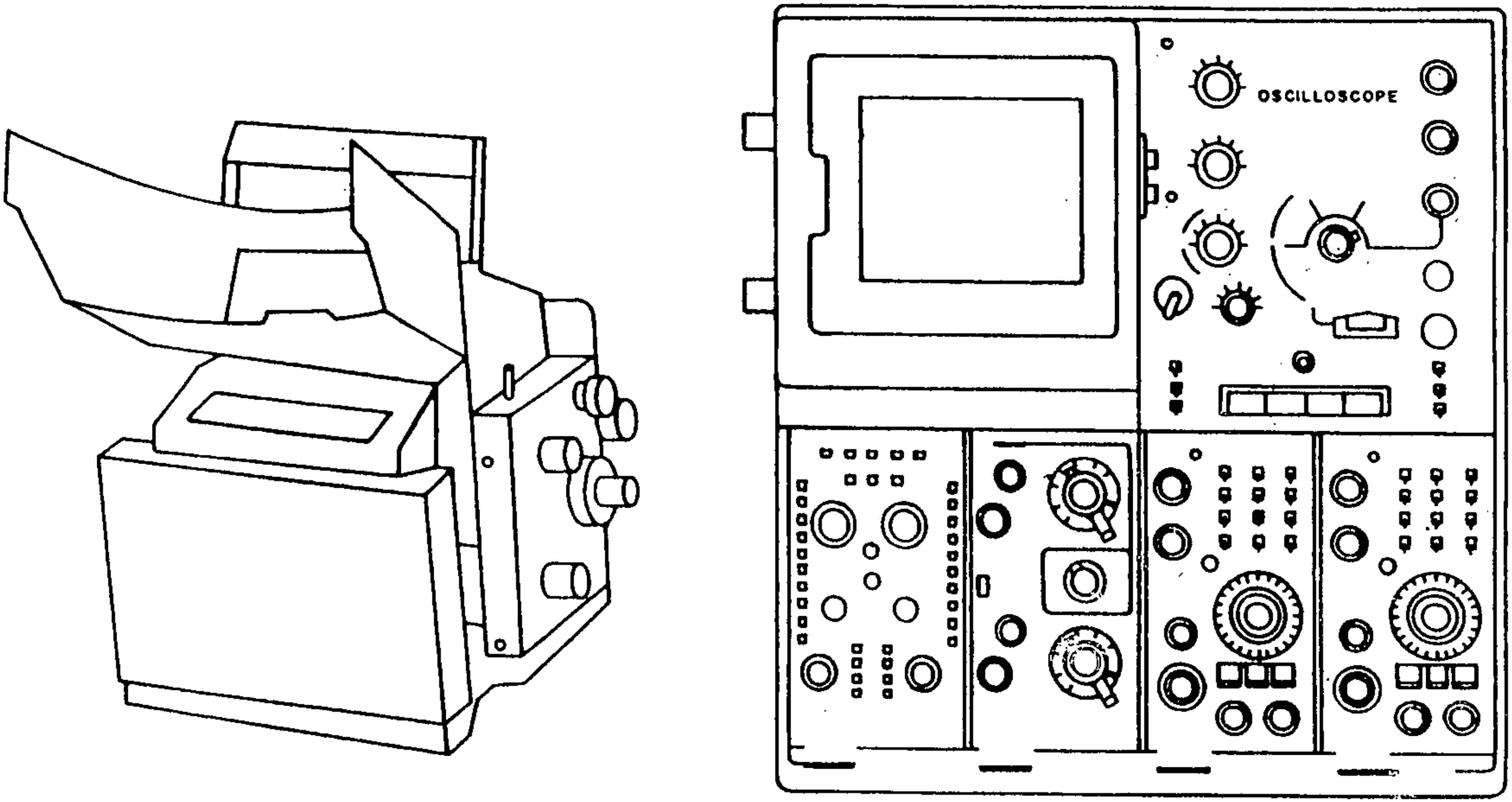


FIGURE 108.1-2. Typical oscillograph.

X-4199

METHOD 109.1b

MEASUREMENT OF SPEED

109.1.1 General. Speed of rotation is derived by counting revolutions and measuring elapsed time. This operation may be performed very accurately by means of a counter and electric clutch, automatically timed by a synchronous clock and a standard frequency source. One commercially available device of this type is called a chronotachometer and is shown in figure 109.1-1.

Rotational speed may be translated to frequency by the use of an ac generator driven by the rotating element. This then may be measured electrically (see Method 104.1).

109.1.2 SPEED COUNTERS. One of the ways to measure speed during a test is to count revolutions for a measured time interval. This may be done by observing the readings of a counter permanently attached to the machine shaft, or by temporarily attaching a counter to the shaft, through a friction wheel or disk. In either case, the duration of the observation should be great enough to minimize all the errors due to starting and stopping the stop watch or counter. In the case of a portable counter, which, in use, is started and stopped, either the counter should be started as the clock hand sweeps through zero, or vice versa. No attempt should be made to start both the counter and stop watch simultaneously.

109.1.3 DIRECT READING TACHOMETERS. Several methods are used to indicate speed directly. Among them are the position of centrifugal flyballs, the voltage of a magneto, the pressure of a centrifugal hydraulic pump, photocell sensors, and the eddy-current drag of a rotating magnet on a conducting disk. Each of these devices may be used as a tachometer, and each has its own advantages and disadvantages. Direct reading tachometers are available either for positive connection to the machine under test, or for hand use. The latter are shown in figure 109.1-2.

Chronographs or recording tachometers are speed recording instruments in which a graphic record of speed is made. In the usual forms, the record paper is driven at a certain definite speed by clockwork or weights, combined with a speed controlled motor or device such that a specific distance of chart travel represents a definite time. The pen which makes the record may be attached to the armatures of electromagnets, servo-driven, or operated on a proportional electrical signal. The speed sensing pickup may consist of a mechanically coupled tachometer generator or a magnetic proximity device whose function is to generate a voltage, the magnitude of frequency of which is supplied to the recorder. Some recorders accept electrical signals directly from the ac generator output and record the frequency on the chart as a corresponding speed (revolutions per minute).

109.1.4 STROBOSCOPES. Stroboscopic methods are especially suitable for determining the speed of machine parts which are not readily accessible, where it is not practicable to use mechanical methods, or where the speed is variable. Stroboscopes are devices for producing periodic light flashes of high intensity and short duration. If a piece of moving machinery is illuminated by such a light source, an observer sees the machine only during the periodic light flashes. If the period is adjusted to coincide with a periodic movement or rotation of the machine, the machine will appear to stand still. Any deviation from syncronism will appear as a slow movement of the machine through its operating cycle. Therefore, if the frequency of the light is held constant, the machine speed may be held constant by keeping it "standing still". Also, if a disk having radial stripes is mounted on the machine as a target for the stroboscope, and the stroboscope is excited with a constant frequency, the machine speed may be held to any integral multiple or fraction of the stroboscope frequency.

The accuracy of stroboscopes depends on calibration of the dial and since most dials only have cardinal markings, stroboscopes cannot be used for accurately determining speed unless the instrument has an external input connection for an input from an oscillator of known accuracy.

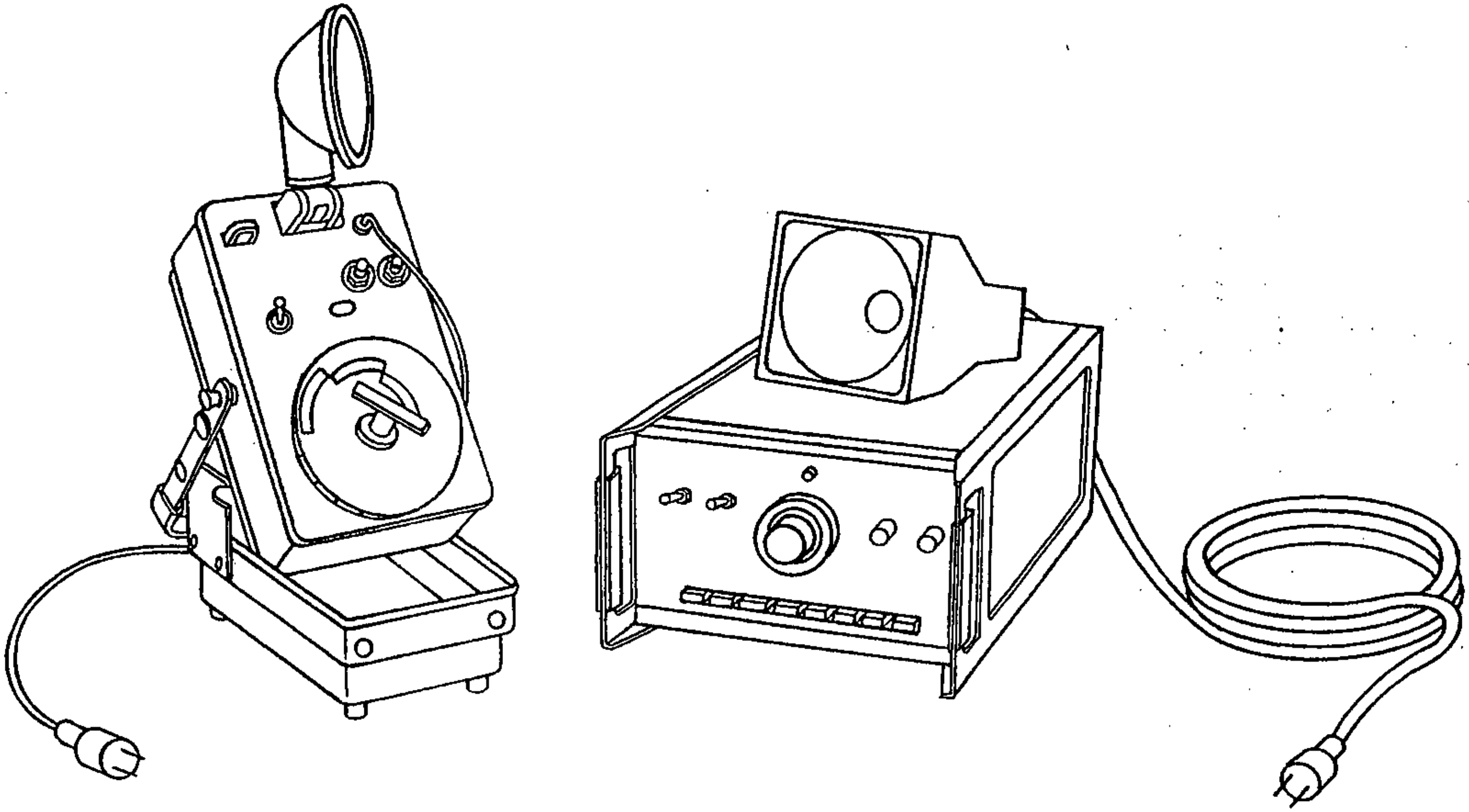


FIGURE 109.1-1. Representative type of speed and revolution counter.

X-4200A

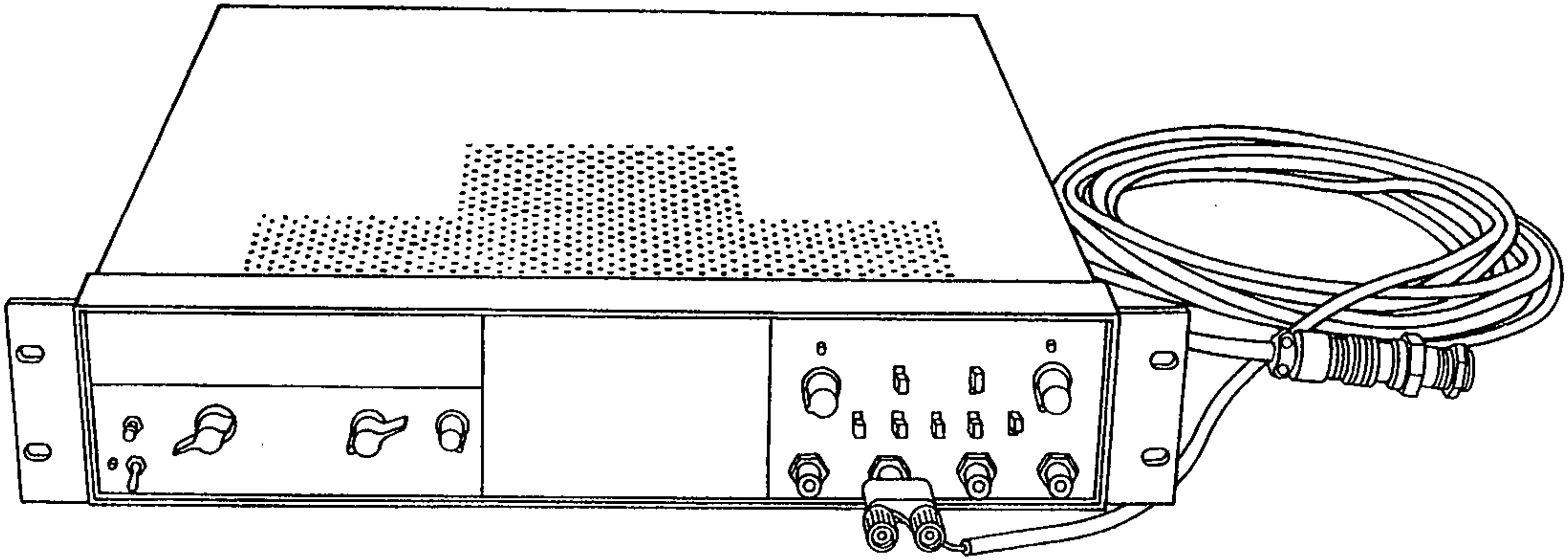


FIGURE 109.1-1.1. Representative type of speed and revolution counter.

X-4201A

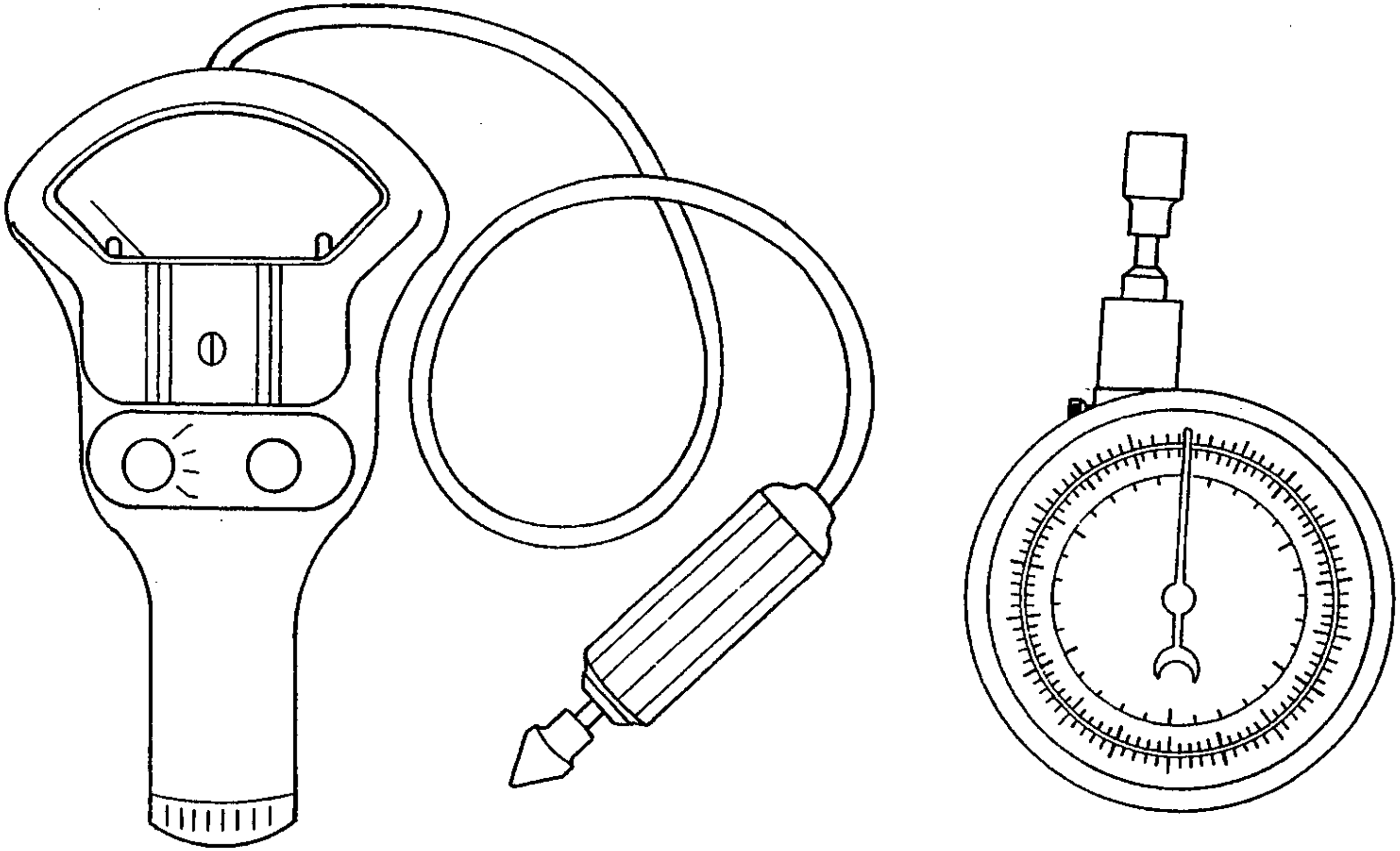


FIGURE 109.1-2. Representative hand-type tachometers.

X-4202A

METHOD 110.1b

MEASUREMENT OF TEMPERATURE

110.1.1 GENERAL. Temperature measurement by electric means is carried out almost exclusively with direct current. There are three methods used to determine temperatures of various components of an engine-generator set, as well as the temperatures of coolants, lubricants, etc. These three methods are: contact, resistance, and embedded detector.

When temperatures are to be obtained by thermocouples, resistance thermometers, or other electric temperature measuring devices, care should always be taken to insure that these elements and their indicating instruments are functioning properly. The wiring between the detecting elements and the indicating instrument should be installed so there are no loose connections. A quick check to determine the functioning of an instrumented generator set is to take a complete set of ambient temperature readings on the set prior to starting the set. The set should not have been operated for 12 hours prior to the readings. The complete set of readings should then be compared with the temperature of principal metal parts of the machine, as measured with several reliable mercury or alcohol thermometers. The electric devices should indicate consistent temperatures in close agreement with the thermometers. If appreciable temperature differences exist, a check should be made for loose connections, stray fields, and the possibility that the machine has not reached a uniform temperature. It may be necessary to replace the faulty temperature measuring device.

The temperature rise of certain components and materials during operation of the generator set is an important characteristic. Temperature rise is defined as the difference between the temperature of the component or material, and the ambient temperature, at a point in operation of the generator set where temperatures have stabilized. Temperature stabilization of a component is reached when three consecutive readings, taken at 10-minute intervals, of an individual component or material, are the same, or within the limits of variation as specified in the procurement documents.

The limits of temperature rise for various components and materials are given in the procurement documents.

110.1.2 CONTACT METHOD. The contact method consists of determining temperature by placing a mercury or alcohol thermometer, a resistance thermometer, or a thermocouple in direct contact with the component or material whose temperature is to be measured.

When these devices are used in connection with the measurement of surface temperatures, they shall be covered with oil putty, or a felt pad. The covering material is used to protect the temperature device from the air above the surface but should not be so large as to interfere with the natural cooling of the surface by circulation of the ambient air.

Thermometers with broken columns of mercury or alcohol should not be used.

During use, the thermometer bulb shall not be located higher than any other part of the thermometer.

A thermocouple consists of two metals in contact with each other. The two metals are of different molecular structure, and electromotive force is produced at the junction of the two metals due to temperature. Iron constantan and chromel alumel are the only types of thermocouples that have sufficient temperature range to be used throughout the test methods contained in MIL-STD-705. Other types are acceptable, however, for normal ambient tests of a generator set. The electromotive force produced at the junction is compared to another thermocouple output that is at a known temperature, usually either 0 °C or room ambient as measured by a thermometer.

Thermocouples are fabricated in different shapes and in different combinations of metals to suit individual locations and for differenct ranges in temperature (figure 110.1-1). These thermocouples are used in connection with various types of thermal potentiometers which indicate temperature in degrees, or in numbers which can be converted to degrees. Complete temperature data acquisition systems are commercially available for handling inputs from a few to several hundred thermocouples.

A block diagram of a typical system is shown in figure 110.1-2.

To determine the temperature rise, convert both the ambient temperature readings and the maximum contact device readings to degrees Celsius. Then subtract the ambient from the contact readings.

110.1.3 RESISTANCE METHOD. The resistance method determines temperature by the comparison of the resistance of a winding, at the temperature to be determined, with the resistance of the winding at a known temperature. Since a small error in measuring either the hot or cold resistance will make a comparatively large error in determining the temperature rise, the Wheatstone or Kelvin bridge method of obtaining resistance (see Method 105.1) should be employed to assure accuracy. This method utilizes that characteristic of generator wingings whereby a change of resistance is proportional to a change of temperature. The following steps will be followed in determining the temperature rise by this method.

(1) The resistance of the winding at a known temperature shall be obtained. Cold resistance measurements shall be made with the generator set at approximately the surrounding ambient temperature; that is, the measurements shall be taken after the generator set has been inoperative for a sufficient time (approximately 12 hours) to bring the major generator mass temperature, as measured by a thermocouple, to within 3 °C of the ambient temperature.

(2) The device being tested shall be operated as prescribed by the test method until it reaches the condition at which the temperatures or temperature rise of the winding is to be obtained.

(3) The ambient air temperature at this time shall be recorded and if in degrees F, it shall be converted to degrees C.

(4) The hot resistance of a dc field winding may be computed from the ammeter and voltmeter readings, as follows:

$$R_h = \frac{V_{ef}}{I_{ef}}$$

where:

R_h is the hot resistance of the field winding.
V_{ef} is the voltage across the field winding.
I_{ef} is the current in the field winding.

(5) The above method may be used on the stationary fields but should not be used on rotating fields. However, the method described in (6) below, is preferred.

(6) The Kelvin, Wheatstone bridge or other means of equivalent accuracy will be used to determine the hot resistance of the generator armature, exciter armature, and the generator field except in the case of rotating windings of less than 1 ohm resistance (see Method 105.1).

(7) The drop-in-potential method will be used to obtain the hot resistance of rotating windings of less than 1 ohm resistance (Method 105.1).

(8) To determine the hot resistance by either the bridge method or drop-in-potential method, the following shall be observed:

(a) The generator will be shut down.

(b) A reading shall be made immediately (in less than 30 seconds).

(c) Additional readings will be made at intervals of 30 seconds or less for at least 3 minutes. If the resistance is increasing at the end of 3 minutes, readings shall continue at 30 seconds intervals until the resistance definitely begins to decrease.

(d) A precision timer will be employed to determine time from shutdown to initial reading and between subsequent readings (see Method 108.1).

(e) The resistance readings will be plotted against time on semi-logarithmic paper. Time will be plotted along the divisions of equal size and resistance will be plotted along the logarithmic divisions. This curve will be extrapolated (extended) from the first reading back to the time of shutdown. The highest resistance on the curve will be used as the hot resistance. Automated data systems may be utilized for numerical calculations and presentation of this data. In lieu of plotting the data, a linear regression (least squares fit) may be used to determine the resistance at shutdown. The temperature rise for copper windings is calculated from the formula:

$$T_r = T_h - T_a = \frac{R_h}{R_c}(234.5 + T_c) - (234.5 + T_a)$$

where:

T_r is the temperature rise in Celsius degrees.

T_h is the temperature of the winding in degrees C when hot resistance (R_h) was measured.

T_a is the ambient temperature in degrees C.

R_h is the hot resistance.

R_c is the cold resistance.

T_c is the temperature of the winding in degrees C when cold resistance (R_c) was measured.

110.1.4 EMBEDDED DETECTOR METHOD. The embedded detector method of determining temperature employs thermocouples or resistance temperature detector built into the machine. Usually they are used on machines rated above 500-kW and then only if other means of temperature measurement are not practicable.

The embedded resistance temperature detector is a resistance of a known value at a specific temperature. To determine a temperature with an embedded resistance detector, accurate measurement of the detector resistance will be made (see Method 105.1) and the temperature calculated from the formula:

$$T_r = T_h - T_a = \frac{R_h}{R_c}(234.5 + T_c) - (234.5 + T_a)$$

(The above formula applies only to copper windings.)

where:

T_r is the temperature rise in Celsius degrees.

T_h is the temperature of the detector in degrees C when R_h is measured.

T_a is the ambient temperature in degrees C.

R_h is the hot resistance.

R_c is the known resistance of the detector at T_c degrees C.

T_c is the temperature of the detector in degrees C when the known resistance (R_c) was measured.

110.1.5 CONVERTING FAHRENHEIT TO CELSIUS, AND VICE VERSA. To convert Fahrenheit to Celsius:

$$C = \frac{5}{9} (F - 32)$$

To convert Celsius to Fahrenheit:

$$F = \frac{9}{5} C + 32$$

When converting a temperature rise from degrees Fahrenheit to degrees Celsius, and vice versa:

Temperature rise in degrees C. = 5/9 (Temperature rise in degrees F.)

Temperature rise in degrees F. = 9/5 (Temperature rise in degrees C.)

NOTE: The addition or substraction of 32 degrees is not used for temperature rise conversions because a difference in temperatures, rather than a temperature, is being converted.

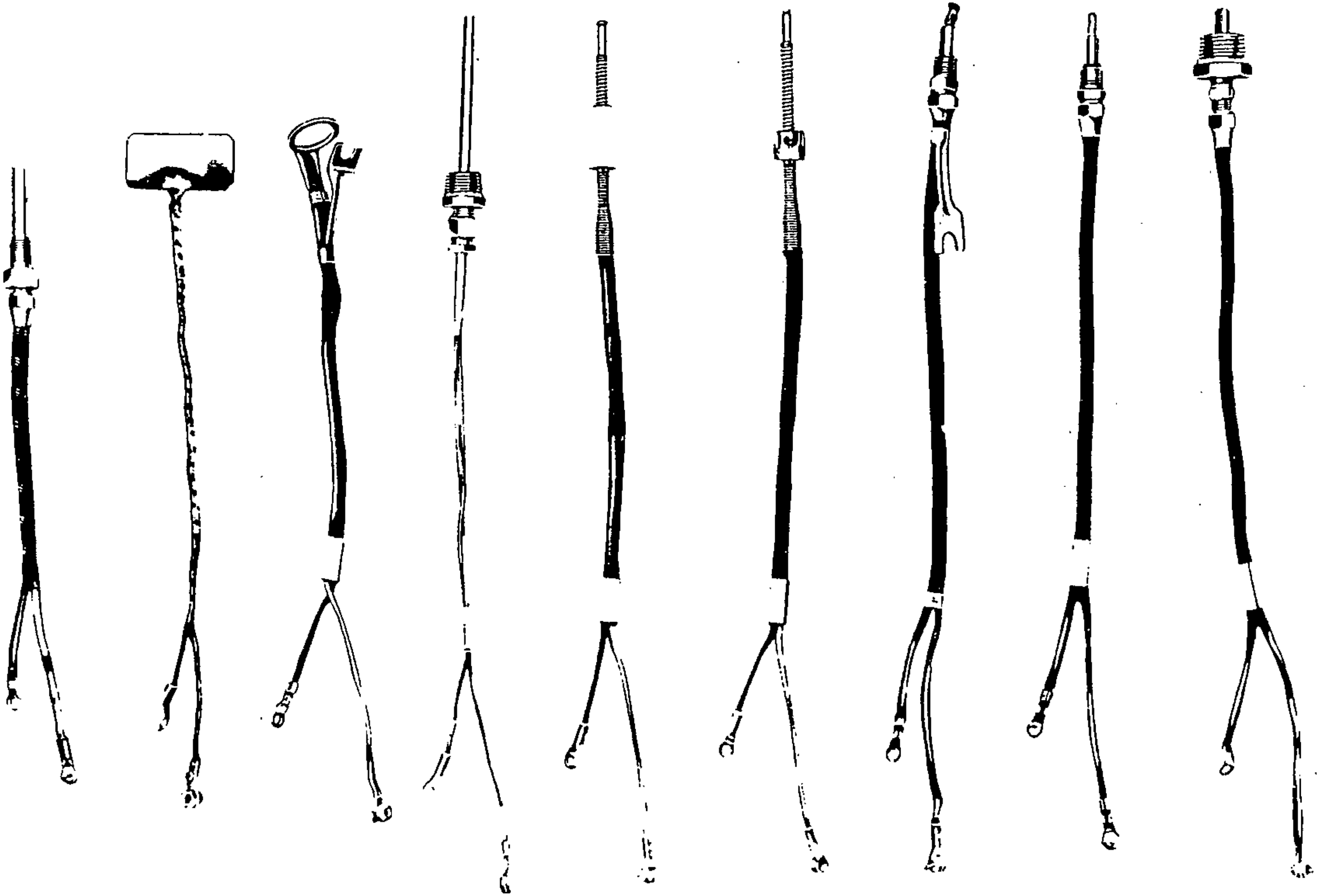


FIGURE 110.1-1. Various types of thermocouples.

X-4203

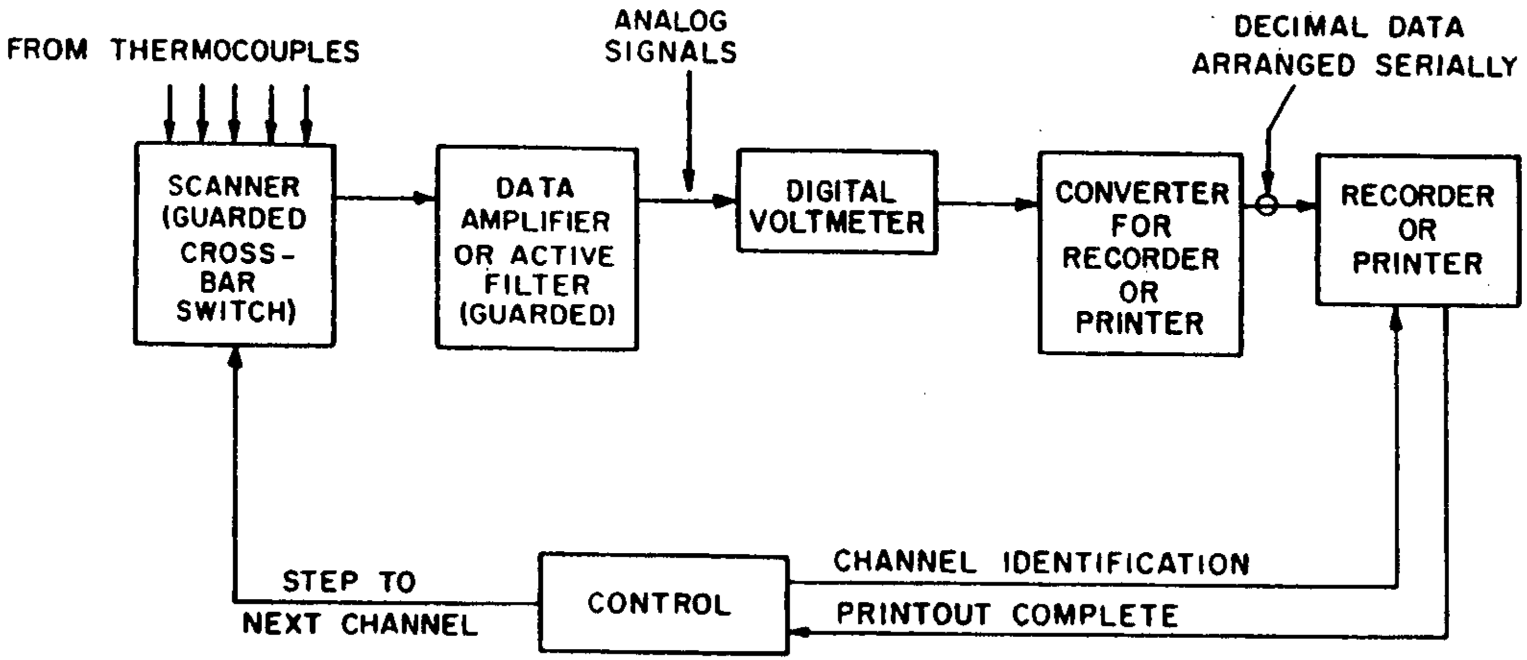


FIGURE 110.1-2 Multiple-sensor automatic data-logging system.

X-4204

METHOD 111.1b

MEASUREMENT OF WEIGHT AND FORCE

111.1.1 GENERAL. Weights, operating forces, spring tensions, and brake torques are measured on one of the following instruments:

111.1.2 PLATFORM BALANCES. Platform balances are the most accurate means of measuring force that are readily available, and they should be used in preference to other means whenever practicable. They should be used for all fuel consumption and other weight measurements.

A platform balance should be inspected before use to insure that the beam swings freely and to determine if the balance has any zero error. Balances should be proved every six months to insure that their calibrations remain constant.

Platform balances should not be used where they will be subject to shock or serious vibration, because of the danger of damaging the knife-edge pivots of the instrument.

Platform balances must be level when in use.

111.1.3 SPRING BALANCES. Spring balances are much more convenient to use for most force measurements than are platform balances. However, spring balances usually are less accurate. Spring balances may be used in any position, but the zero error should be noted with the balance in the position in which it is to be used.

Spring balances are most useful for measuring such quantities as brush pressure, valve spring pressures, and operating forces of all kinds. In these measurements it is necessary to use care in order to avoid errors due to friction in the balance. Spring balances are subject to calibration errors due to changes in the spring tension which may occur in normal use. Therefore, these balances should be checked frequently.

111.1.4 OTHER DEVICES. Load cells, utilizing known materials and strain gages, and hydraulic jacks, with known piston area and a pressure gage, are acceptable methods of measuring and controlling weight and force.

METHOD 112.1b

MEASUREMENT OF PRESSURE

112.1.1 GENERAL. The following instruments are used to measure any of the various fluid pressures encountered in testing engine-generator sets.

112.1.2 DEADWEIGHT GAGES. The most accurate pressure-measuring instruments for gage pressures above one atmosphere are deadweight gages. These devices employ a small piston loaded with a known deadweight to balance the pressure of oil in a vertical cylinder below the piston. Accurate measurements of the piston area and value of the deadweights are easily obtained so that the instrument can be very accurately calibrated. The only remaining source of error is static friction and this is eliminated by rotating the piston and weights about their vertical axes. These instruments can be used, however, only for constant pressures greater than atmospheric, since they are not direct reading instruments. They are most useful as standards for relatively high pressures, to be used to calibrate other instruments.

112.1.3 MANOMETERS. Liquid manometers (figure 112.1-1) always consist of two chambers partially filled with a liquid and connected so that the liquid is free to flow from one to the other. A pressure applied to the liquid in one chamber is communicated to the other chamber only through the liquid. If the pressures in the two chambers are unequal, the liquid will flow from one chamber to the other until the unbalanced pressure is exactly offset by the unbalanced liquid head. If the density of the liquid is known, the pressure can be computed from the measured difference between the liquid levels. The liquid used in manometers may be water, mercury, alcohol, oil, or any other, depending upon the pressures to be measured. Manometers always measure a pressure difference. Therefore, the absolute pressure on one chamber must be known before the absolute pressure on the other chamber can be calculated. for measuring pressure differences such as the drop across an orifice, or in a venturi, the manometer is connected to show the difference directly. Manometers are simple, direct reading, accurate instruments that can be used for a wide range of applications and for pressures both above and below atmospheric. They are impractical for use with pressure differences much greater than one atmosphere, but anywhere within their useful range, their accuracy and simplicity make them the preferred type of instrument for static or slowly changing pressures.

112.1.4 MECHANICAL GAGES. Pressure gages making use of bellows and bourdon tubes to change pressure into a mechanical reading are available for all ranges of pressures encountered in testing engine-generator sets. These instruments are convenient to use, direct reading, and durable, they must not be subject to pressures greater than their ratings, nor to high temperature gases because their condition may destroy the calibration. Because of their low mass moving systems, they are better adapted to the measurement of changing pressures than either of the types previously discussed. Mechanical gages are available with ranges above and below atmospheric pressure, although they usually indicate only gage pressure (absolute pressure may be calculated by summing atmospheric pressure and gage pressure). Both indicating and recording types are available.

112.1.5 HIGH-SPEED MECHANICAL GAGES. For the measurement of dynamic pressures such as firing pressures in an engine, and diesel fuel-injection pressures during operation, instruments having very high-speed response are necessary. This is achieved mechanically by limiting the number of moving parts to small piston and spring, or a small diaphragm, and restricting the motion of these parts to a few thousandths of an inch. This motion usually is detected electrically by the opening or closing of a pair of contacts. Two methods are employed to secure a reading from such an instrument. One method uses a calibrated spring to oppose the motion of the piston or diaphragm. The other uses compressed gas and a standard pressure gage. In either case, the opposing force is increased until the contacts just fail to close, as indicated by a neon light energized through them. The peak test pressure is then equal to the value of the opposing force. A variation of this instrument is the Parnsboro Engine Indicator. In this instrument, a sensitized drum is rotated in synchronism with the engine crankshaft. A stylus near the drum moves along it in proportion to the value of the force opposing the gage piston. Each time the contacts open or close, an external spark coil causes a spark to pass from the stylus to the drum, thus marking the drum. To operate the instrument, the piston force is gradually increased from zero while the engine being tested is running under the desired condition. As soon as the sparking ceases, the drum is stopped. It then will show a complete record of cylinder pressure against crankshaft position, as a series of dots on the drum. All of these mechanical instruments are subject to errors due to differences in the dynamic and static calibrations, and due to mechanical resonance effects in the instrument inself. However, they are convenient to use and easy to calibrate statically.

112.1.6 HIGH-SPEED ELECTRICAL GAGES. Some of the disadvantages of the mechanical instruments described above are overcome by using electrical pickups. In these devices, a stiff diaphragm usually is mounted flush with the surface of the engine combustion chamber. Its motion is then measured electrically and recorded by an oscillograph. Because of the lack of long, narrow passages, resonance is avoided, and, because of the low-mass-elastance ratio, mechanical resonance is avoided in the diaphragm. The instrument can be made sensitive to very high-frequency impulses, depending upon the response of the connected electrical circuit. Electrical pressure transducers are available to measure a wide range of pressures.

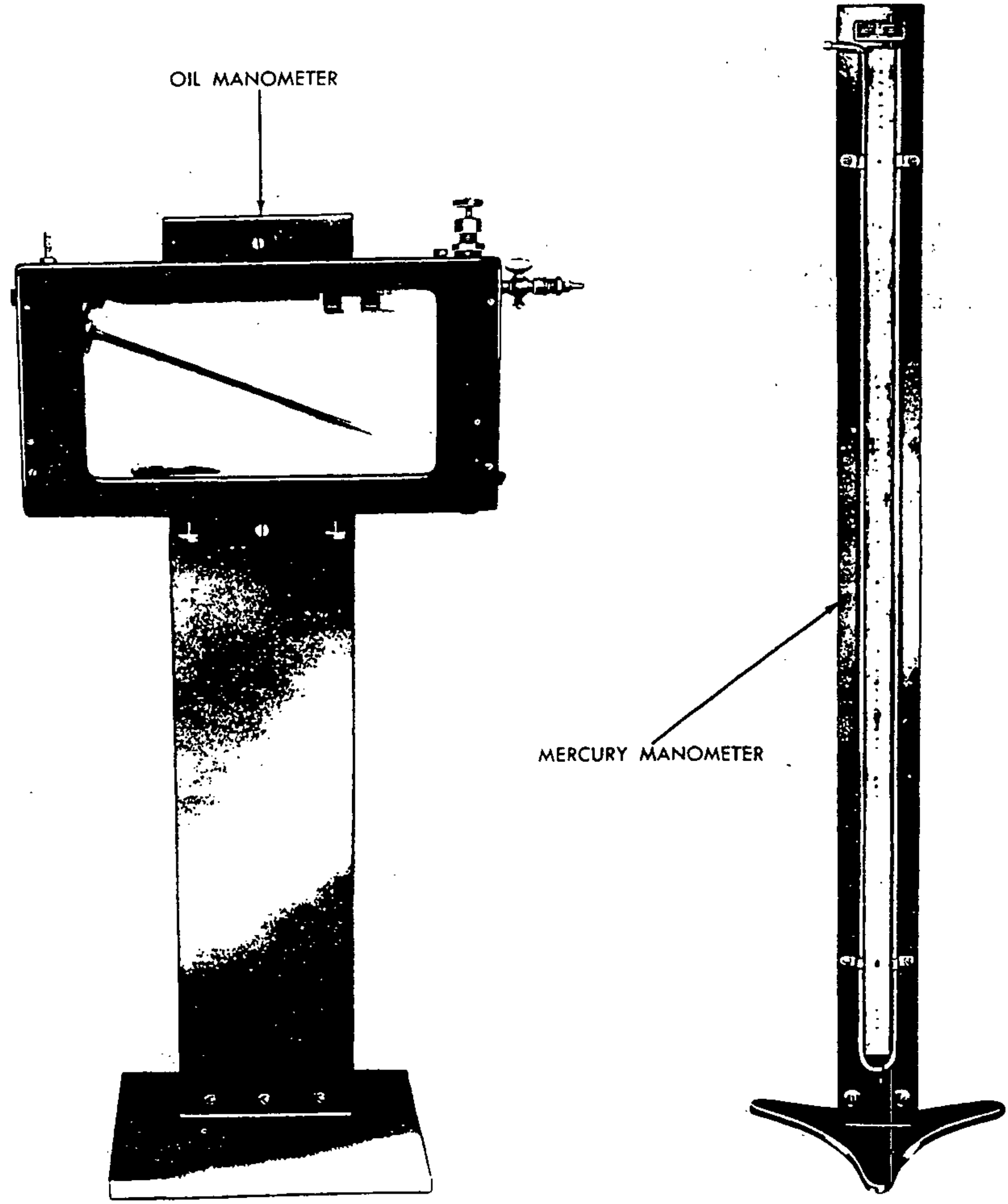


FIGURE 112.1-1. Representative types of manometers.

X-4205

METHOD 114.1b

TEMPERATURE CONTROL (HOT ROOMS)

114.1.1 GENERAL. Test chambers in which conditions such as temperature humidity, and atmospheric pressure are accurately controlled are called environmental chambers. The environmental chambers to be considered in this handbook are "hot rooms", "cold rooms", and "altitude chambers".

114.1.2 CONTROL OF TEMPERATURE. Hot rooms used to test generator sets must have adequate temperature control to meet the requirements of the high temperature test. The average ambient air temperature shall not vary more than 3 °C throughout the test, as measured by thermocouples placed in accordance with Method 202.1. A typical hot room, capable of maintaining such temperature control is shown in figure 114.1-1. The hot room shall have provisions to heat the intake air, to recirculate a certain amount of the heated air, to admit fresh air, to keep all the air in the room circulating and to allow the excess heat and engine exhaust to escape. The recirculated air shall not return within the hot room, but shall be conducted around the chamber in a separate duct.

114.1.3 SIZE OF HOT ROOM. The hot room shall be large enough so that the walls are at least 6 feet away from the generator set under test, with the exception that if the room has an inner screen or "false" wall with the air passing on both sides so that it is uniformly at the hot room ambient temperature, this screen or "false" wall may be less than 6 feet, but not less than 3 feet, from the generator set. In this case, the outer wall may be as close to the screen or "false" wall as desired, provided that the ambient air is made to circulate between the screen or "false" wall and the outer wall. It may also be necessary to use air baffles and deflectors in the room to maintain good temperature and air flow control, and, as long as the baffles and deflectors are at nearly the same temperature as the ambient air in the hot room, they may be placed closer to the generator set than 6 feet. The room shall be at least 3 feet higher, inside dimension, than the generator set being tested.

114.1.4 AIR CIRCULATION IN HOT ROOM. The air in the hot room shall be in continuous motion to prevent the formation of local conditions, "hot" or "cold" spots, within the room which are different from the average in the room. However, the chamber air velocity shall not exceed 5 mph. Air velocities greater than 5 mph are allowable provided the increased velocities are necessary to maintain the specified chamber temperature but in no instance shall the velocity exceed 15 mph. In general, it is easier to control the conditions in the hot room if the air flow is from the generator end of the set toward the engine cooling air exhaust.

114.1.5 SAFETY. A viewing port should be installed to allow visual inspection of the generator set without entering the chamber. Carbon monoxide (CO) and explosive mixtures detectors and a means to shut down the set in an emergency are also required. Working personnel should be aware of conditions within the test chamber prior to entering.

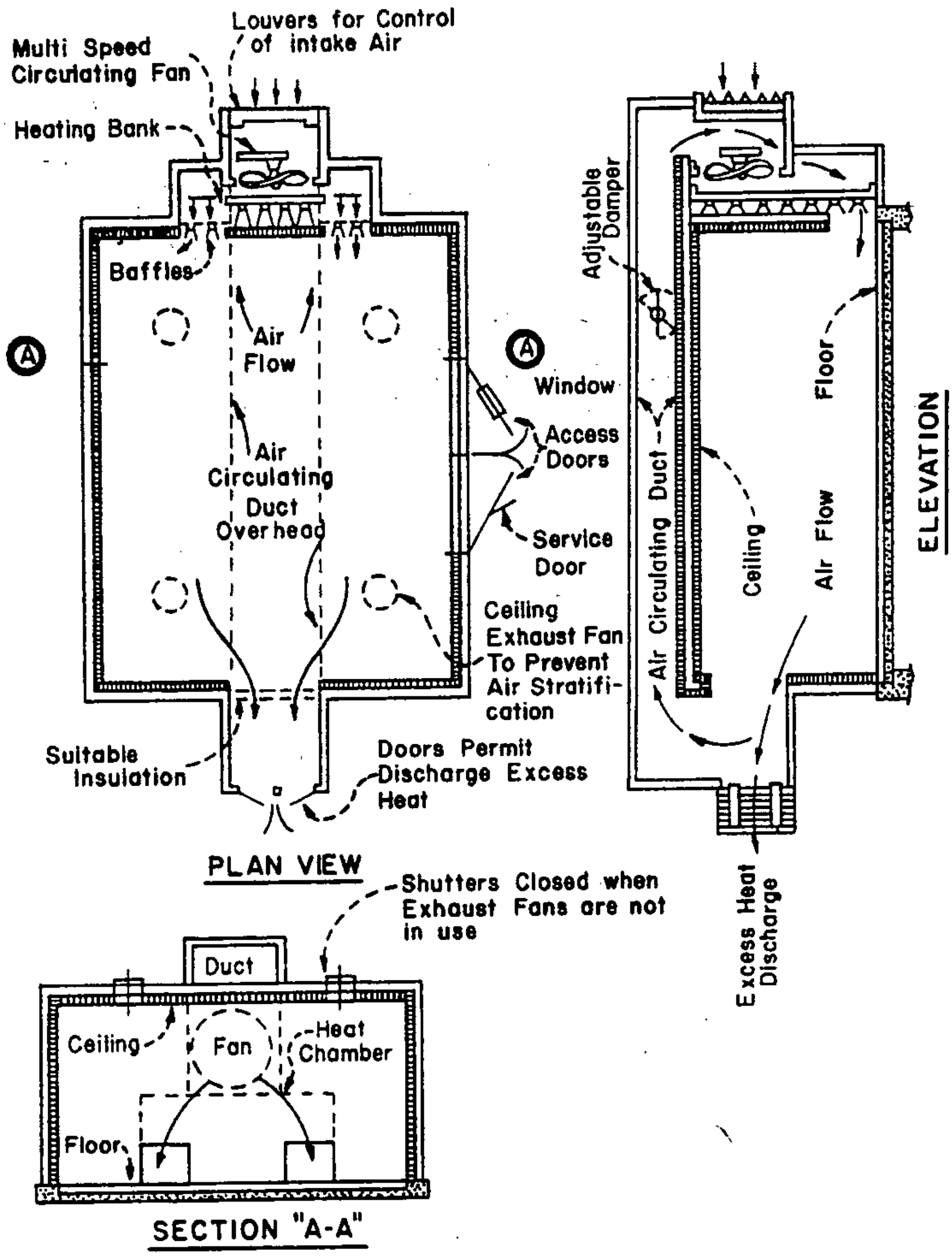


FIGURE 114.1-1. Layout for typical hot room.

X-4206

METHOD 114.2a

TEMPERATURE CONTROL (COLD ROOMS)

114.2.1 GENERAL. Test chambers in which conditions such as temperature, humidity, and atmospheric pressure are accurately controlled are called environmental chambers. The environmental chambers to be considered in this handbook are "hot rooms", "cold rooms", and "altitude chambers".

114.2.2 CONTROL OF TEMPERATURE. Cold rooms used to test generator sets must have adequate temperature control to meet the requirements of the cold test. The average ambient air temperature shall be uniform within 3C° throughout the test as measured by thermocouples placed in accordance with Method 202.1. A typical cold room, capable of maintaining such temperature control is shown in figure 114.2-1. The cold room shall have provisions to dry and chill the intake air, to recirculate the chilled air, to keep all the air in the room circulating, to remove the heat generated by the set, and to allow the engine exhaust to escape.

An estimate of the amount of heat generated by a generator set operating at rated load is 1/3 of the total heat as useful power, 1/3 as exhaust heat and 1/3 as engine heat to be removed by the engine cooling system. This is true for spark or compression ignition engines. For operation in a cold room the exhaust system must be vapor tight, not only due to the poisonous gases but because even a slight leak will emit water vapor to the room which will freeze to the cooling coils, thus lowering the ability of the coils to transfer heat. In addition to being vapor tight the exhaust system may be insulated to prevent excessive heat transfer to the room.

The fresh air intake to the chamber must have provisions to dry air entering the cold room as well as chill it to the ambient temperature of the cold room. A suggested method of drying the air is to pass it through dry silica gel. The air dryer must have sufficient capacity to supply dry air for the duration of the operational portion of the cold test(s). Dry air is defined as air having a dew point of at least 3 C° less than chamber ambient.

114.2.3 SIZE OF COLD ROOM. The cold room shall be large enough so that the walls are at least 6 feet away from the generator set under test, with the exception that if the room has an inner screen or "false" wall with the air passing on both sides so that it is uniformly at the cold room ambient temperature, this screen or "false" wall may be less than 6 feet, but not less than 3 feet, from the generator set. In this case, the outer wall may be as close to the screen or "false" wall as desired, provided that the ambient air is made to circulate between the screen or "false" wall and the outer wall. It may also be necessary to use air baffles and deflectors in the room to maintain good temperature control, and, as long as the baffles and deflectors are at nearly the same temperature as the ambient air in the cold room, they may be placed closer to the generator set than 6 feet. The room shall be at least 3 feet higher, inside dimension, than the generator set being tested.

114.2.4 AIR CIRCULATION IN COLD ROOM. The air in the cold room shall be in continuous motion to prevent the formation of local conditions, "hot" or "cold" spots within the room which are different from the average in the room. It is recognized that large quantities of air must be circulated through the cooling coils in order to remove the heat generated by the equipment under test; however, any air movement generates heat within the cold room and the optimum condition of air flow within the cold room must be found individually for each cold room design.

114.2.5 ATMOSPHERE WITHIN COLD ROOM. The ambient atmosphere within the cold room shall, at all times, be chilled normal air. At no time shall the room be cooled by the direct injection of carbon dioxide (CO_2) or any other gas or liquid other than normal air. Should the atmosphere of the room become contaminated by any foreign gas which can affect the results of the test, the test shall be suspended, the room cleared of the foreign gas and the test restarted.

114.2.6 SAFETY. A viewing port should be installed to allow visual inspection of the generator set without entering the chamber. Carbon monoxide (CO) and explosive mixtures detectors and a means to shut down the set in an emergency are also required. Working personnel should be aware of conditions within the test chamber prior to entering.

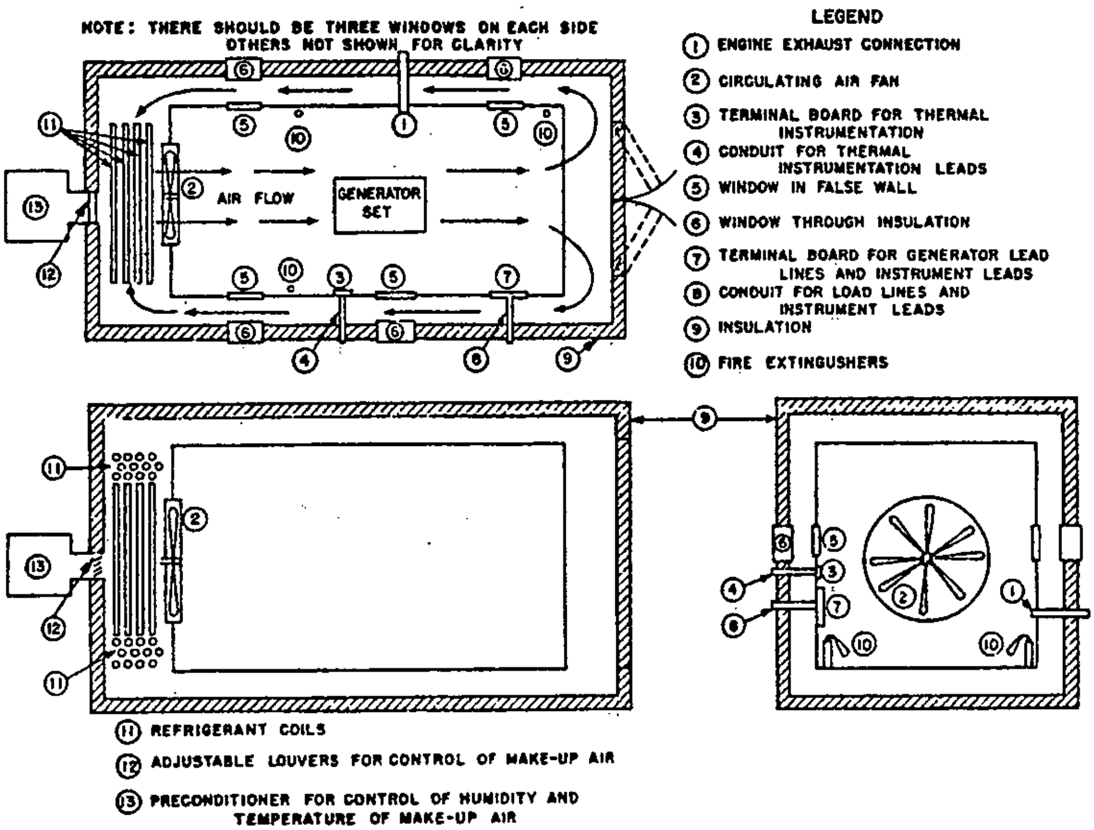


FIGURE 114.2-1. Schematic diagram of controlled low temperature chamber.

X-4207

METHOD 114.3a

TEMPERATURE CONTROL (ALTITUDE CHAMBERS)

114.3.1 GENERAL. Test chambers in which conditions such as temperature, humidity and atmospheric pressure are accurately controlled are called environmental chambers. The environmental chambers to be considered in this handbook are "hot rooms", "cold rooms", and "altitude chambers".

114.3.2 CONTROL OF TEMPERATURE. Altitude chambers used to test generator sets must have adequate temperature control to meet the requirements of the altitude operation test. The average air temperature shall be uniform within 3 °C around the set, and it shall not vary more than 3 °C throughout the test, as measured by 8 thermocouples placed in accordance with Method 202.1. The altitude chamber shall have provisions to heat the intake air, to recirculate a certain amount of the heated air, to keep all the air in the room circulating, to rid the chamber of excess heat, to rid the chamber of engine exhaust while maintaining the exhaust back pressure at the same value as it would be if it was exhausting into the chamber proper.

114.3.3 SIZE OF ALTITUDE CHAMBER. The altitude chamber shall be large enough so that the walls are at least 6 feet away from the generator set under test, with the exception that if the chamber has an inner screen or "false" wall with the air passing on both sides of it so that it is uniformly at the chamber ambient temperature, this screen or "false" wall may be less than 6 feet, but not less than 4.5 feet, from the generator set. In this case, the outer wall of the chamber may be as close to the screen or "false" wall as desired, provided that the ambient chamber air is made to circulate between the screen or "false" wall and the outer wall. In addition to the loading door to the chamber some method (air-lock) shall be provided to enter and leave the chamber without affecting the chamber ambient temperature or vacuum. It may also be necessary to use air baffles and deflectors in the chamber to maintain good temperature control, and, as long as the baffles and deflectors are at nearly the same temperature as the ambient air in the chamber and do not interfere with the ambient air thermocouples, they may be placed closer to the generator set than 6 feet. The room shall be at least 3 feet higher, inside dimension, than the generator set being tested.

114.3.4 CONTROL OF PRESSURE. A means of controlling and maintaining the pressure of the chamber must be provided. The pressure shall be controlled to within ±50 feet of the specified altitude value.

114.3.5 AIR CIRCULATION. The air in the altitude chamber shall be in continuous motion to prevent the formation of local conditions within the chamber which are different from the average in the chamber. In general, it is easier to control the conditions in the chamber if the air flow is from the generator end of the set toward the engine cooling air exhaust.

114.3.6 SAFETY. A viewing port should be installed to allow visual inspection of the generator set without entering the chamber. Carbon monoxide (CO) and explosive mixtures detectors and a means to shut down the set in an emergency are also required. Working personnel should be aware of conditions within the test chamber prior to entering. An emergency relief valve to bring the air pressure to the outside ambient pressure that is operational from inside the chamber, and some method of limiting the vacuum inside the chamber should be provided.

METHOD 115.1a

MEASUREMENT OF SOUND LEVEL

115.1.1 GENERAL. For some applications it is desirable that an engine-generator set operate as quietly as possible without impairing its operating efficiency. Some manufacturing specifications contain requirements for limits of operating noise, in terms of units of standard reference sound level. The standard reference level is defined as 0.0002 microbar (a pressure of 0.0002 dyne per square centimeter) at 1,000 Hertz.

115.1.2 SOUND LEVEL METER. A sound level meter (figure 115.1-1) is an instrument for reading, in terms of a standard reference sound level, the sound level at its microphone. The instrument consists essentially of a microphone, electronic amplifying and filtering equipment, octave band analyzer and an indicating meter calibrator. The American National Standards Institute (ANSI) Standards for these meters include those listed in MIL-STD-1474 for octave, half-octave, and third-octave band filter sets.

This instrument is extremely sensitive to sound from any source. Therefore, to accurately determine the noise characteristics of a generator set, the test should be made in a quiet rural area where sources of sound other than from the unit under test are at a minimum.

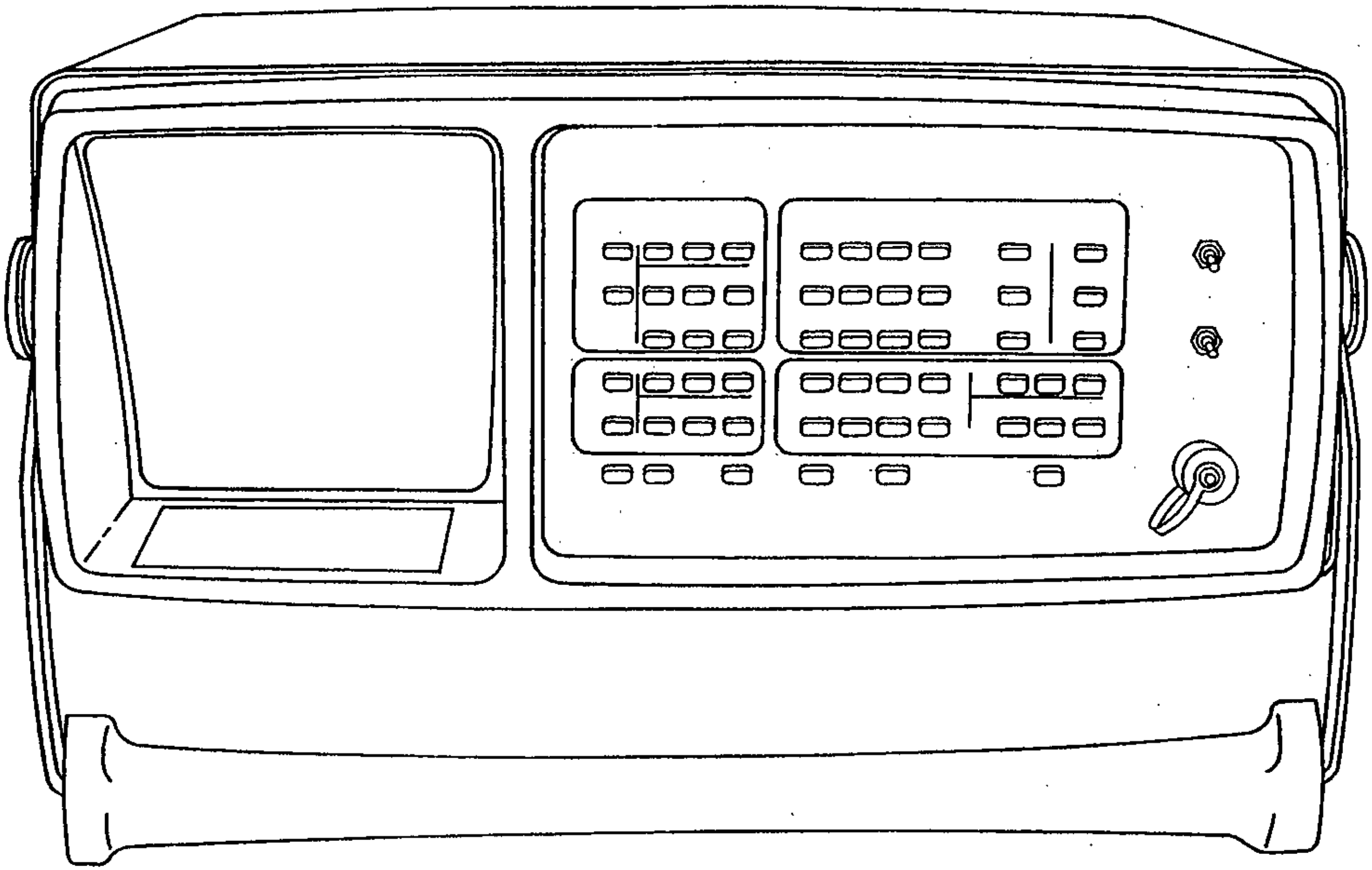


FIGURE 115.1-1. Sound level meter.

X-4208A

METHOD 116.1b

DETERMINATION OF PHASE ROTATION

116.1.1 GENERAL. During any cycle, an ac voltage varies from zero volts to a maximum, to zero, to a minimum, and finally back to zero. When each of the voltages of a three-phase system are observed simultaneously, it is noted that the time of arrival at the maximum voltage of each phase is different. If phase one reaches a maximum first, followed by phase two and then phase three, the phase rotation is 1-2-3. If phase one reaches maximum, followed by phase three and then phase two, the phase rotation is 1-3-2. This orientation of the leads is important since a three-phase motor will run in one direction when connected 1-2-3, and in the reverse direction if connected 1-3-2. Moreover, if two generator sets are to be operated in parallel, the phase rotation of the connections must be the same for both sets, or a short circuit will occur.

116.1.2 PHASE ROTATION INDICATORS.

116.1.2.1 MOTOR TYPE. A three phase ac motor with a disc or rag fastened to the shaft to indicate the direction of rotation, whose leads are marked to show which are 1, 2 and 3, and whose direction of rotation is known when lead 1 is connected to phase one, lead two is connected to phase two and lead 3 is connected to phase three, may be used.

116.1.2.2 PORTABLE INDICATORS. Two types of portable indicators are available. The first type is essentially a small motor whose speed of rotation is low and whose direction of rotation is known and easily seen. The second type consists of an electrical circuit with two neon tubes appropriately internally connected so that one or the other will light, depending upon the phase rotation. Both of these types are illustrated in figure 116.1-1.

116.1.2.3 MAKESHIFT INDICATOR. Phase rotation may be determined by connecting two sets of two lamp bulbs in series between corresponding terminals of the test generator and a source of three phase voltage of the same frequency and a known phase rotation. The third terminal of the test generator shall be connected directly to the third terminal of the source (figure 116.1-2). If the phase rotation of the generator is the same as that of the source, the lamps will blink simultaneously. If the phase rotation is not the same, the lamps will blink alternately.

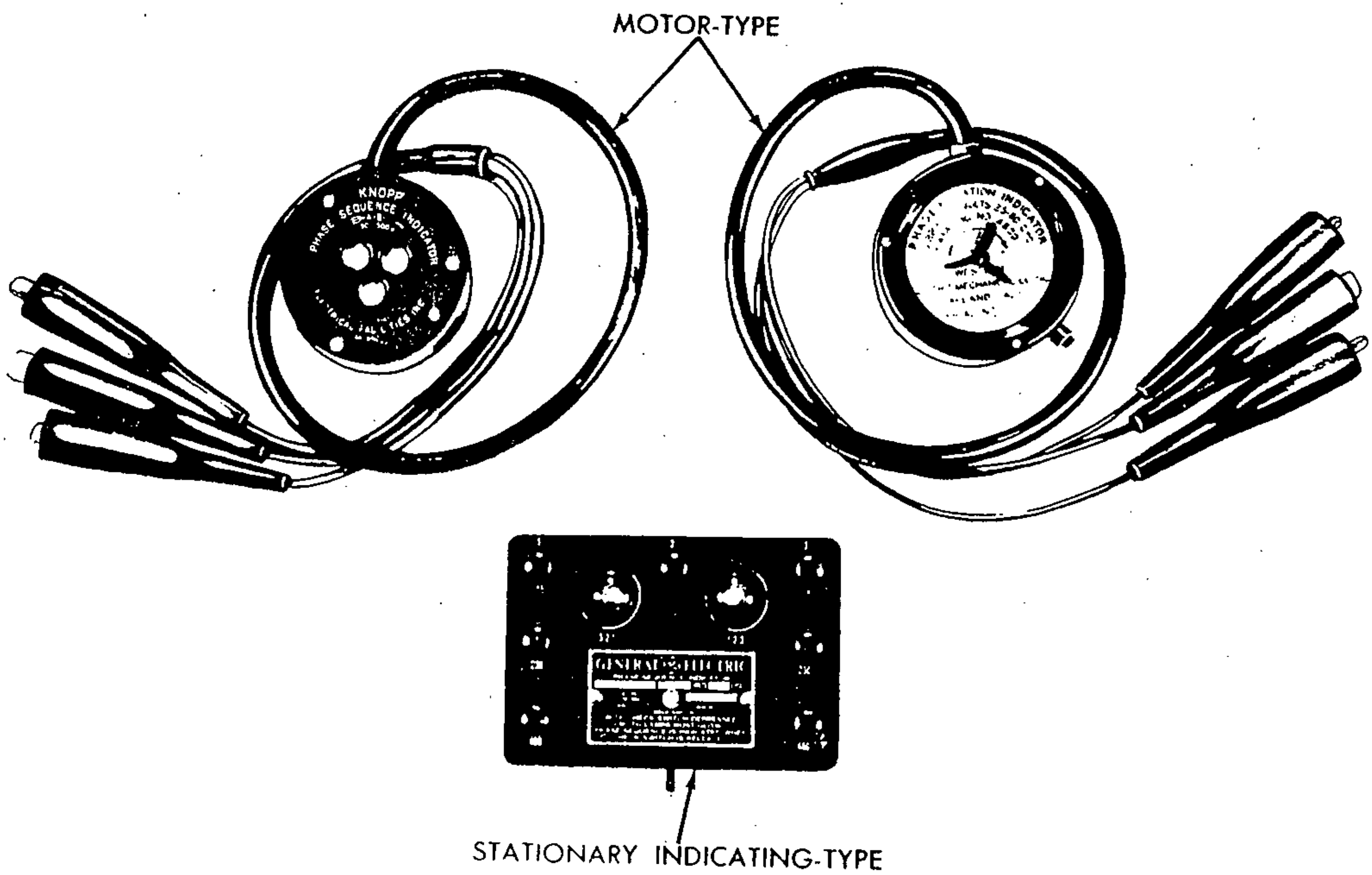


FIGURE 116.1-1. Portable phase rotation indicators.

X-4209

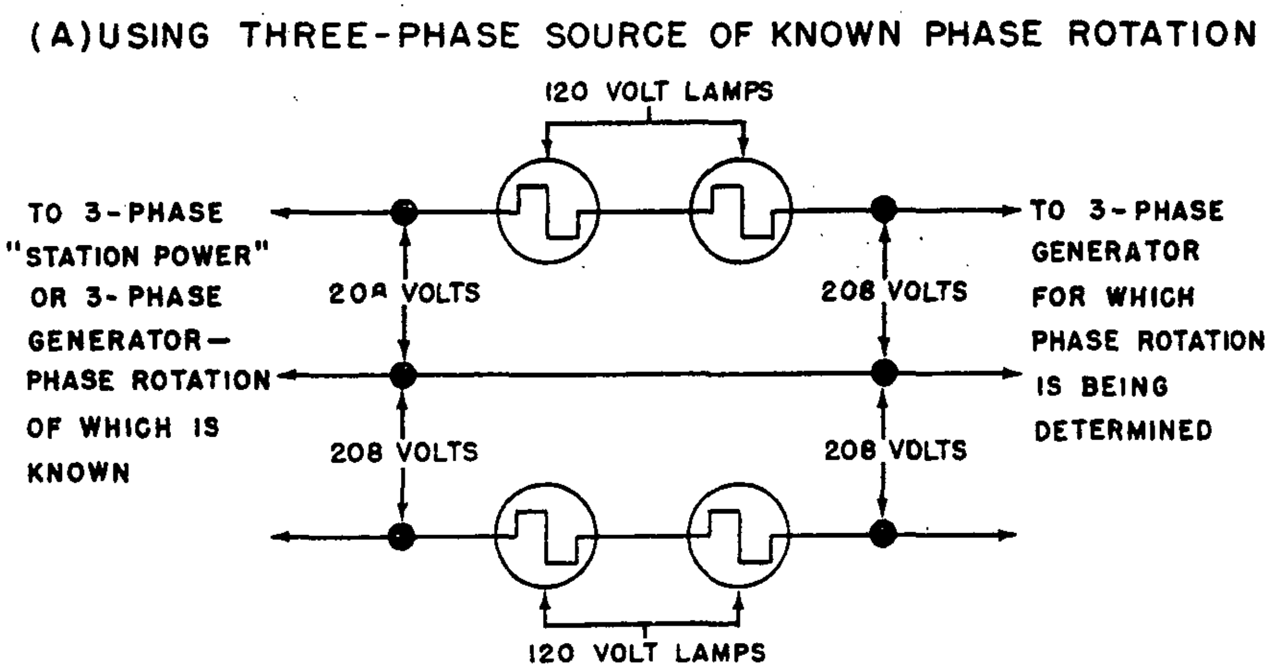


FIGURE 116.1-2. Makeshift phase rotation indicator.

X-4210

METHOD 117.1b

DETERMINATION OF PHASE RELATIONSHIP

117.1.1 GENERAL. Two or more ac generator sets may be operated in parallel provided that their (1) phase sequences, (2) voltages and (3) frequencies are the same. The usual method of determining that two or more sets are in phase is the dimming of the paralleling lights. However, some generator sets contain paralleling aid devices which must be tested to determine the exact phase relationship between the sets at the time the sets are allowed to parallel.

117.1.2 PHASE ANGLE METER. The phase angle meter employs pulse measurement of the difference in time between zero and crossover of the compared voltages. The phase angle meter differentiates the input waves and the difference signal is displayed on a direct reading meter in electrical degrees.

117.1.3 OTHER METHODS. It is possible to determine phase relationship in various ways using instruments other than the aforementioned types. These other methods include, but are not limited to, the use of oscilloscopes; however, the set-ups, procedures and interpretations of results of these other methods are usually complex. Before electing to use any other method, careful consideration should be given to its acceptability, ease of comprehension and potential for misinterpretation. If such a method is intended to be used for government acceptance or qualification tests, prior approval of such use should be obtained through the government contracting officer as early in the program as possible.

5.2 INSTRUMENTATION METHODS - 200 SERIES

METHOD 201.1b

ELECTRICAL INSTRUMENTS: CARE, INSPECTION, USE, AND REQUIRED ACCURACY

201.1.1 GENERAL. The following requirements applicable to instruments and equipment commonly used in the testing of engine generator sets shall be complied with.

201.1.2 CARE, INSPECTION AND USE OF INSTRUMENTS. The following precautions apply in general to the use of electrical instruments and those mechanical instruments, employing jewel bearings, small operating torques, or delicate movements.

Before any instrument is used, it should be inspected to determine that the pointer is free and rests at zero, if applicable. No instrument shall be used that sticks or binds at any part of the scale, or has a zero error.

Instruments containing permanent magnets shall neither be carried through nor placed in strong magnetic fields because the accuracy of the instrument may be affected.

Cables carrying high currents to an instrument, or near it, shall be kept close together and must never be placed on opposite sides of iron or steel objects, especially if they are resting on an iron or steel surface.

An instrument should read the same in each of four horizontal positions, 90 degrees apart, if it is unaffected by stray fields.

Instruments should not be dropped, bumped against each other, or placed on tables or benches used for such work as hammering, chipping, or riveting. Steel pivots resting on jewel bearings support the moving parts of most instruments and the pressures exerted on the jewel by the pivot in such a bearing is usually of the order of several tons per square inch. For this reason, shock and vibration can easily damage jewel bearings and cause erroneous readings.

Instrument cover glasses should never be cleaned or rubbed with a dry cloth because of the danger of building up a static electric charge on the glass. If a cover glass becomes charged, it may be discharged by rubbing gently with a damp cloth, or by moistening it with the breath. In either case, no moisture should be allowed to collect inside the instrument case.

Care should be taken to avoid errors due to parallax when reading any instrument. Recording instruments should be calibrated and read on the chart paper graduations rather than on the indicator scale.

Actual instrument readings shall be entered on all data sheets and all curves shall be carefully plotted. Readings shall never be corrected for instrument errors, transformer ratios, or scale factors before being entered on the data sheets. When it is desirable to have true values appear on the data sheet, two columns shall be used; the first for the actual instrument reading, and the second for the corrected value.

201.1.3 ACCURACY OF INSTRUMENTS. Indicating laboratory-type electrical instruments referred to in this handbook, and illustrated in section 100, shall have an accuracy at least 0.5 percent of full scale. Instruments will be selected and connected to indicate in the accurate portion of their range.

Digital meters generally offer greater resolution than the analog models they replace. For MIL-STD-705 testing, three significant digits are required for all electrical measurements unless additional digits are needed for clarity or definition for the applicable test.

201.1.4 PROCUREMENT DOCUMENT REQUIREMENTS. One of the following items must be specified in the individual procurement documents:

a. Accuracy of instruments used for acceptance testing shall be in accordance with MIL-HDBK-705, Method 201.1.

b. Accuracy of instruments used for acceptance testing shall be in accordance with (the individual procurement document shall specify the document or clause governing accuracy of instruments).

METHOD 202.1b

THERMAL INSTRUMENTATION

202.1.1 GENERAL. Thermal instrumentation includes instructions for locating various measuring devices for determining temperature of components and materials, and the surrounding (ambient) air.

The usual methods of obtaining temperatures at the various locations are: contact, resistance, or embedded detector. Each of these temperature measurement methods are discussed in detail in Method 110.1.

202.1.2 GENERATOR SET COMPONENTS:

202.1.2.1 CONTACT METHOD. The contact method of temperature measurement is used in the following locations: generator bearing housing or housings, generator frame, stator coils, intake and exhaust cooling air, collector rings, commutator, pole tips, rotor windings, and engine coolant and lube oil (by immersing the detector). Temperature measurements on moving components must be attached immediately once the moving part is at rest.

202.1.2.2 RESISTANCE METHOD. This method is applicable for measuring the temperature of the generator output winding, the generator field and exciter field. It shall not be used on a rotating winding whose resistance at ambient temperature is less than 1.0 ohm.

The application of the devices and the formula for calculating the temperature rise are given in Method 110.1.

202.1.2.3 EMBEDDED DETECTOR METHOD. Usually, only generator sets rated at 500 kW, or larger, are equipped with embedded detectors for the determination of the temperature of the electrical windings. The temperature of stationary windings will be measured periodically by this method during a test, while that of rotating windings will be taken at a standstill, immediately following shutdown.

Embedded detectors are of two types: the thermocouple type and the resistance type. Either of these types may be employed as stationary or rotating detectors.

Before measuring temperatures by the embedded detector method, make sure that the detectors have been properly located in accordance with the applicable procurement document.

202.1.3 ENGINE COMPONENTS. All temperature measurements of the engine components normally use the contact method. The contact detector can be either the thermocouple type or the resistance type.

202.1.4 AMBIENT AIR TEMPERATURE.

202.1.4.1 APPARATUS. Ambient air temperature measurements shall be made with of thermometers or thermocouples. These devices shall be exposed directly to the ambient air. When chambers are used, the thermal sensing devices used for controlling the chamber temperature shall be separate from the apparatus used for measuring and recording the chamber ambient.

202.1.4.2 LOCATION.

202.1.4.2.1 ENVIRONMENTAL CHAMBERS. Precautions will be taken to insure that none of the thermometers or thermocouples are located in either "hot" or "cold" spots in the chamber. The thermometers or thermocouples shall be placed at the following positions:

Unhoused generator set - The ambient air temperature shall be measured at a distance of approximately 2 feet diagonally outboard from the corners of the generator set as the air approaches the set. A minimum of 2 thermometers or thermocouples shall be recorded and averaged to establish the ambient air temperature specified in the applicable test document. The distance from walls or obstructions shall be 1 foot minimum. The temperature measurement devices shall not be located near the engine exhaust outlet or in the cooling air exhaust from the generator set.

Housed generator sets - The ambient air temperature shall be measured at the generator air intake to the housing. This measurement shall be taken by a minimum of 2 thermometers or thermocouples. The outputs shall be recorded and averaged to establish the ambient air temperature specified in the appropriate test document.

202.1.5 CONTROL PANEL TEMPERATURES. The temperature within the control panel enclosure shall be taken by means of a thermocouple. The thermocouple shall be mounted in the space behind the control panel and shall be so located that it is surrounded only by air and is not in contact with any object. When testing a generator set on which the control panel has been opened for inspection, always close the control panel before measuring the temperature of the enclosure behind it.

202.1.6 BATTERY ELECTROLYTE AND BATTERY BOX AMBIENT AIR TEMPERATURES.

202.1.6.1 BATTERY ELECTROLYTE TEMPERATURES. The battery electrolyte temperature shall be taken by a thermometer or thermocouple in the opening to a central battery cell in all batteries, if there is more than one. When a thermocouple is used, it shall be enclosed with a corrosion resistant material which is flexible and sealed on the end in the battery. One such corrosion resistant material is "Teflon". To install the thermocouple halfway down the plates, a wooden separator about the thickness of the thermocouple can be carefully forced down between the plates, then the thermocouple installed and the separator removed. The thermocouple junction shall be located so that it is completely immersed in the electrolyte. The plates will hold the thermocouple in place. If a thermometer is used, it shall be located so that its bulb is completely immersed in the electrolyte.

202.1.6.2 BATTERY BOX AMBIENT AIR TEMPERATURES. The battery box ambient air temperatures shall be measured by means of two thermocouples located at opposite sides of the battery box, approximately halfway up the inside wall, and free from contact with any object other than the ambient air.

202.1.7 WINTERIZATION HEATER TEMPERATURES.

202.1.7.1 COOLANT TYPE HEATERS. For winterization heaters that heat and circulate the engine coolant, the temperature of the coolant shall be measured at both its inlet and outlet to the heater. The temperature shall be taken by thermometers or thermocouples located in the piping at these points.

202.1.7.2 HOT AIR TYPE HEATERS. For heaters that heat and circulate uncontaminated hot air, the temperature of the air shall be measured at its inlet and outlet to the heater. The temperatures shall be measured by thermocouples located in the heater ducts at these points.

202.1.7.3 EXHAUST GAS MEASUREMENTS (BOTH TYPES OF HEATERS). The heater exhaust gas temperature shall be measured by a thermocouple located as close as possible to the point at which the exhaust gases leave the heater. When the exhaust gas is used in heating the oil pan, the temperature of the exhaust gas, after passing through or around the oil pan, shall also be measured.

METHOD 203.1b

DATA SHEETS AND RECORD ENTRIES

203.1.1 GENERAL. Tests do not fulfill their purpose unless complete and accurate data are recorded.

When the data are compared directly with the requirements of the procurement documents, or when calculations are made from the information on the data sheets, and the results compared to the requirements of the procurement documents, the acceptance or rejection of the set under test is dependent upon the data obtained.

To avoid accepting equipment which fails to meet the requirements of the procurement documents, and to be absolutely certain that any rejects fail to meet these requirements, repeat any test procedure if there is any doubt as to the accuracy of the recorded data.

Each data sheet must be trackable to a complete series of information which will identify the set under test and the test method, in addition to the data. The following is a list of information each data sheet shall be trackable to or will be included on the data sheet:

1. The make, rating, model number, and serial number of the set under test.

2. The name and number of the test method.

3. Columns for all instrument readings, with the serial number of the instruments used, and the multiplying factor.

4. The date on which the test is performed, the consecutive reading number and the time of each reading.

5. The names of the personnel performing the test and the observer/or Government inspector.

6. Notes as necessary to clarify the conditions of the test.

7. The name or designation of the agency responsible for inspection of the unit under test. For example: "Philadelphia Region-Defense Contract Services Administration."

8. Data sheet number. If more than one data sheet is used to record data at the same time, each data sheet used shall be numbered, e.g., sheet 2 of 3.

9. The ambient temperature reading.

10. References by reading number to attached charts.

11. A series of instrument readings taken within five minutes after starting the set (only for tests requiring stabilization of the set).

NOTE: Zero instrument readings will be recorded as such. Do not leave the space blank.

All instruments shall be carefully read. The readings shall be recorded directly on the data sheet and not multiplied by the multiplying factor before recording. Both maximum and minimum readings for cyclic values shall be recorded on the data sheets.

When making readings for steady-state conditions, be certain that these conditions have been reached before recording the readings.

No erasures of readings shall be made. Errors shall be neatly crossed out with a single straight line. Consecutive reading numbers will begin with the first test conducted during first article (preproduction) tests and shall be continued throughout these tests.

Individual tests requiring a series of data points shall be repeated if an interruption occurs during the test (e.g., data points being taken for plotting a curve, etc.).

Complete, accurate and neat data are essential when performing the tests in MIL-STD-705.

Samples of data sheets for many test methods will be found in MIL-STD-705. The format of each shall be followed so far as possible, to facilitate the obtaining of comparative data.

METHOD 205.1b

GENERAL INSTRUCTIONS FOR CONNECTING TESTING INSTRUMENTS

205.1.1 GENERAL. Instrument usage is of critical importance in the determination of the quantitative value of effects occurring during tests. If the apparatus is improperly connected, the resulting data will either be useless or qualitative at best.

On the following pages are instructions and schematic diagrams indicating the methods of connecting the most commonly used instruments required during the performance of the methods contained in MIL-STD-705. It is recognized that the terminal posts of all instruments are not in the same place as those shown in the diagrams and judgement must be exercised in connection of any specific instrument. The manufacturer's instructions should always be consulted in case of doubt as to the proper utilization of any test apparatus.

The general theory of operation of the instruments shown in the diagrams is covered in the 100 Series of methods of this Handbook. When recording instruments are required, they are to be connected into the circuit in the same manner as shown for indicating instruments.

205.1.2 CALIBRATION OF INSTRUMENTS. All test instruments shall be calibrated at maximum intervals of 6 months to insure their accuracy. Test instruments shall be calibrated within 30 days prior to the start of any new test program. Instruments used in calibration shall have at least five times the accuracy of the instrument being calibrated. Calibrated reference instruments of lesser accuracy than standard, which are not used for any other purpose, may be used for the required periodic check of test instruments. The calibration of all instruments shall be traceable to the National Bureau of Standards.

Instruments shall be calibrated at the frequencies at which they are going to be used.

205.1.3 SELECTION OF INSTRUMENTS. Prior to connecting instruments into circuits, thought should be given to the range of readings which will be required. The range of the instrument should be great enough so that it will not be burned out during normal use, but the range should not be so great that the reading will be so low on the scale as to make the accuracy of reading unreliable. On analog dc instruments, the readings shall not be made on the lower 15 percent of the scale. On analog ac instruments, the readings shall not be made on the lower one-third of the scale.

Instrumentation accuracy shall be not less than ± 0.5 percent of the full scale value, unless otherwise specified herein or in the procurement document.

Some instruments have leads which are calibrated for use with particular instruments. These instruments shall always be used with the leads provided or the calibrations will be useless. The calibrated leads shall not be used for any purpose other than that for which the leads were calibrated.

Some instruments have ON-OFF hold-down buttons on their cases. These instruments usually are designed for intermittent use and should not be connected into live circuits with the buttons taped down so that the meters read continuously. Serious overheating and possible destruction of the instrument may occur if this precaution is ignored. Instrumentation shall be used in accordance with its manufacturer's recommendations, especially where pre use "warm up" is recommended.

Care should be taken to keep unshielded instruments out of any stray fields to avoid errors and permanent damage to instruments.

205.1.4 VOLTMETERS. Since voltmeters are potential measuring devices, they are placed "across the line" in use. Care in selection of voltmeters is necessary since these instruments consume power in operation. Where measurement of potential of high impedance or high resistance circuits is required, high resistance (low current drain) instruments must be used or the instrument power drain may disturb the basic circuit. However, except for the smallest generator sets, the power consumption of a voltmeter may be considered negligible.

205.1.4.1 AC VOLTMETERS. Figure 205.1-1 shows the method of connecting an ac voltmeter so as to measure the potential between two wires. Care in selection of the proper range should be exercised. When in doubt, use the highest range instrument available just to approximate the range needed for the measurement.

When the range of the available voltmeter is not adequate for the potential to be measured, or when instrument isolation is required, a potential transformer may be used. Figure 205.1-2 shows the connection diagram for such a combination. When a potential transformer is used, a piece of paper with the multiplying factor, resulting from the transformer ratio, shall be affixed to the indicating instrument. More than one instrument may be connected to one potential transformer, but the rated burden of the transformer shall not be exceeded.

In some instances, the range of an ac voltmeter may be extended by use of a multiplier which is a non-inductively wound calibrated resistor. Figure 205.1-3 indicates the method of connecting such a range extending device.

It should be emphasized that the voltage sensing connections for the voltmeter or the primary of the potential transformer shall be connected immediately prior to the load contactor or curcuit interrupter of the generator set when performing the methods of MIL-STD-705. This is to standardize the voltage measuring points and to avoid voltage drops due to line loss when the set is operating under load. To connect the voltage sensing lines to the load side of the load contactor would open circuit all voltage sensing when the load contactor was open.

When numerous readings of potential of different circuits must be made, it is recommended that a switching device be used to facilitate the use of a single voltmeter. Figure 205.1-4 shows a schematic wiring diagram of such a switch. Note that the switch points must be of the non-shorting type and the voltage rating of the switch must be in excess of the maximum voltage to be measured. Figure 205.1-5 shows a selector switch, fabricated from easily obtained materials, which might be used to read all six voltages of a three-phase, four-wire system, with one voltmeter.

When recording meters are used, the clock drive should be connected to a stable source of power, such as public utility supply, so as to eliminate paper speed changes and bias voltage variations during operation (figure 205.1-6). When multiple recording units are used to measure different values, their clock devices shall be connected to the same power supply. When mechanical clocks are used as drives, it is desirable to use mechanical ties between the recorder, so that the paper speeds will be the same.

Note: Figures 205.1-1 thru 205.46 show the voltage instrumentation sensing lines connected to the output load terminals. These voltage sensing lines shall be connected immediately prior to the set load interrupter when voltage instrumentation sensing is required with the set load interrupter in the "open" position.

205.1.4.2 DC VOLTMETERS. Figure 205.1-7 shows the connection of a self-contained dc voltmeter. It should be noted that polarity is important when D'Arsonval instruments are used. When extreme accuracy is required, such as during calibration, and a dynamometer-type instrument is used, readings should be taken with the leads direct and reversed and the result should be taken to be the average of the two readings.

Most of the notes contained in 205.1.4.1 (ac voltmeters) apply to dc voltmeters, but it should be noted that potential transformers cannot be used to extend the range of the dc voltmeter. Transfer switches, to measure voltages of different circuits with one voltmeter, are more complicated since polarity must be correct for all connections.

In the measurement of dc voltages which have a ripple content, D'Arsonval instruments shall be used.

205.1.5 AMMETERS. Since ammeters are current measuring devices, they are placed "in the line" and never "across the line". When ammeters are used they should be protected by short circuiting switches so that transient current surges will not damage the instrument.

205.1.5.1 AC AMMETERS. Figure 205.1-8 shows the connection of a self-contained ac ammeter with a protective short-circuiting switch.

When the range of the instrument is not adequate to measure the current in the line or when the voltage is above that to which the instrument can safely be connected directly in the line, current transformers, for testing purposes, having a five-ampere instrument side and multiple taps for the line side shall be used (figure 205.1-9). Where the line current is greater than the taps provided, turns may be passed through the core of the transformer, as shown in figure 205.1-10.

When multiple readings of several line currents are required, it is usually preferable to use a transfer switch such as shown in figure 205.1-11. This can be readily obtained since most generator sets are equipped with such a device. The connection for a three-wire selector switch with current transformers is shown in figure 205.1-12. At any position, the selector switch must short the current transformers not in use in that position. Moreover, when turned, it must short out all of the transformers before changing the position of the ammeter in the circuit. Because of the difficulties of switching without causing line-to-line shorts, ammeters without current transformers are seldom switched.

205.1.5.2 DC AMMETERS. Figure 205.1-13 shows the connection for a self-contained dc ammeter having three ranges. A shorting switch is desirable across the instrument to protect it from transient surges of current. Figure 205-1-14 illustrates the wiring of a dc ammeter with a shunt. The instrument is essentially a millivoltmeter which measures the drop across a known resistance (the shunt). For that reason, the instrument and its leads are calibrated as a unit and must be used together. Multiple shunts may be arranged in a single case, as shown in figure 102.1-2.

205.1.6 WATTMETERS. Some wattmeters have a compensating circuit in their mechanisms which corrects the indication for the moving coil losses. However, this correction is negligible when a wattmeter is used to measure generator output power and all figures contained in this handbook are drawn as if the wattmeters are not compensated. The range of wattmeters can be extended through the use of current transformers, potential transformers or both. When using transformers, the indicated meter reading must be multiplied by the transformer ratio and the meter ratio to determine the actual power.

205.1.6.1 MEASUREMENT OF SINGLE-PHASE WATTAGES. Figure 205.1-15 shows the connection for a self-contained single-phase wattmeter. The range of the wattmeter may be extended by the use of a potential transformer and a current transformer. Figure 205.1-16 shows the connection of a single-phase wattmeter with a potential transformer.

Caution: When this circuit is used the current winding of the wattmeter must be rated for the line to ground voltage of the circuit.

Figure 205.1-17 shows the connection of a single phase wattmeter with a current transformer. Figure 205.1-18 shows the connection of a single phase wattmeter with both potential transformer and a current transformer. The plus-or-minus binding post of the potential circuit must always be connected to the same side of the circuit under test which contains the current coil of the wattmeter, to have the current and potential coils at the same potential, thus eliminating the electrostatic attraction between them. When current or potential transformers are used, it is necessary to connect the plus-or-minus binding post of the potential circuit to the plus-or-minus binding post of the current circuit. When both potential and current transformers are used, the connection between the plus-or-minus binding posts should be grounded. When instrument transformers are used in the measurement of power, they must maintain the phase relationship between the input and output of the transformer at zero degrees. Any time instrument transformers are used on circuits exceeding 750 volts, one terminal of the transformer secondaries must be grounded through a wire equivalent in current carrying capacity to No. 12 AWG copper or larger (see Rules 93.B.3, 97.A.3, and 150.C of the National Electrical Safety Code ANSI C2.)

205.1.6.2 MEASUREMENT OF POLYPHASE WATTAGES. A single-element wattmeter may be used to measure the power of a balanced, three-wire, polyphase system. This can be accomplished by means of a three-resistor network connected to form an artificial wye with the potential circuit of the instrument as one section of the network. The other two sections each have the same resistance as the instrument, and the voltage across the instrument then is equal to the phase voltage (or the voltage to the artificial neutral). The current circuit of the instrument indicates the power of one phase. The actual wattage will be three times the meter reading. The connections for such use of a single-phase wattmeter are shown in figure 205.1-19.

It is also possible to measure the power in a balanced three-phase, three-wire system by connecting a single-element wattmeter as shown in figure 205.1-20. It should be noted that the wattmeter current coils should be connected for two times the current connection for one transformer. Thus, if five-ampere transformer secondaries are used, the current coils of the wattmeter should be connected for 10 amperes. If the wattmeter reading (adjusted for the 10-ampere connection) is multiplied by the transformer ratio, the result will be the polyphase wattage.

Where unbalanced voltages or currents are encountered, it is recommended that more than one meter be used to measure the power in a polyphase system. These meters can be combined in one unit to form a direct reading polyphase wattmeter. Blondel's Theorem states that "true power can be measured by one less wattmeter element than the number of wires of the system, provided that one wire can be made common to all element potential circuits". Figure 205.1-21 shows the connections for two single-phase wattmeters used on a three-phase, three wire system. If both instruments deflect toward the top of the scale, when connected as shown, the power is the sum of their indications. If one instrument deflects negatively, which will be the case when the power factor is below 50 percent, the reversing switch of that wattmeter should be changed and the power will be the reading of the first instrument minus the reading of the reversed instrument.

The connections for a two-element polyphase wattmeter, used on a three-phase, three-wire system, are shown in figure 205.1-22. Figure 205.1-23 shows the use of the same instrument on a balanced three-phase, four-wire system. This instrument will not read correctly on an unbalanced three-phase, four-wire system.

Figures 205.1-24, 205.1-25, and 205.1-26 show the use of a two-element, polyphase wattmeter on a balanced four-wire, three-phase system, using potential transformers, current transformers, or both.

When the wattage of a four-wire, three-phase unbalanced system is required, three wattmeters connected as shown in figure 205.1-27 shall be used. The sum of the three readings is the required wattage.

In some instances it may be necessary to measure the wattage of a single-phase system with a polyphase wattmeter. Figures 205.1-28 and 205.1-29 show wiring connections which will permit the use of such an instrument. In the connection of figure 205.1-28, the wattmeter will read directly. In the connection of figure 205-1-29, the wattmeter reading must be multipled by the ratios of both the current and potential transformers.

205.1.7 POWER FACTOR. The power factor of a single-phase circuit can be determined by using a single-phase wattmeter, as shown in figure 205.1-15 and voltmeter and ammeter, as shown in figures 205.1-1 and 205.1-8. Since the wattmeter reads EI cos θ (volts x amperes x power factor), if the wattmeter reading is divided by the product of the voltmeter reading times the ammeter reading, the result will be power factor (cos θ).

$$\frac{\text{Watts}}{\text{Volts x Amps}} = \text{power factor}$$

Caution: The resultant power factor must be within the wattmeter operating range.

This value may be read directly by using a single-phase power factor meter connected as shown in figure 205.1-30. Figure 205.1-31 shows the same instrument used with a potential transformer and a current transformer. When instrument transformers are used in the measurement of power factor, they must maintain the phase relationship between the input and output of the transformer at zero degrees.

When the power factor of a balanced three-phase system is desired, it may be computed by using a polyphase wattmeter, as shown in figure 205.1-22, a voltmeter and an ammeter, as shown in figures 205.1-1 and 205.1-8. The wattmeter reads $\sqrt{3}E_{Line} I_{phase} \cos\theta$ ($\sqrt{3}$ x line-to-line volts x phase current x power factor). The wattmeter reading divided by the product of the voltmeter reading and the ammeter reading and $\sqrt{3}$ will be the power factor (cos θ). This value may be obtained directly by the use of a polyphase power factor meter, as shown in figures 205.1-32, 205-1-33, 205-1-34, and 205-1-35 which illustrate the method of connection of the instrument when used alone, with potential transformers, with current transformers, and with both current and potential transformers. Care must be taken to see that the wiring of a polyphase power factor meter is correct, or the reading will be completely erroneous. A check always should be made against the computed value of the power factor, as given above, the first time the instrument is used in a circuit.

Since the system must be balanced (equal voltages, currents, and power factors on all three phases), to use a polyphase power factor meter, a single-phase instrument used as shown in figure 205.1-30, between one line and neutral, also may be used to indicate the system power factor.

The power factor of an unbalanced polyphase system is a complicated, controversial subject, beyond the scope of this handbook, and it is not required in any of the test methods.

205.1.8 REACTIVE VOLT-AMPERES. Occasionally it is necessary to determine the reactive volt-amperes of a polyphase system. This may be accomplished in a balanced three-phase system by using a single-element wattmeter, as shown in figure 205.1-36. The scale reading must be multiplied by $\sqrt{3}$ to get the values of VAR's.

Figure 205.1-37 shows the use of a polyphase wattmeter with a combined phase-shifting autotransformer. This may be used on a three-phase, three-wire system whose voltages are balanced but whose currents are not.

205.1.9 FREQUENCY. Frequency meters are connected in circuits in a manner similar to a voltmeter. Figures 205.1-38 and 205.1-39 illustrate the connections for the use of such instruments.

Figure 205.1-40 shows the connections for a recording frequency meter with the chart and internal power supply connected to utility to prevent inaccuracy related to voltage and frequency transients.

The accuracy of frequency meter readings is influenced by the waveform of the circuit potential. When the waveform differs substantially from that of a sine wave, the readings will be erroneous. When it is desired to read the frequency of non-sinusoidal waves, special instruments, containing band pass filters, must be used. Since the specifications for generators require a low distortion waveform, these special instruments are not needed when the frequency is determined directly from the line voltage of the generator.

Caution: To prevent damage to frequency meters, they should only be electrically connected to the line when the line frequency is known to be within the range of the instrument. Most frequency meters are equipped with an on-off switch for this purpose.

205.1.10 LOAD INSTRUMENTATION. Figures 205.1-41 through 205.1-46 show methods of using instruments in combination to measure the load conditions and field voltage and current of a generator. In order to simplify the diagrams, in some instances, instruments are shown without transformers or other multipliers and, therefore, the wiring principles for such accessories given in the preceeding paragraphs will have to be used, where necessary, to extend the instrument ranges. The connection shown in figure 205.1-45 for a three-wire, three-phase, ac generator set may be used on a four-wire generator set if the loads are balanced. In that case, no connections will be made to the fourth wire (neutral). The instrumentation of figure 205.1-46 is necessary only where unbalanced loads are used and the methods, with few exceptions, do not call for such conditions.

205.1.11 SPECIAL TEST MEASUREMENTS. Figure 205.1-47 shows the connection to measure the short circuit currents of single and three phase shorts, either delta or wye connected. Three phase shorts are shown.

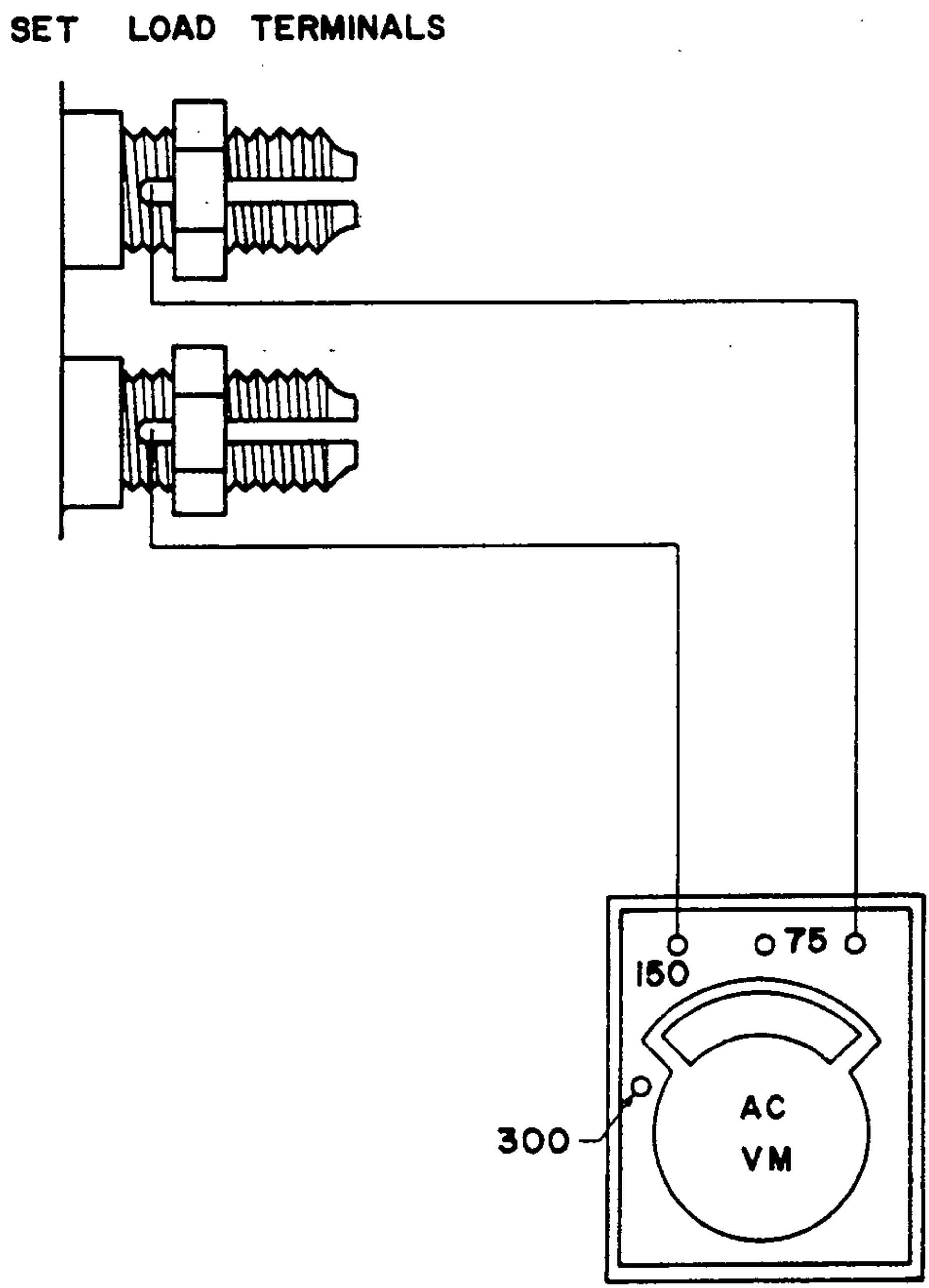


FIGURE 205.1-1. Self-contained ac voltmeter.

X-4214

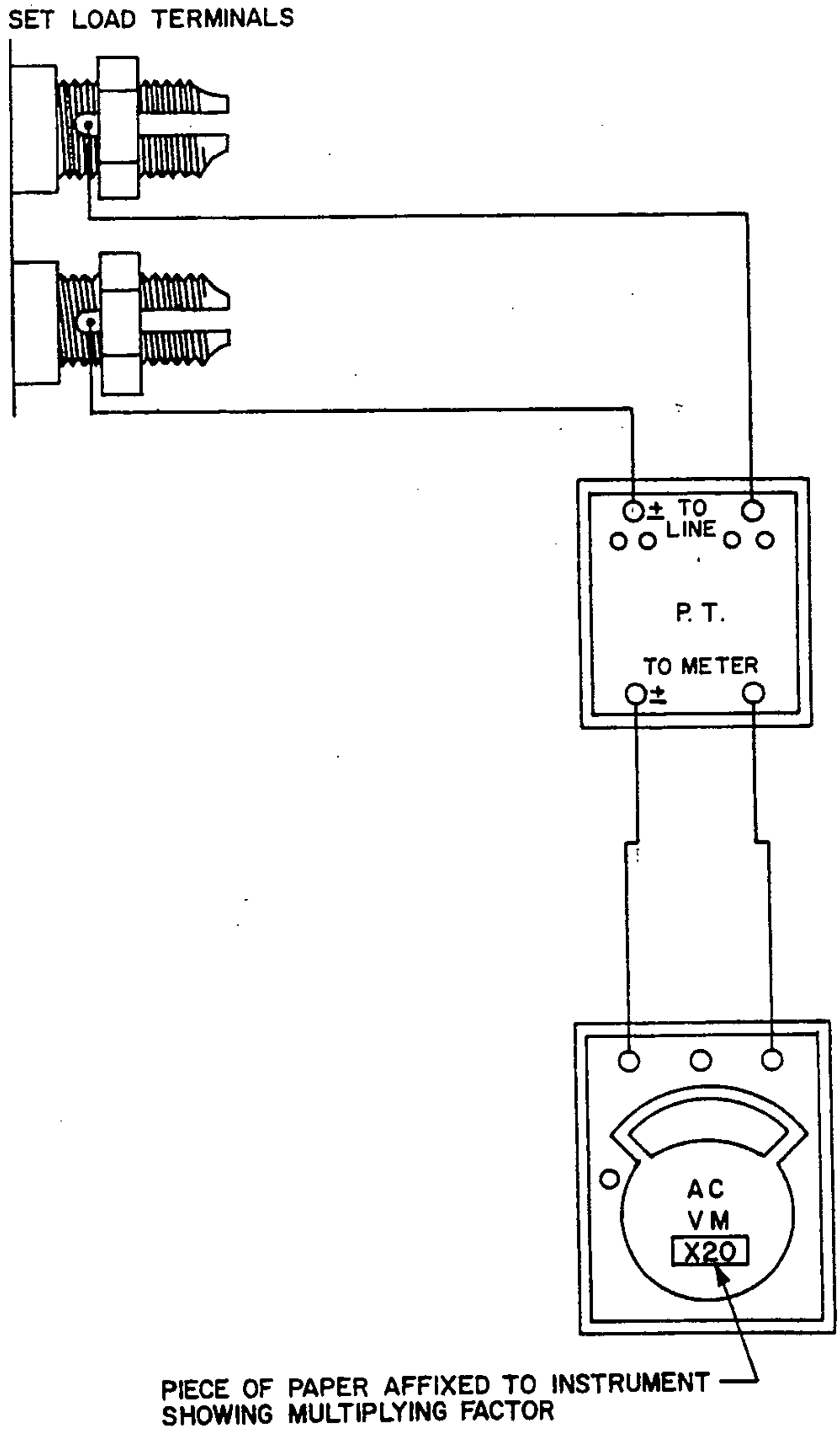


FIGURE 205.1-2. AC voltmeter with potential transformer.

X-4215

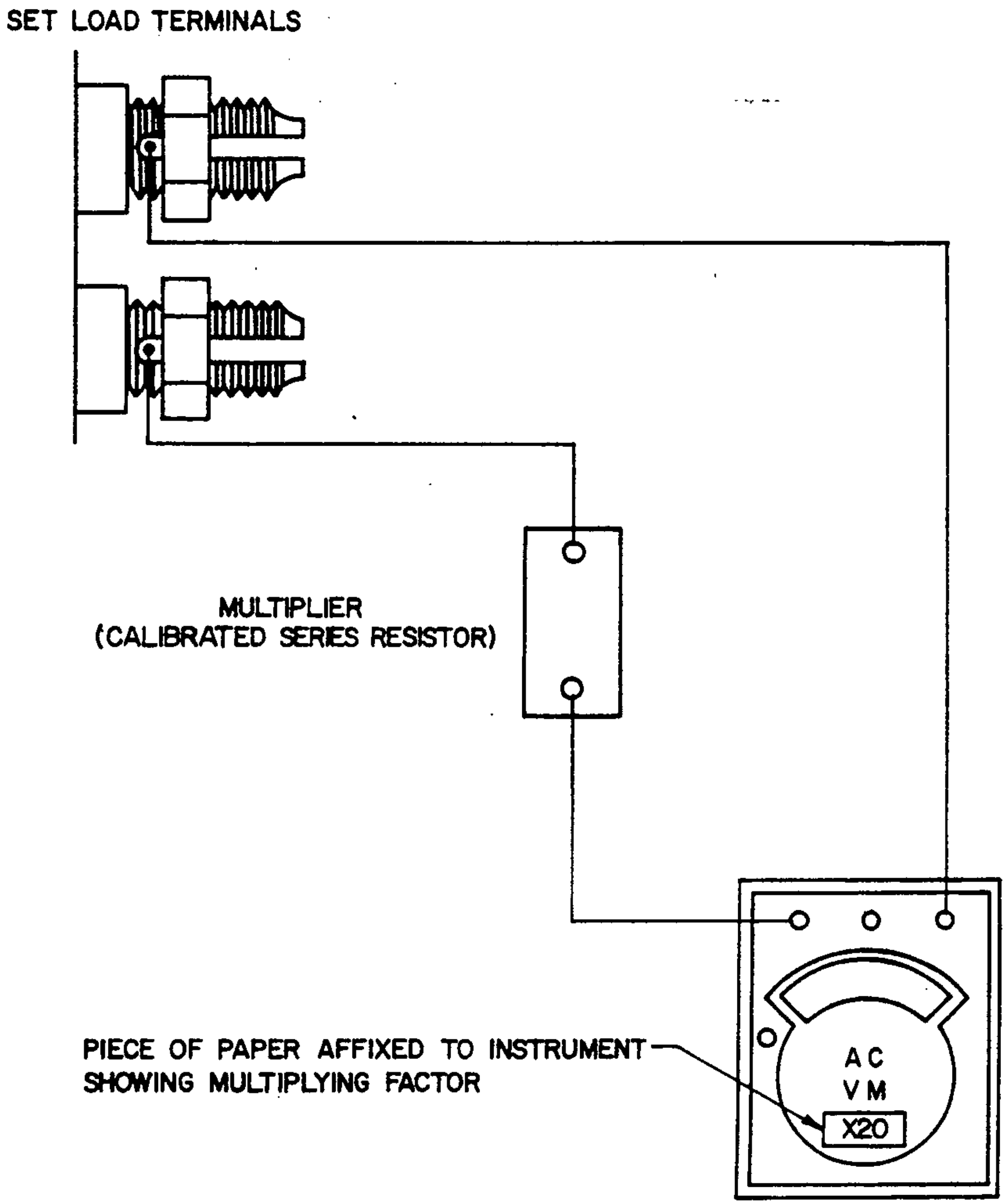


FIGURE 205.1-3. AC voltmeter with multiplier.

X-4216

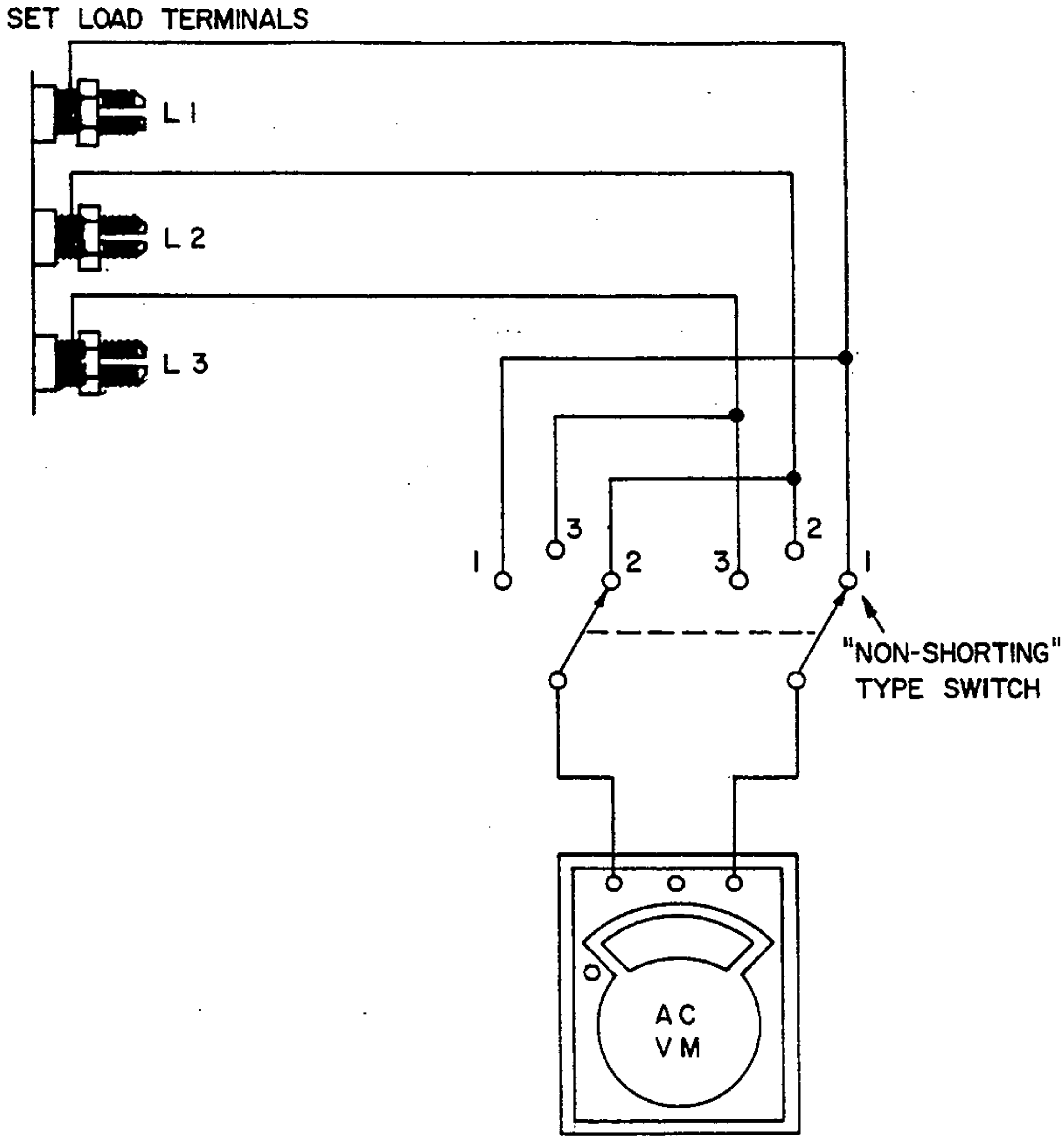


FIGURE 205.1-4. Schematic diagram of voltmeter with selector switch for line-to-line voltage measurements.

X-4217

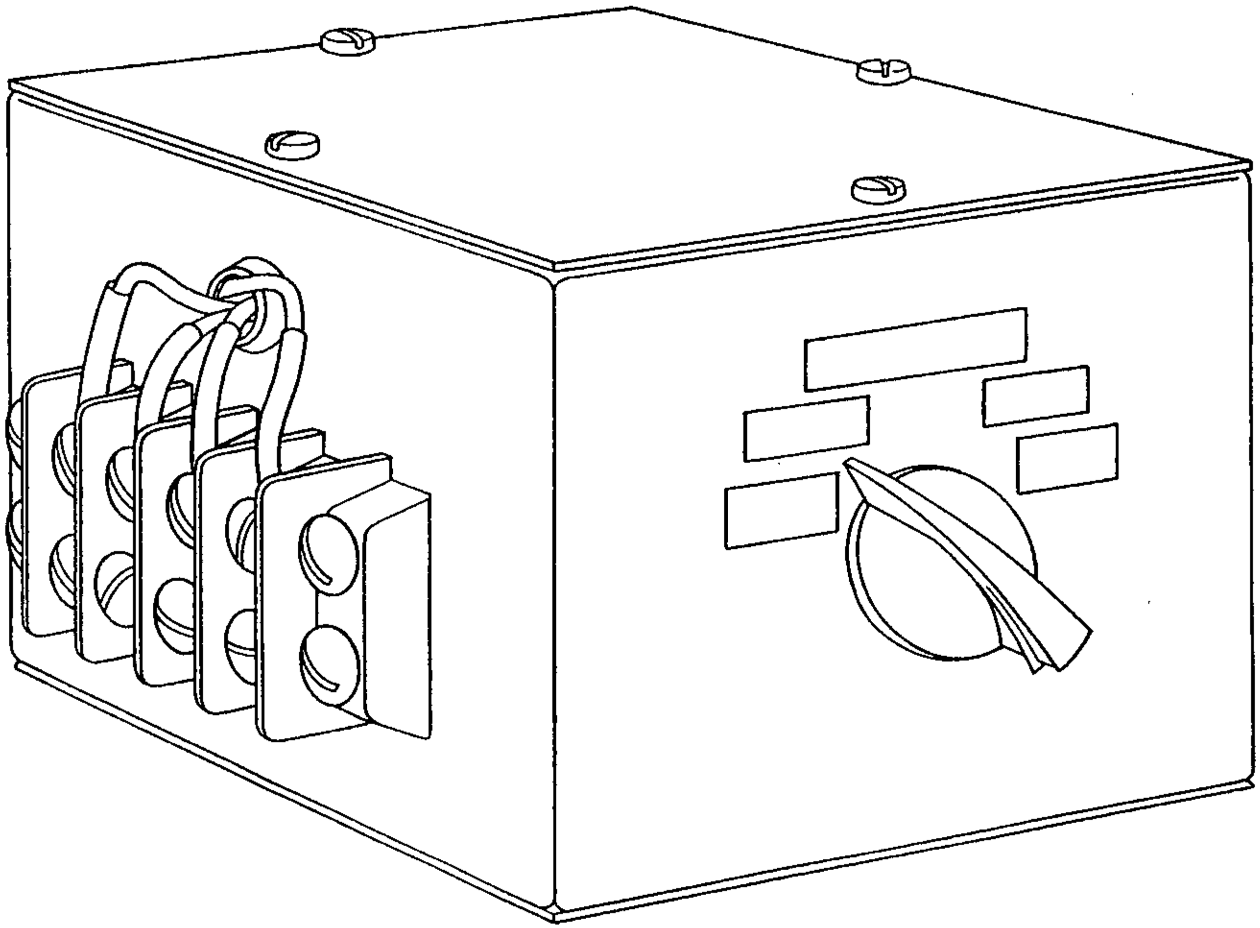


FIGURE 205.1-5. Potential selector switch.

X-4218A

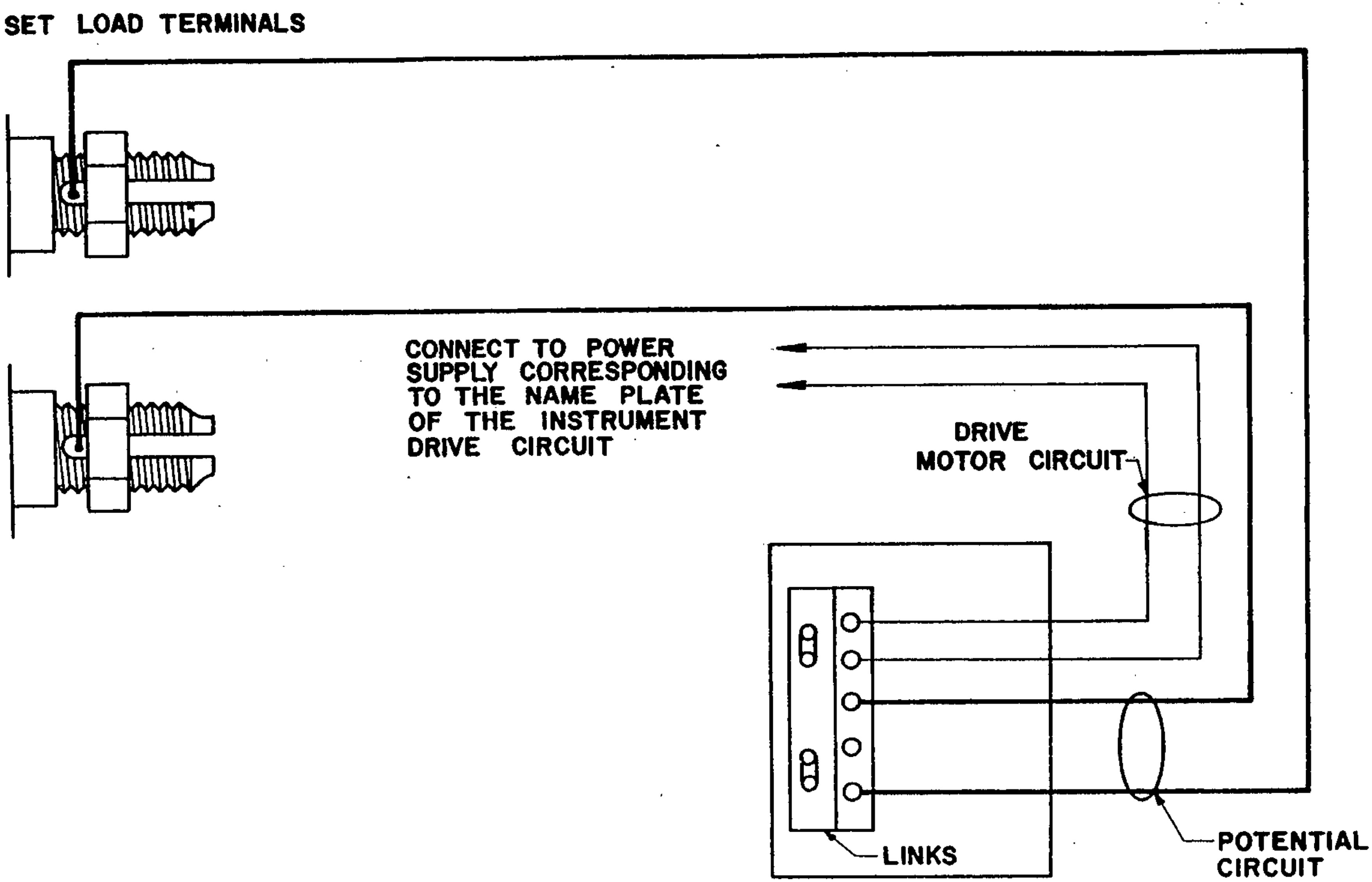


FIGURE 205.1-6. Recording instrument with electric drive.

X-4219

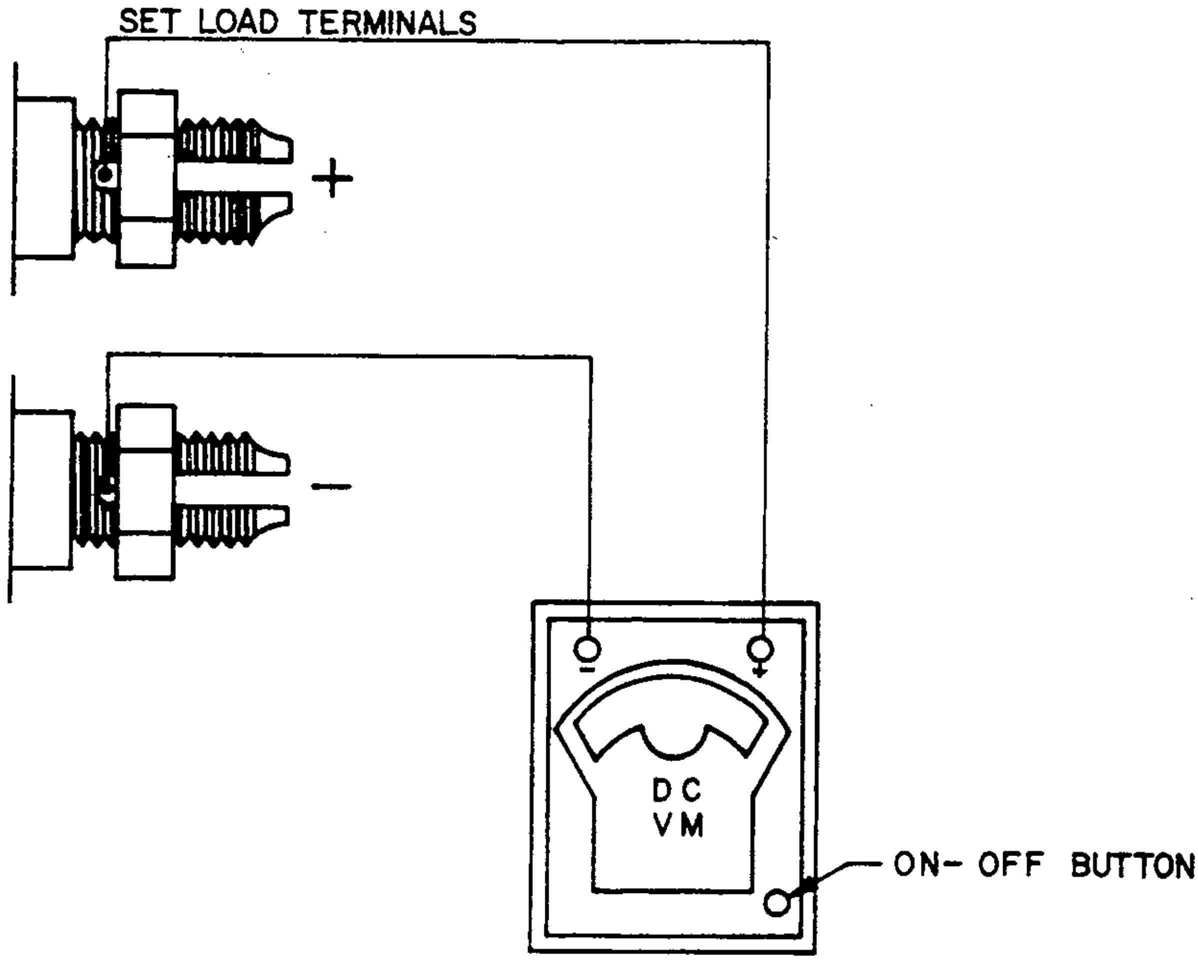


FIGURE 205.1-7. Self-contained dc voltmeter.

X-4220

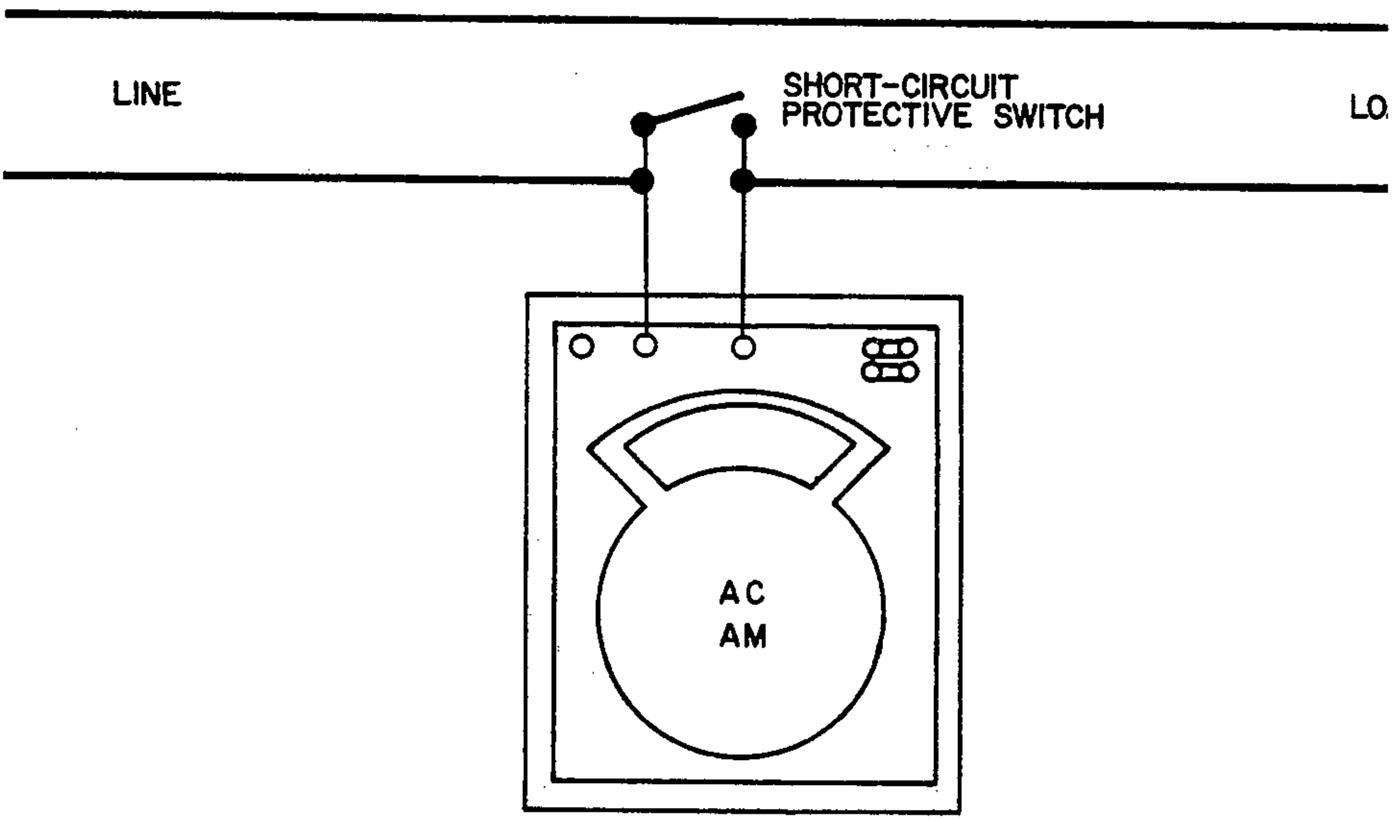


FIGURE 205.1-8. Self-contained ac ammeter with protective switch.

X-4221

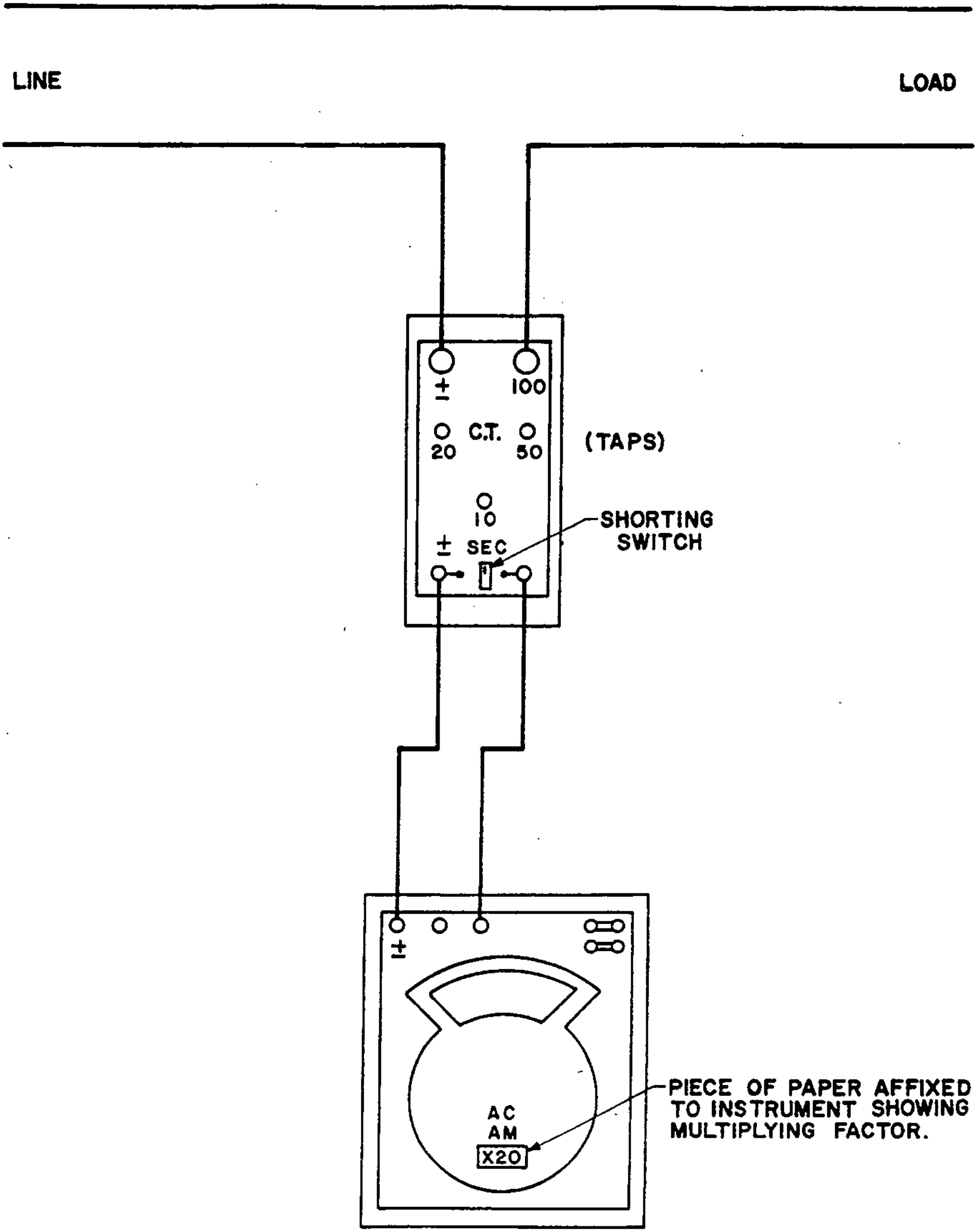


FIGURE 205.1-9. AC ammeter with current transformer using taps.

X-4222

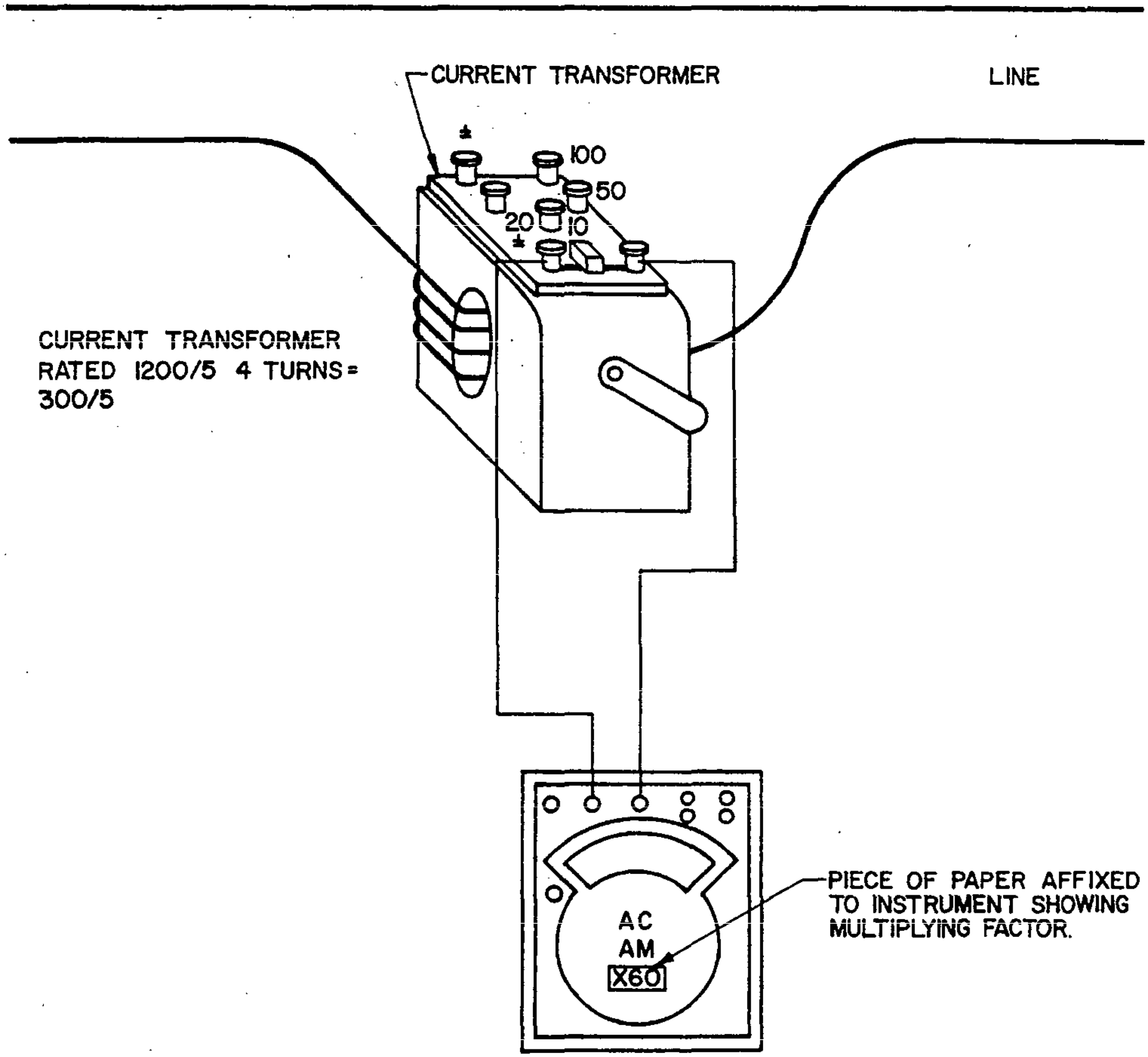


FIGURE 205.1-10. AC ammeter with current transformer using wrapped turns.

X-4223

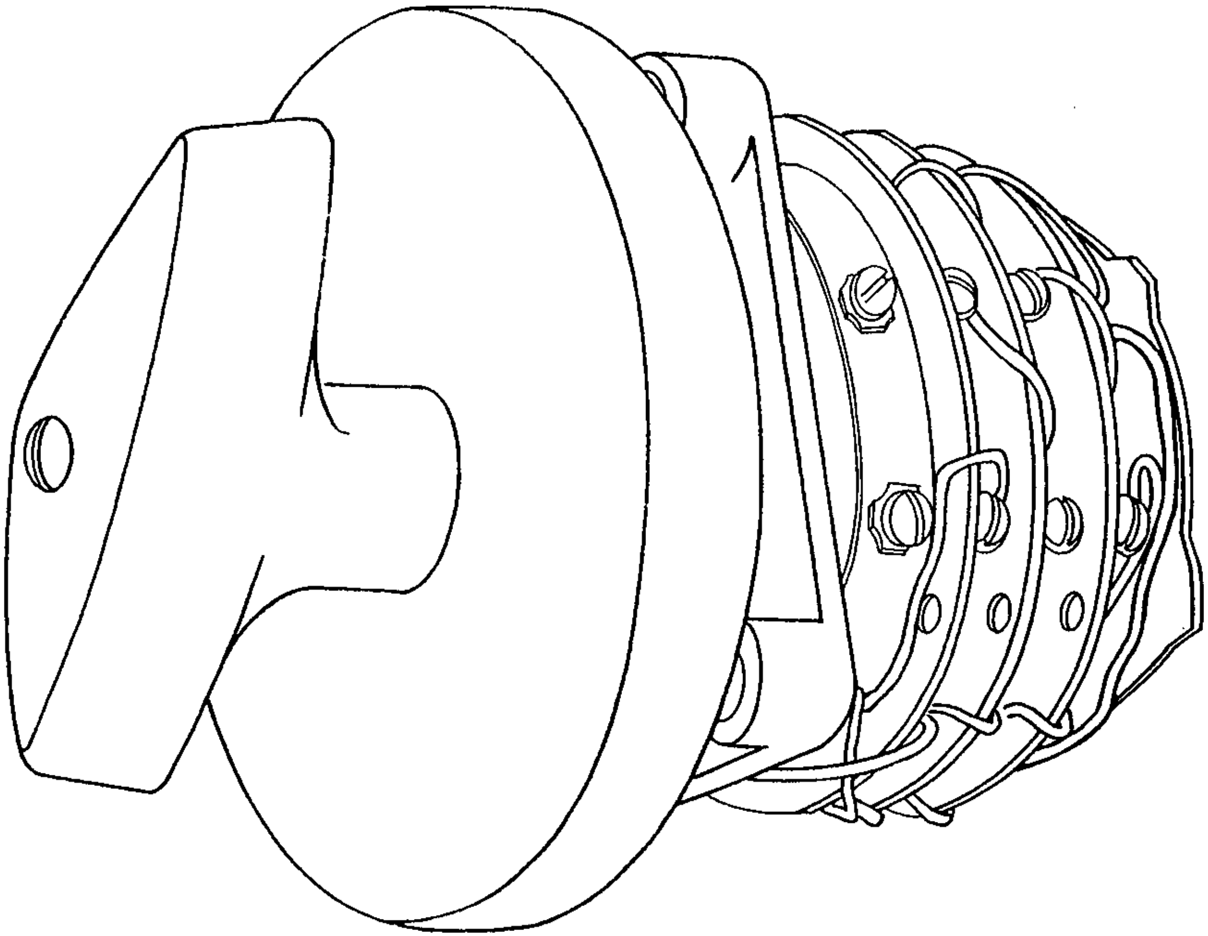


FIGURE 205.1-11. Ammeter transfer switch.

X-4224A

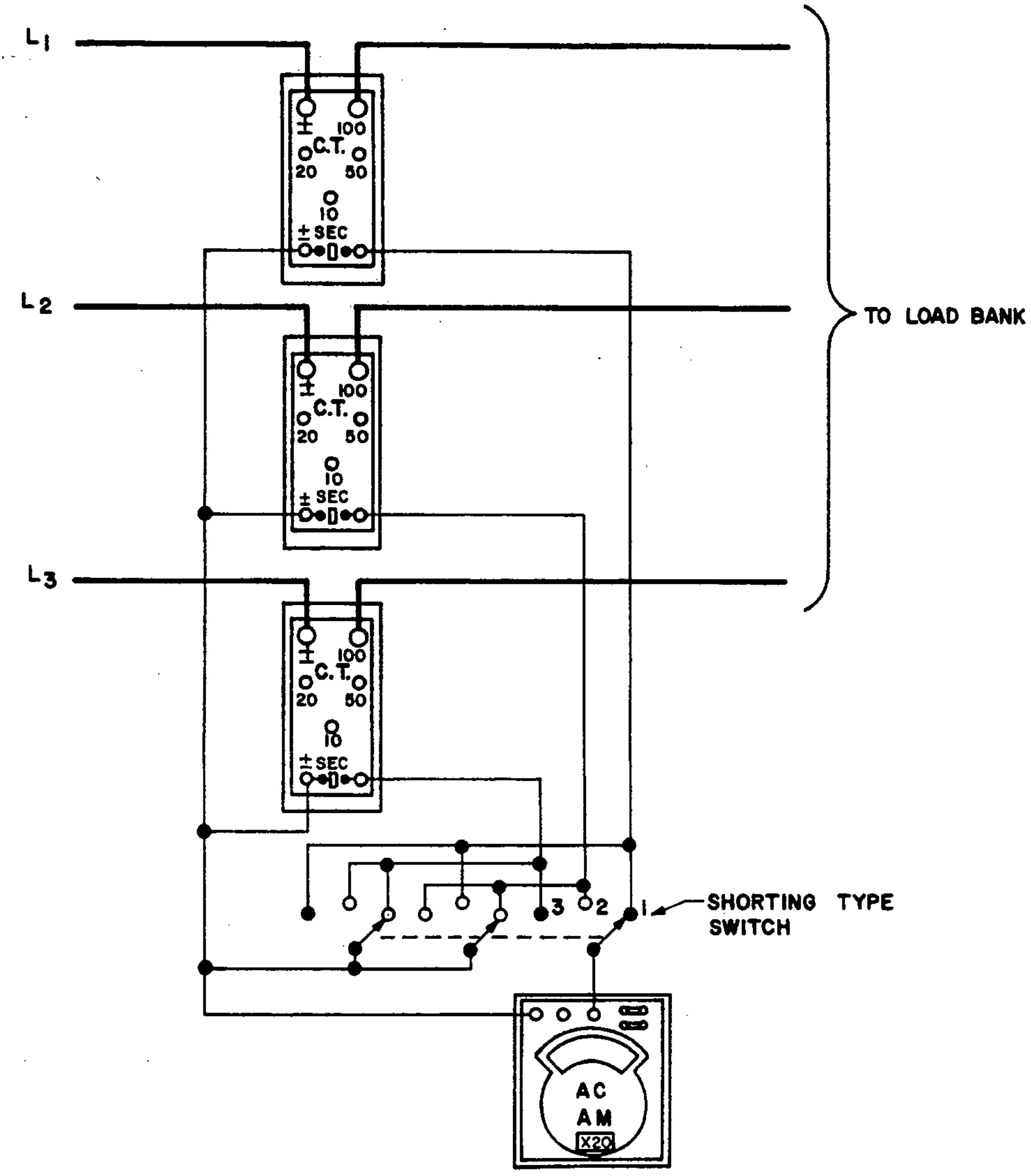


FIGURE 205.1-12. AC ammeter with current transformers and selector switch.

X-4225

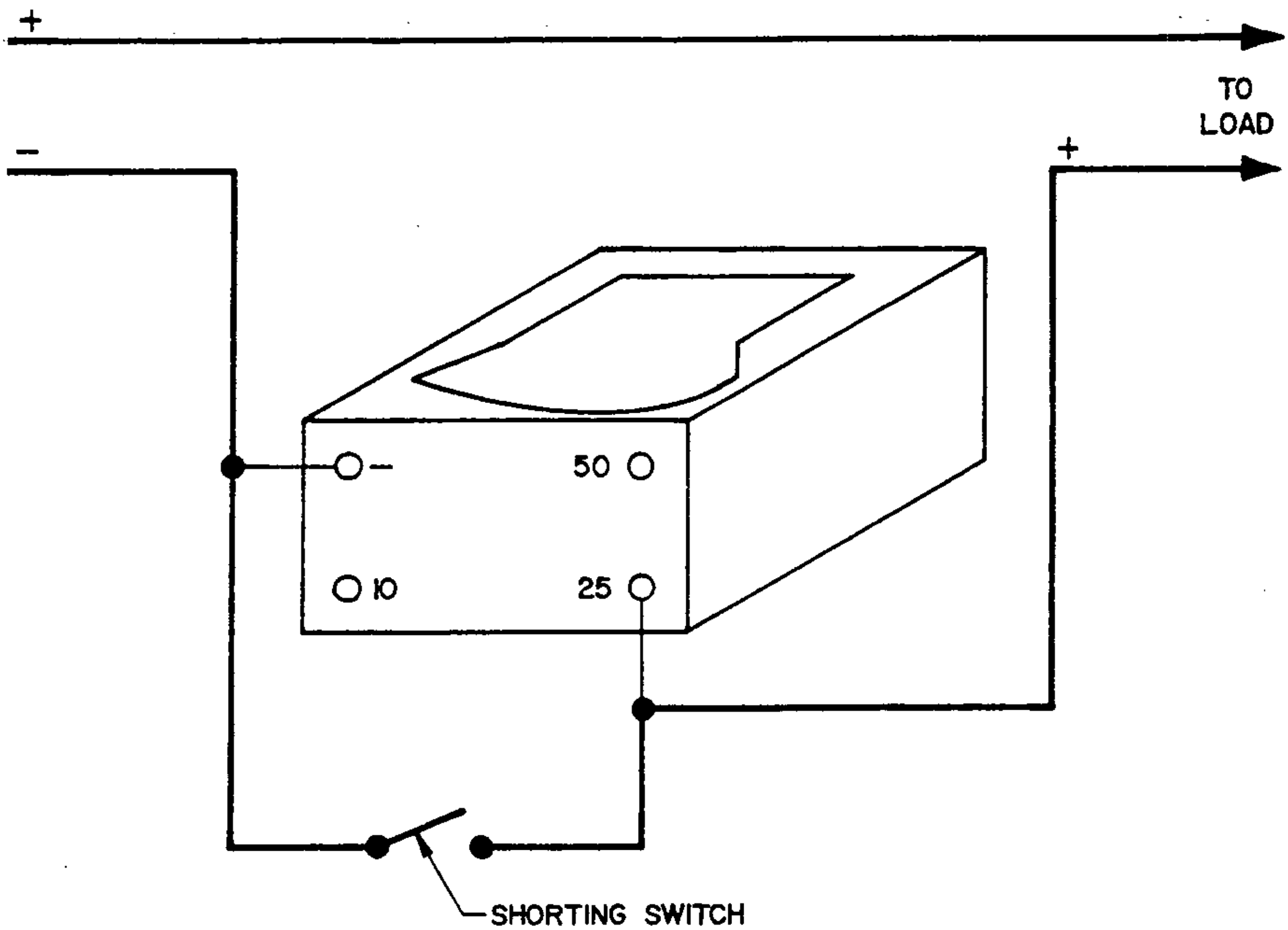


FIGURE 205.1-13. Self-contained DC ammeter.

X-4226

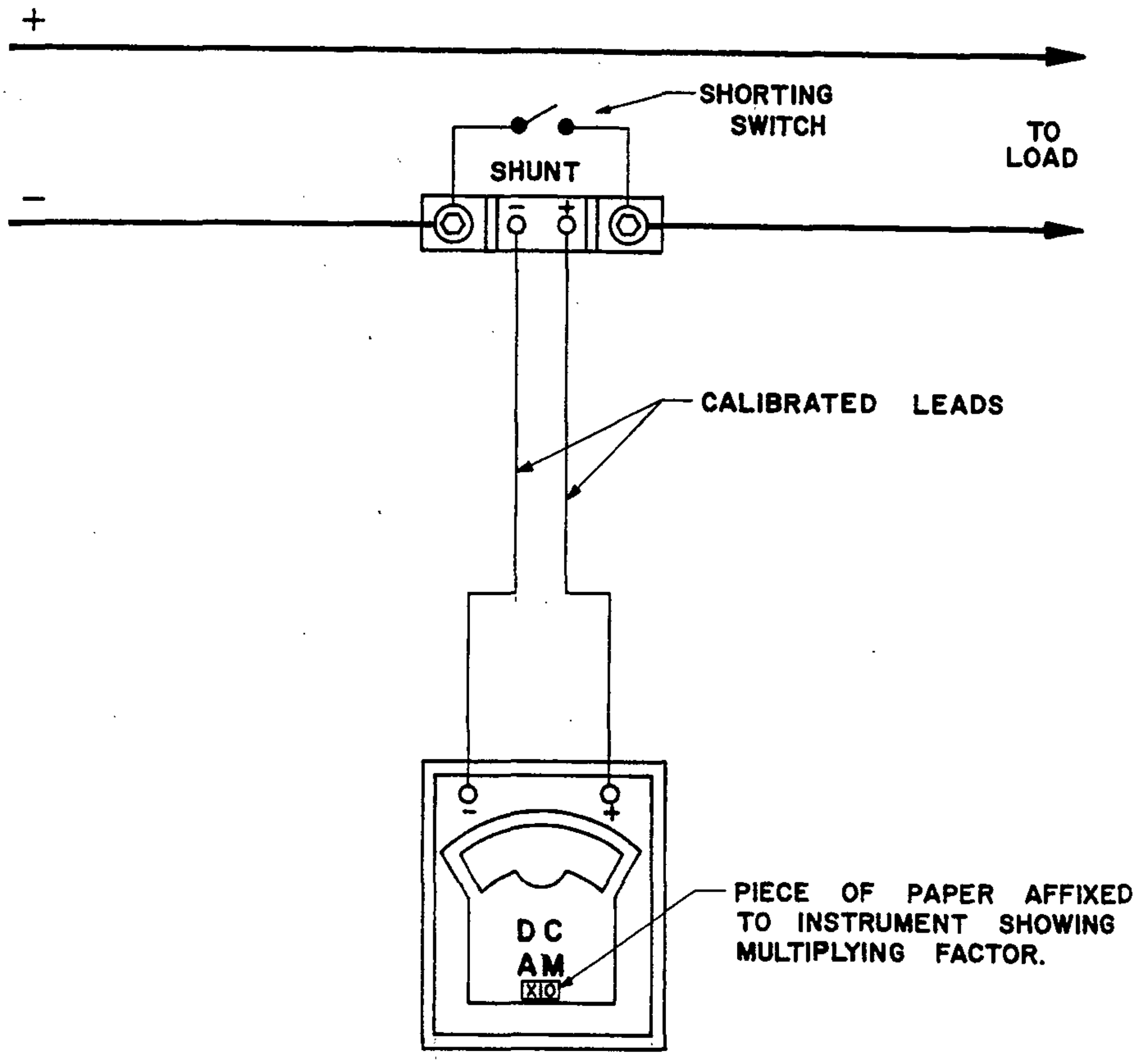


FIGURE 205.1-14. DC ammeter with shunt.

X-4227

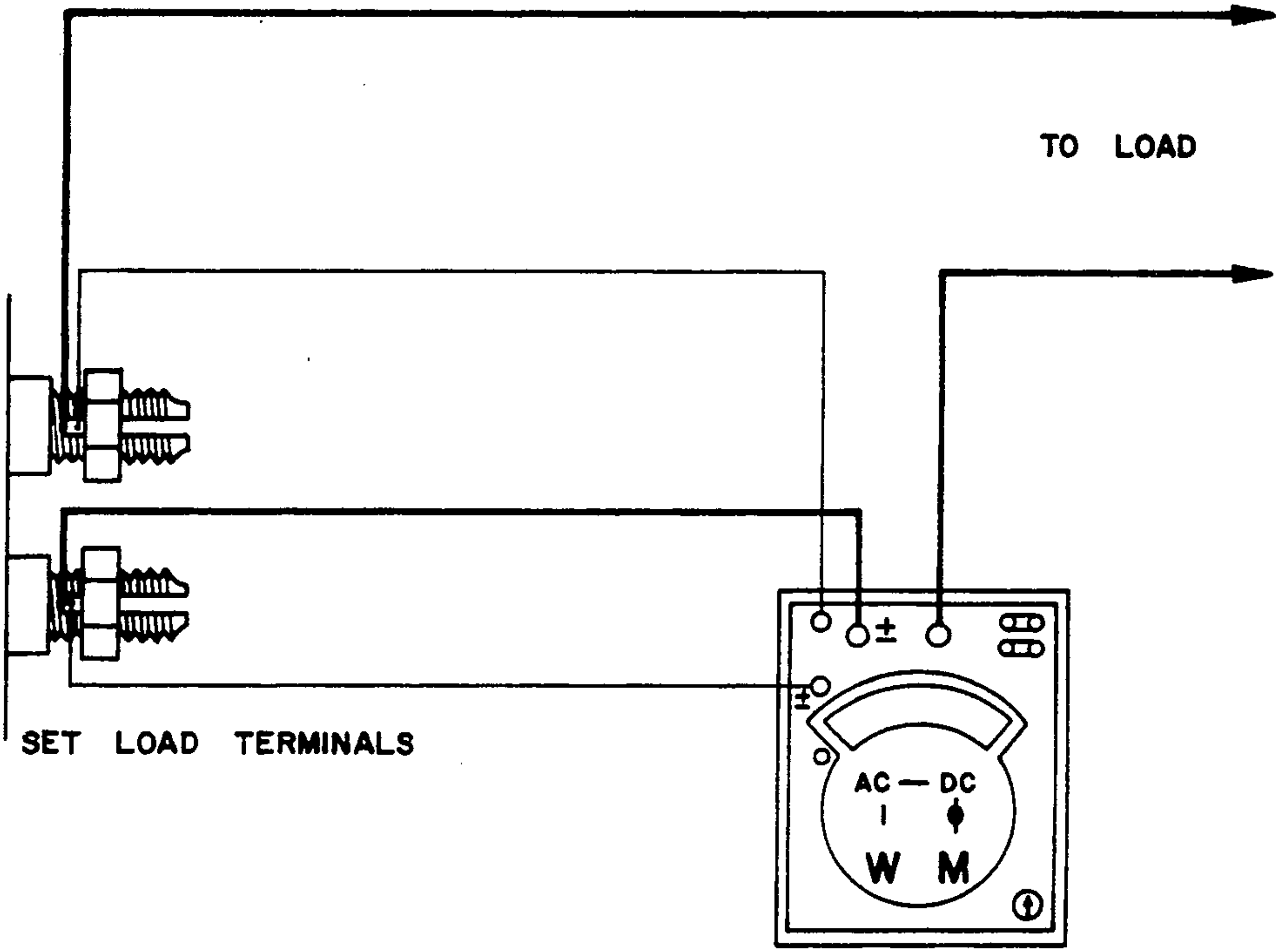


FIGURE 205.1-15. Single phase wattmeter.

X-4228

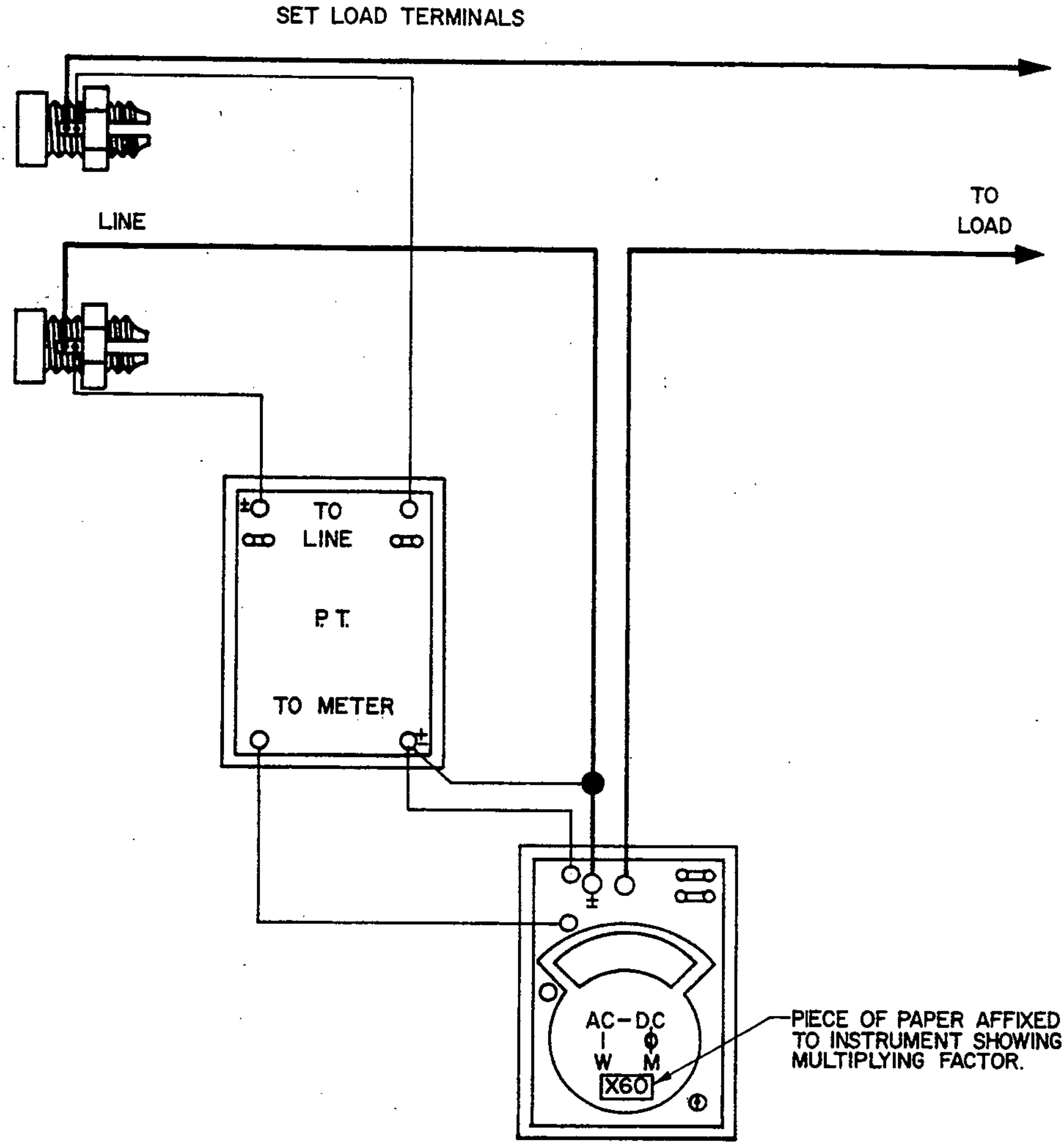


FIGURE 205.1-16. Single-phase wattmeter with potential transformer.

X-4229

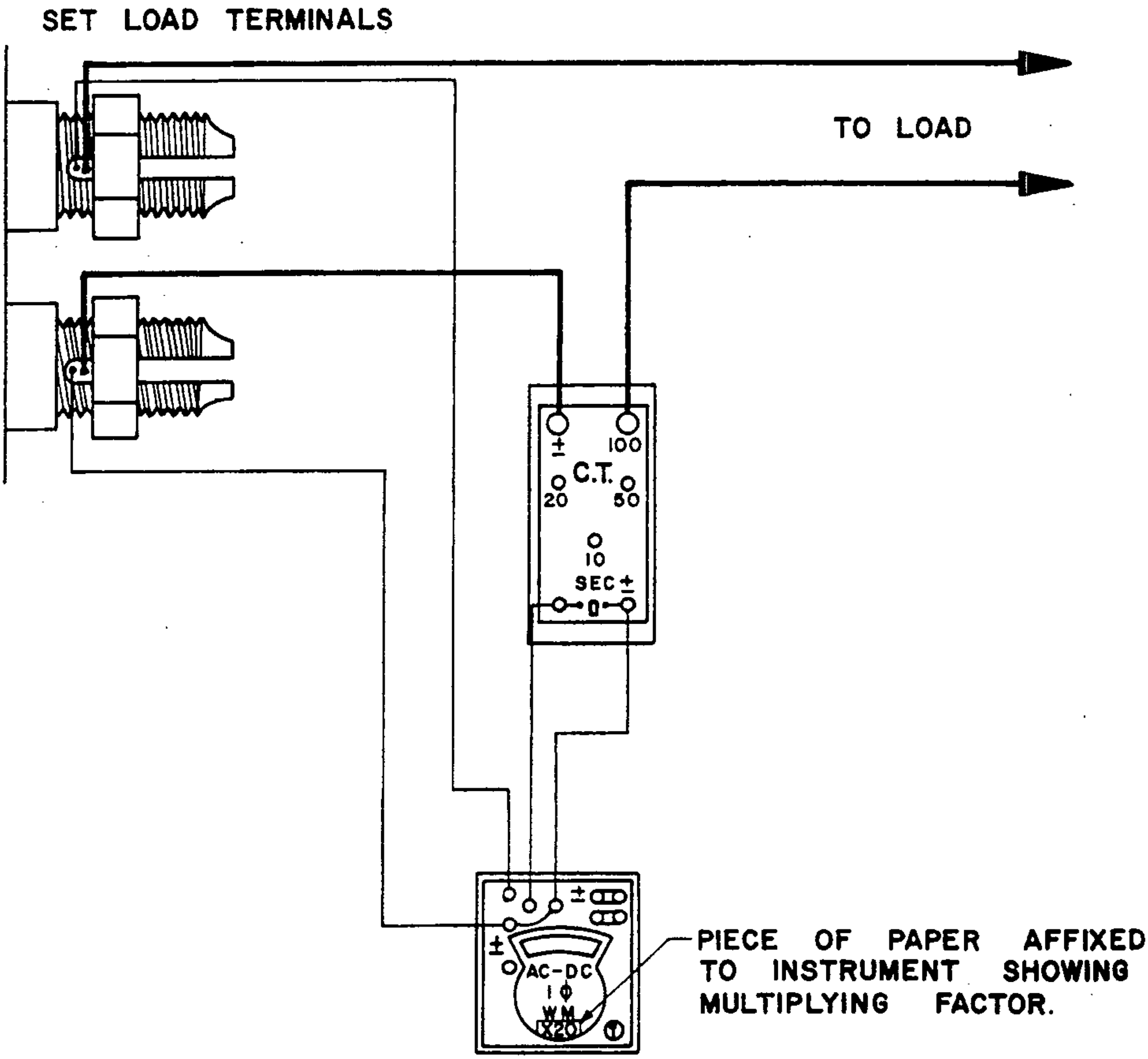


FIGURE 205.1-17. Single-phase wattmeter with current transformer.

X-4230

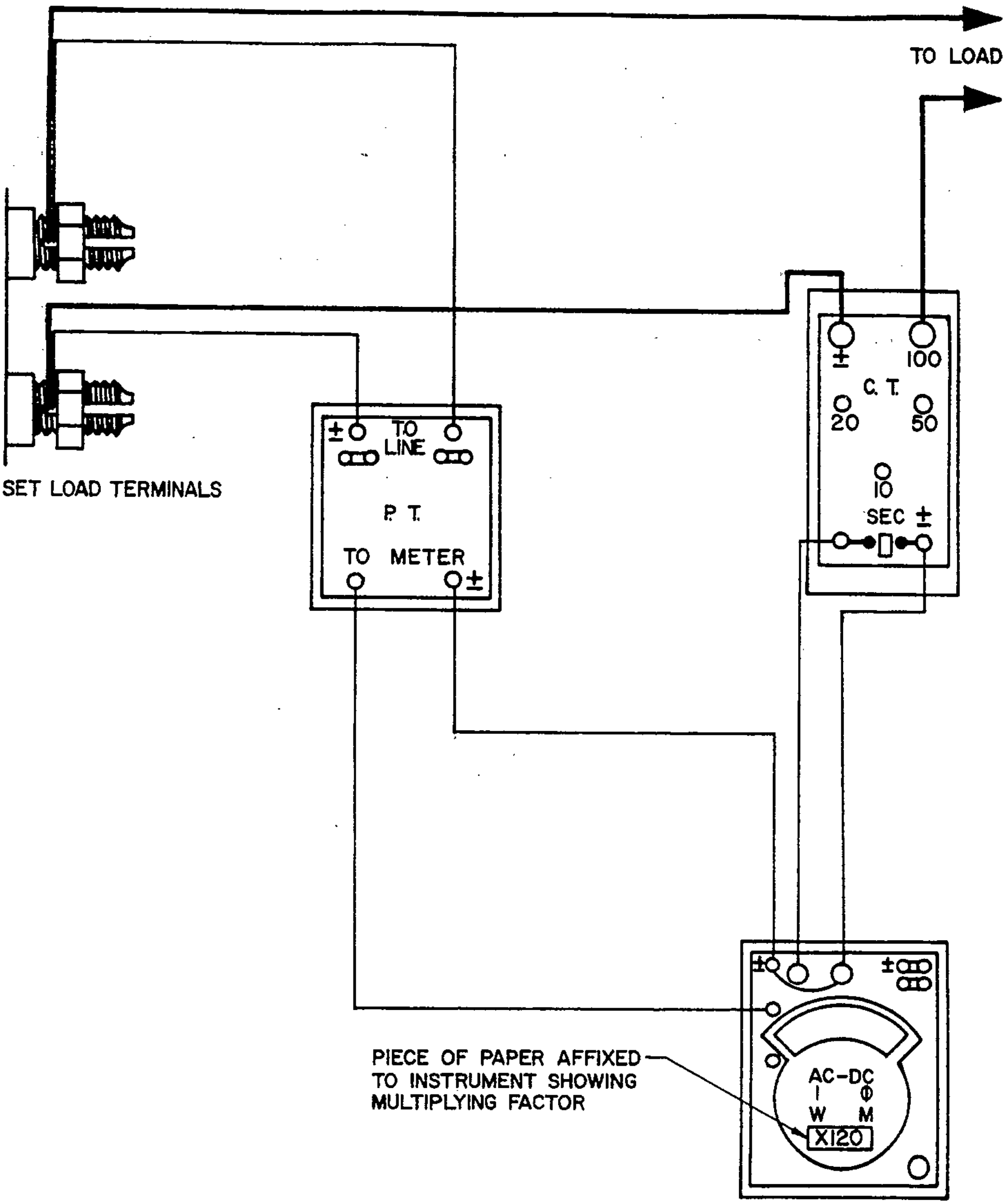


FIGURE 205.1-18. Single phase wattmeter with potential and current transformer.

X-4231

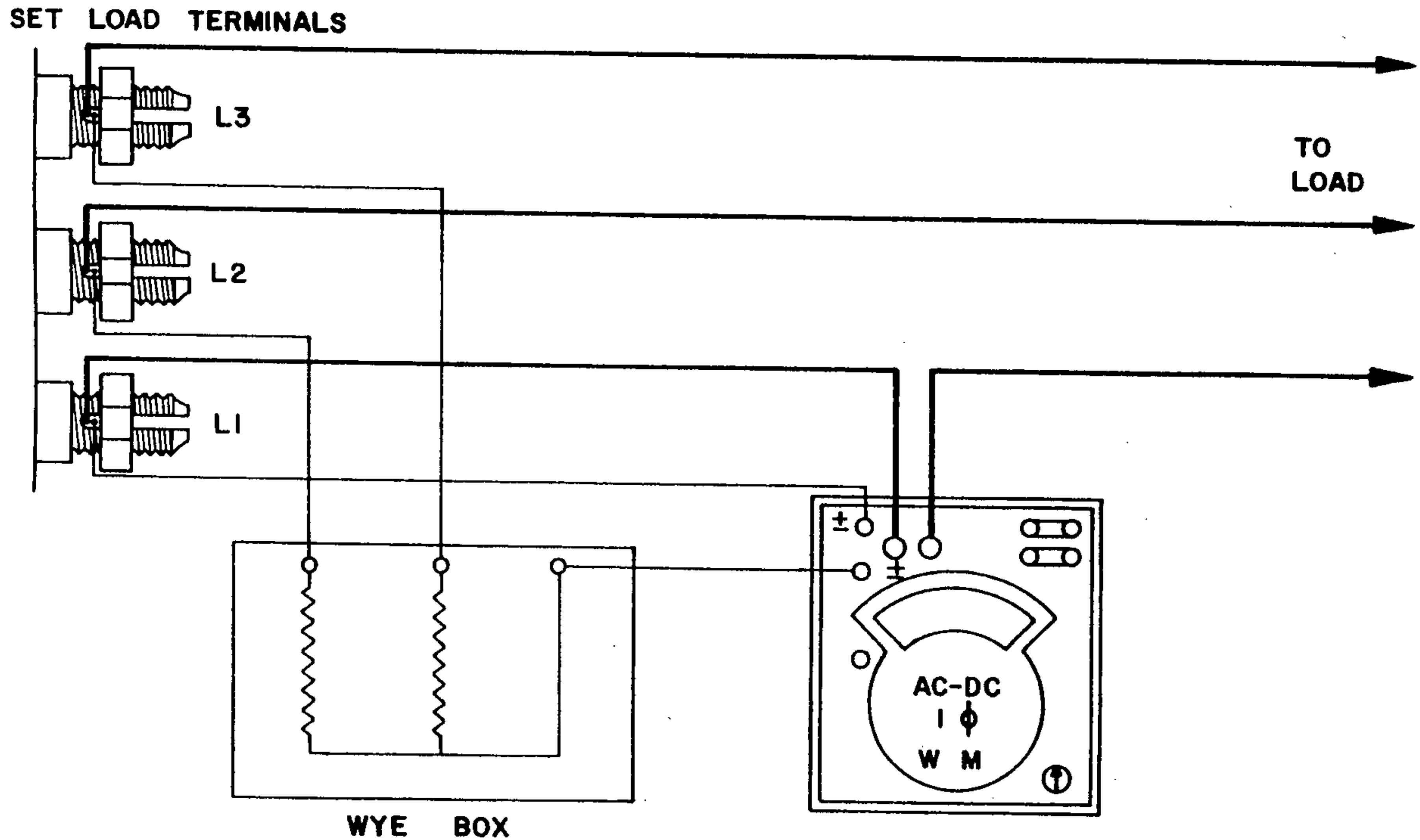


FIGURE 205.1-19. Single-phase wattmeter with wye box on three-phase, three-wire balanced system.

X-4232

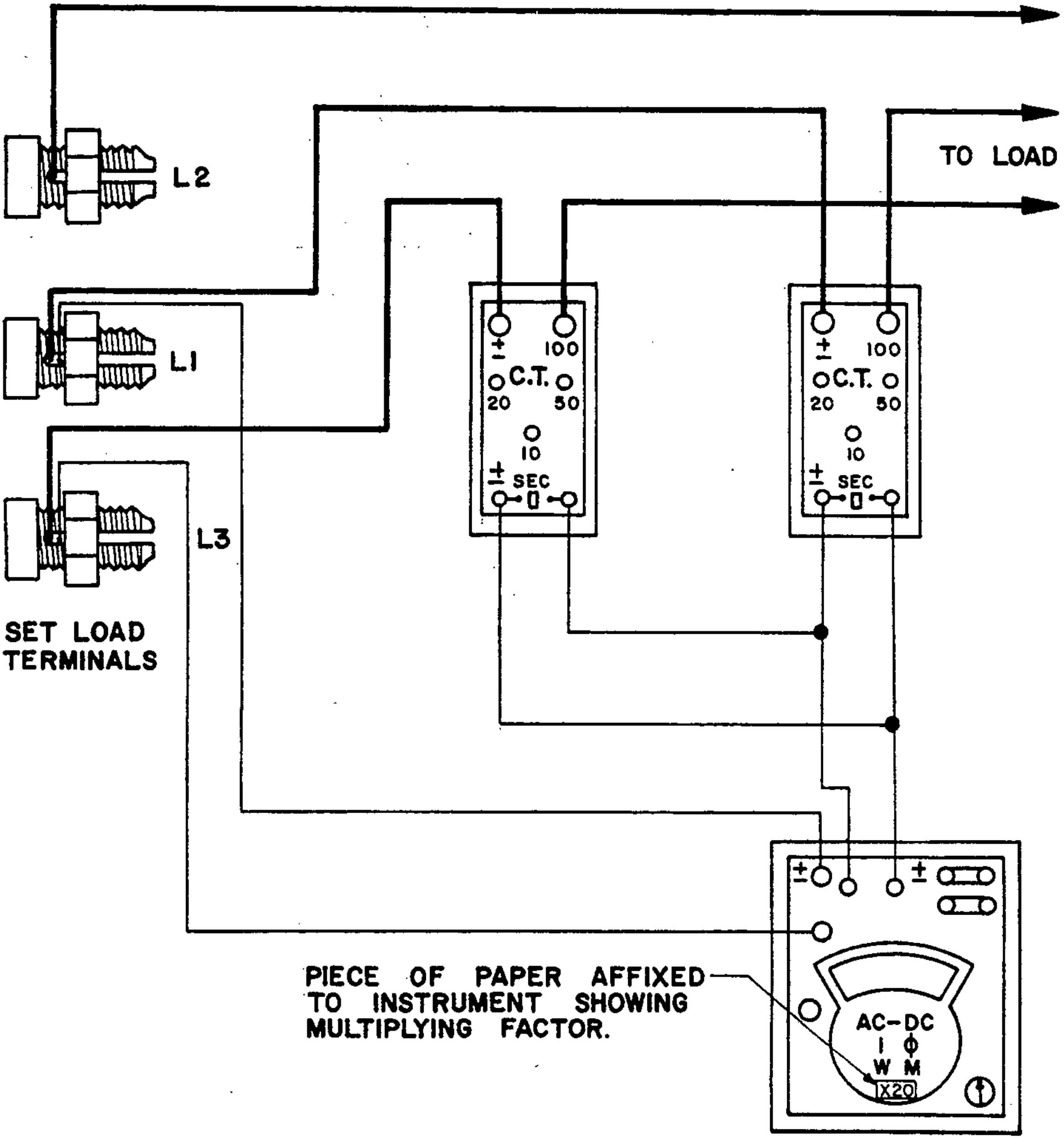


FIGURE 205.1-20. Single-phase wattmeter on three-phase, three-wire balanced system using two current transformers.

X-4233

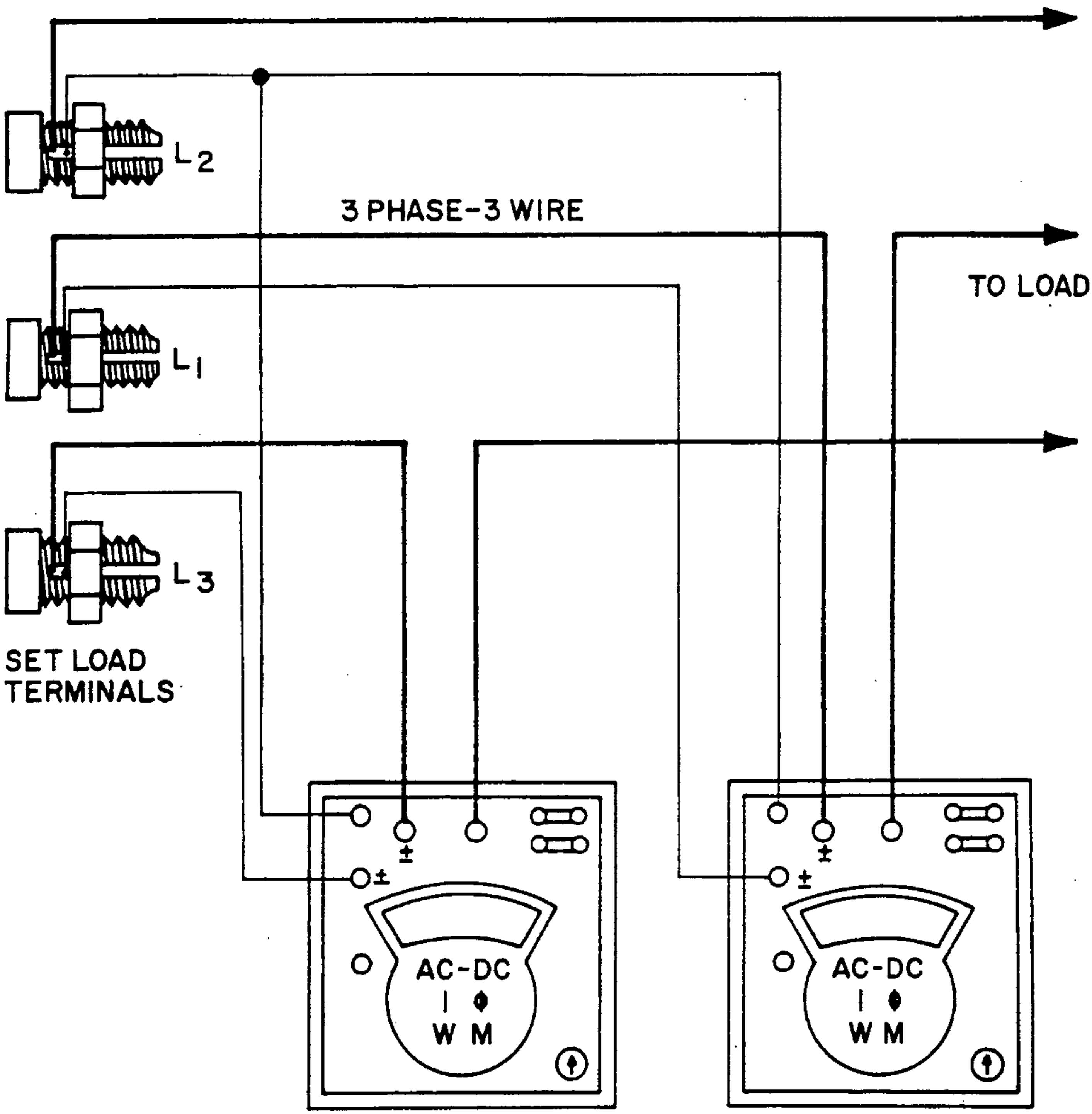


FIGURE 205.1-21. Two single-phase wattmeters on three-phase, three-wire system.

X-4234

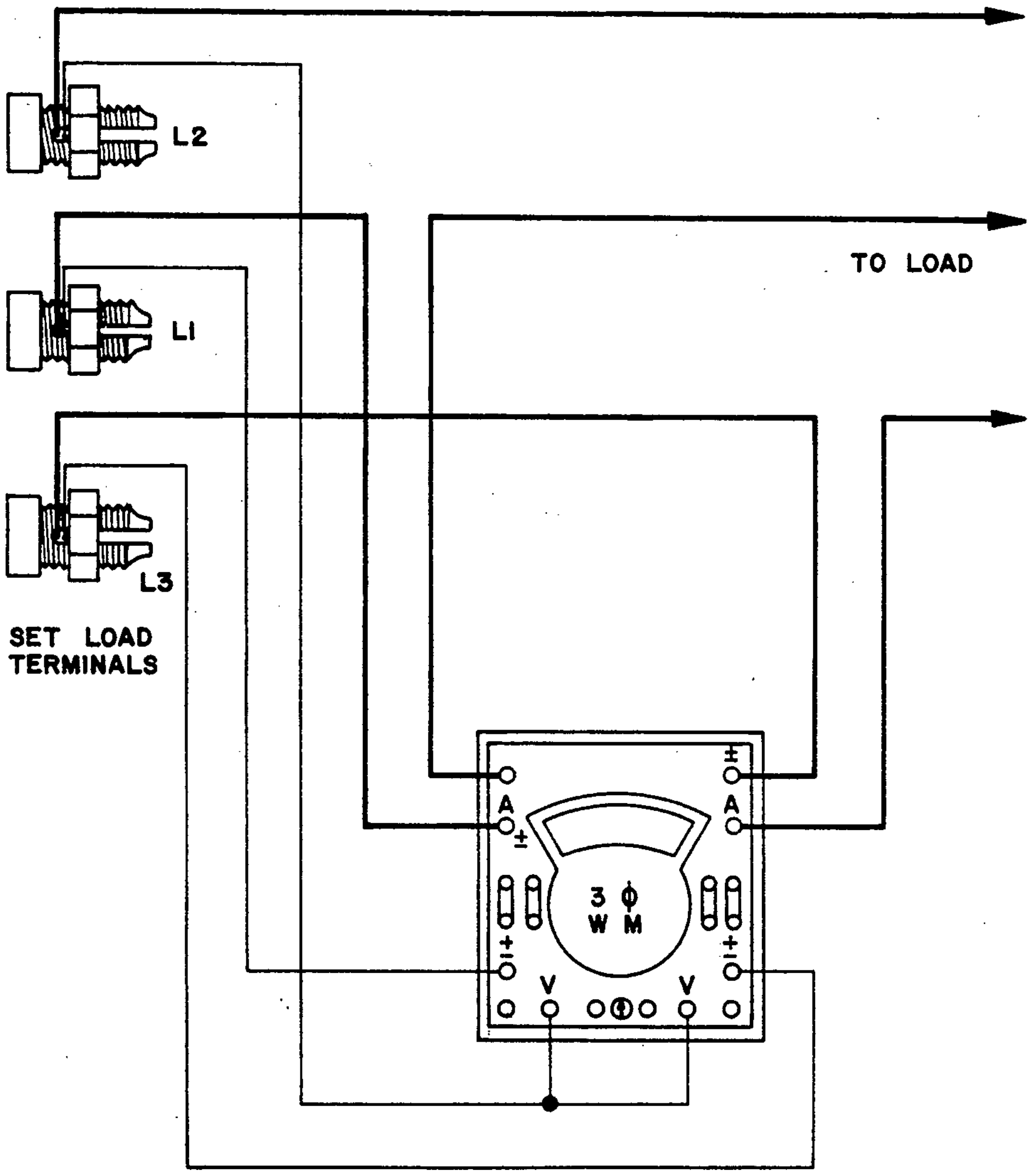


FIGURE 205.1-22. Two-element, polyphase wattmeter on three-phase, three-wire system.

X-4235

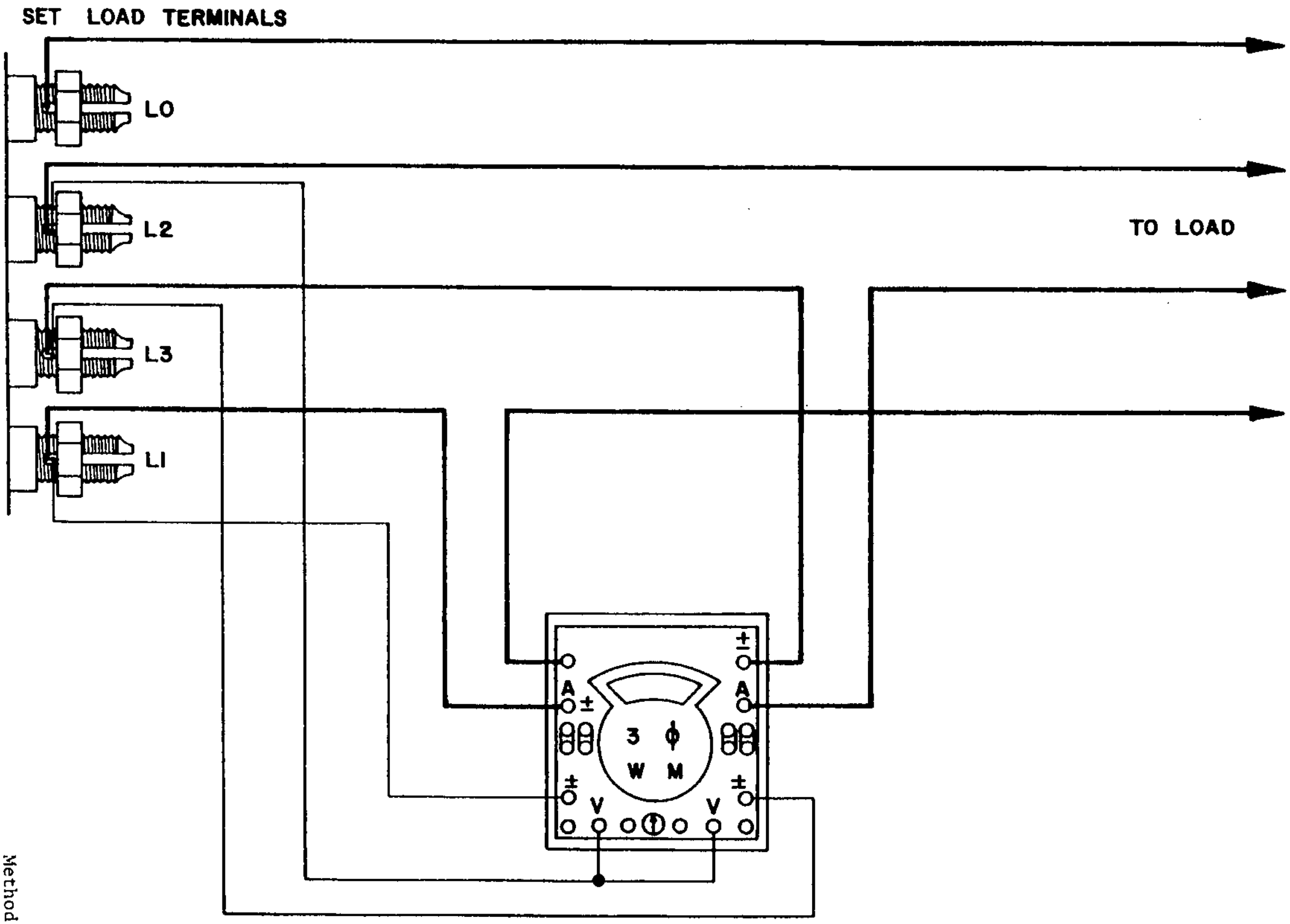


FIGURE 205.1-23. Two-element, polyphase wattmeter on balanced three-phase, four-wire system.

X-4236

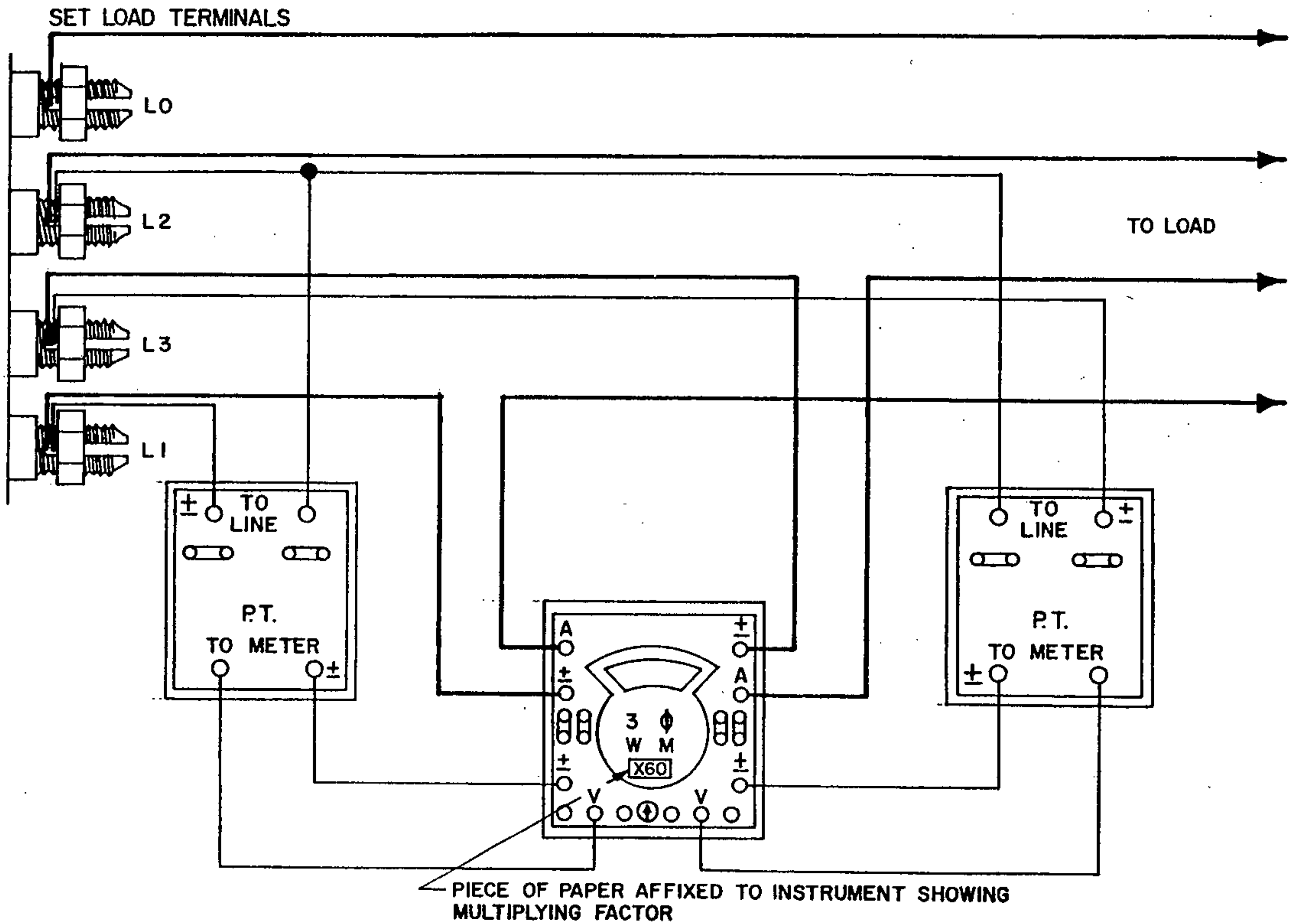


FIGURE 205.1-24. Two element, polyphase wattmeter with potential transformers on balanced three-phase, four-wire system.

X-4237

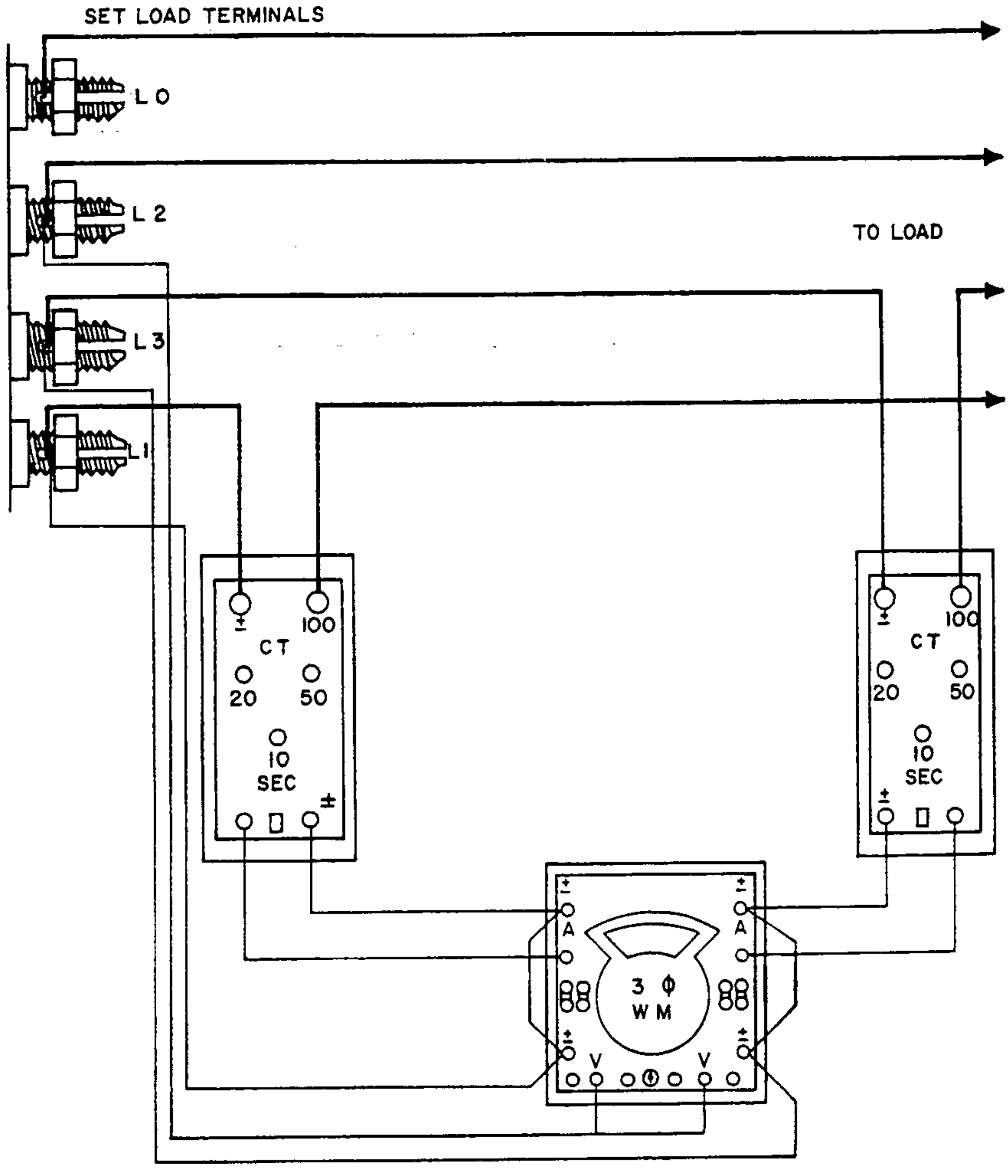


FIGURE 205.1-25. Two-element, polyphase wattmeter with current transformers on balanced three-phase, four-wire system.

X-4238

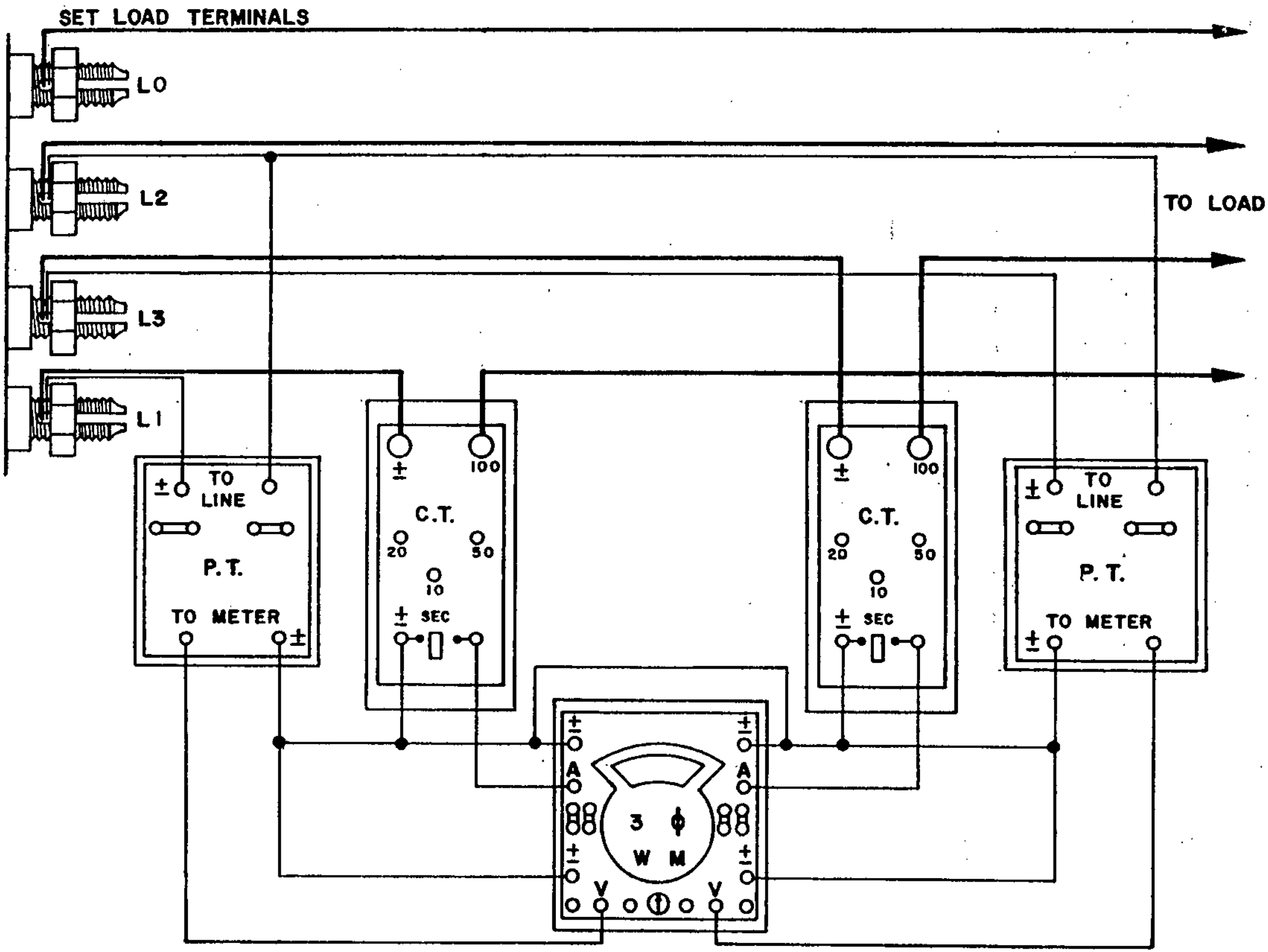


FIGURE 205.1-26. Two-element, polyphase wattmeter with both current and potential transformers on balanced three-phase, four-wire system

X-4239

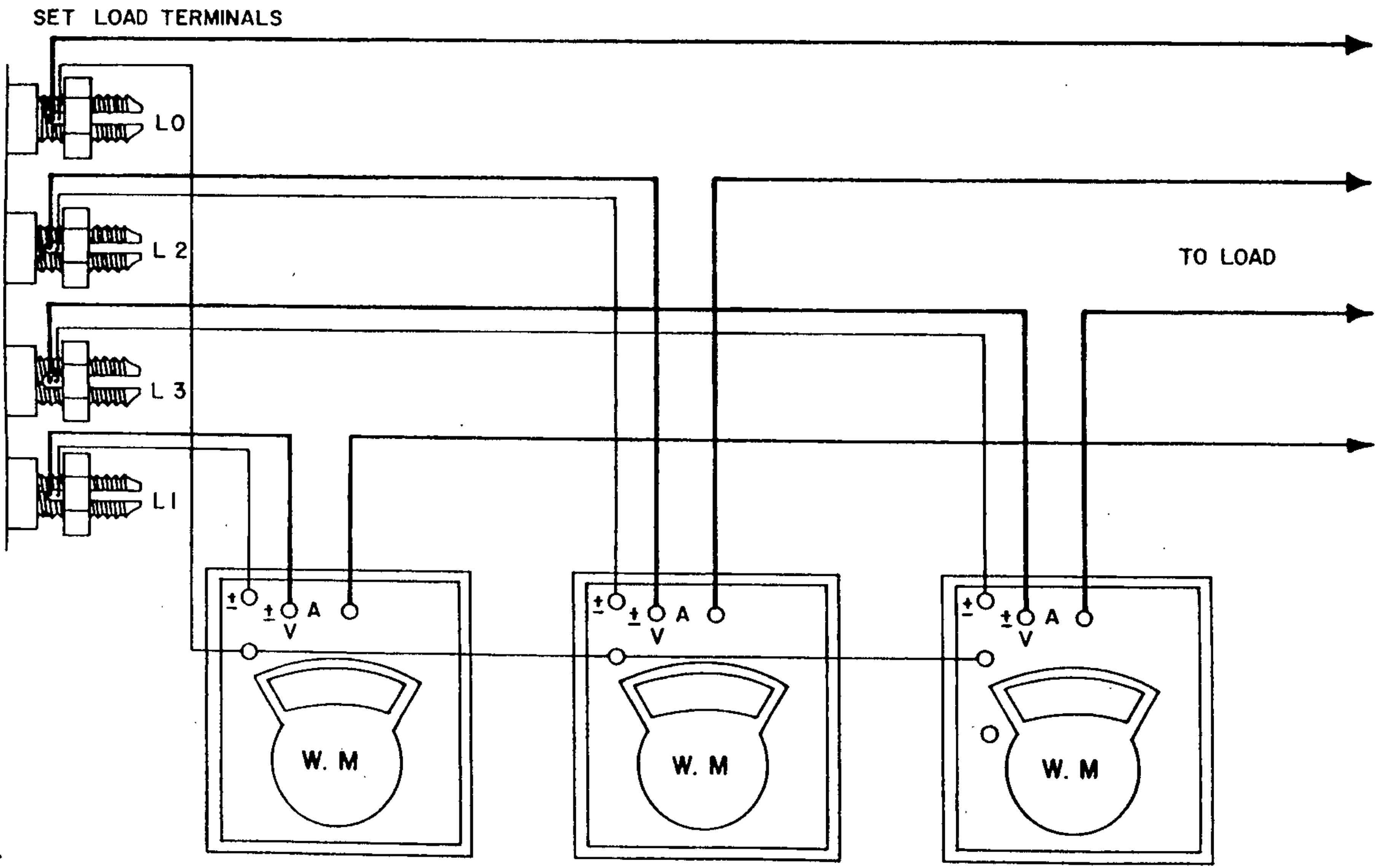


FIGURE 205.1-27. Three wattmeters used on unbalanced three-phase, four-wire system.

X-4240

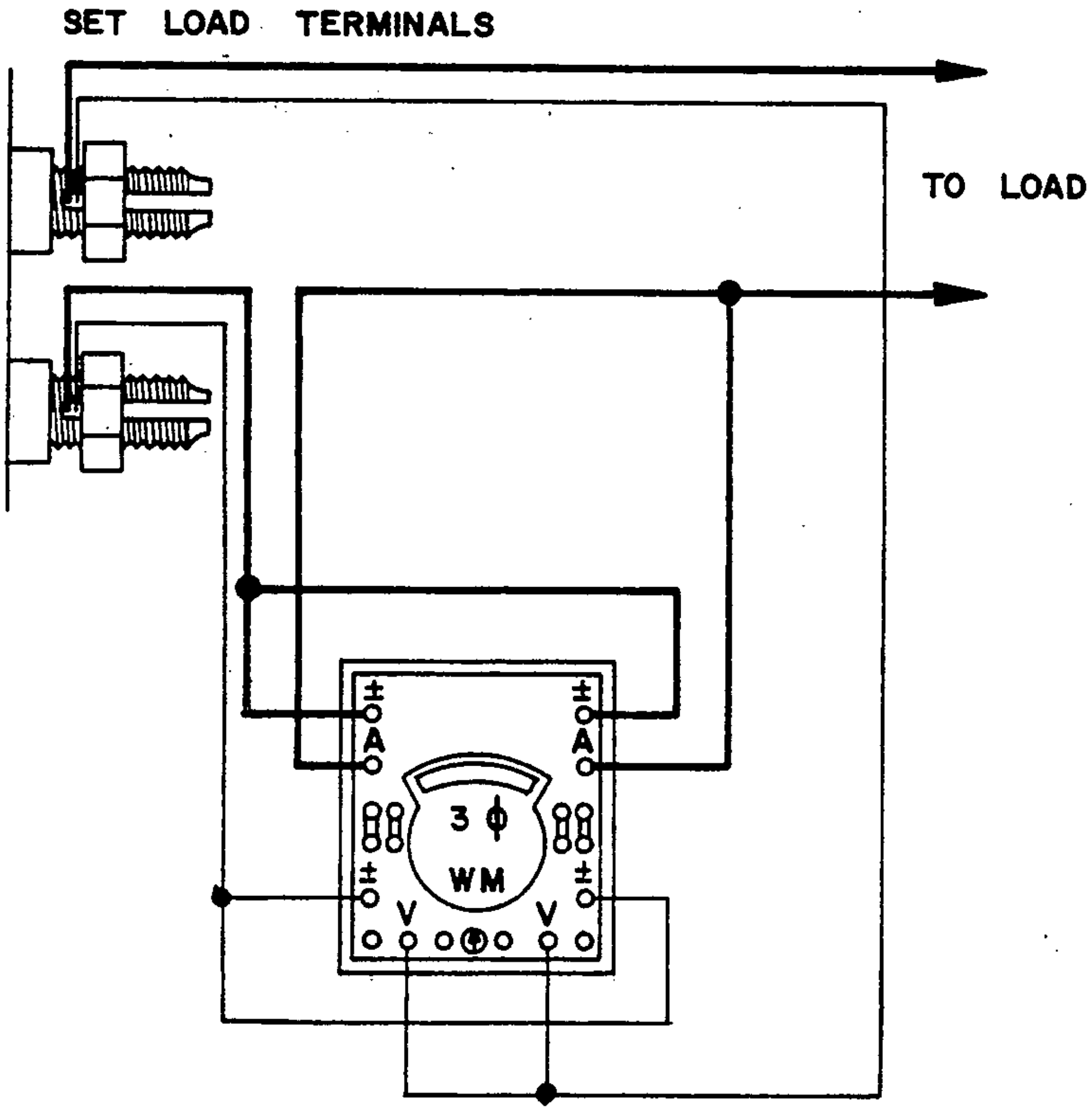


FIGURE 205.1-28. Polyphase wattmeter used on single-phase system.

X-4241

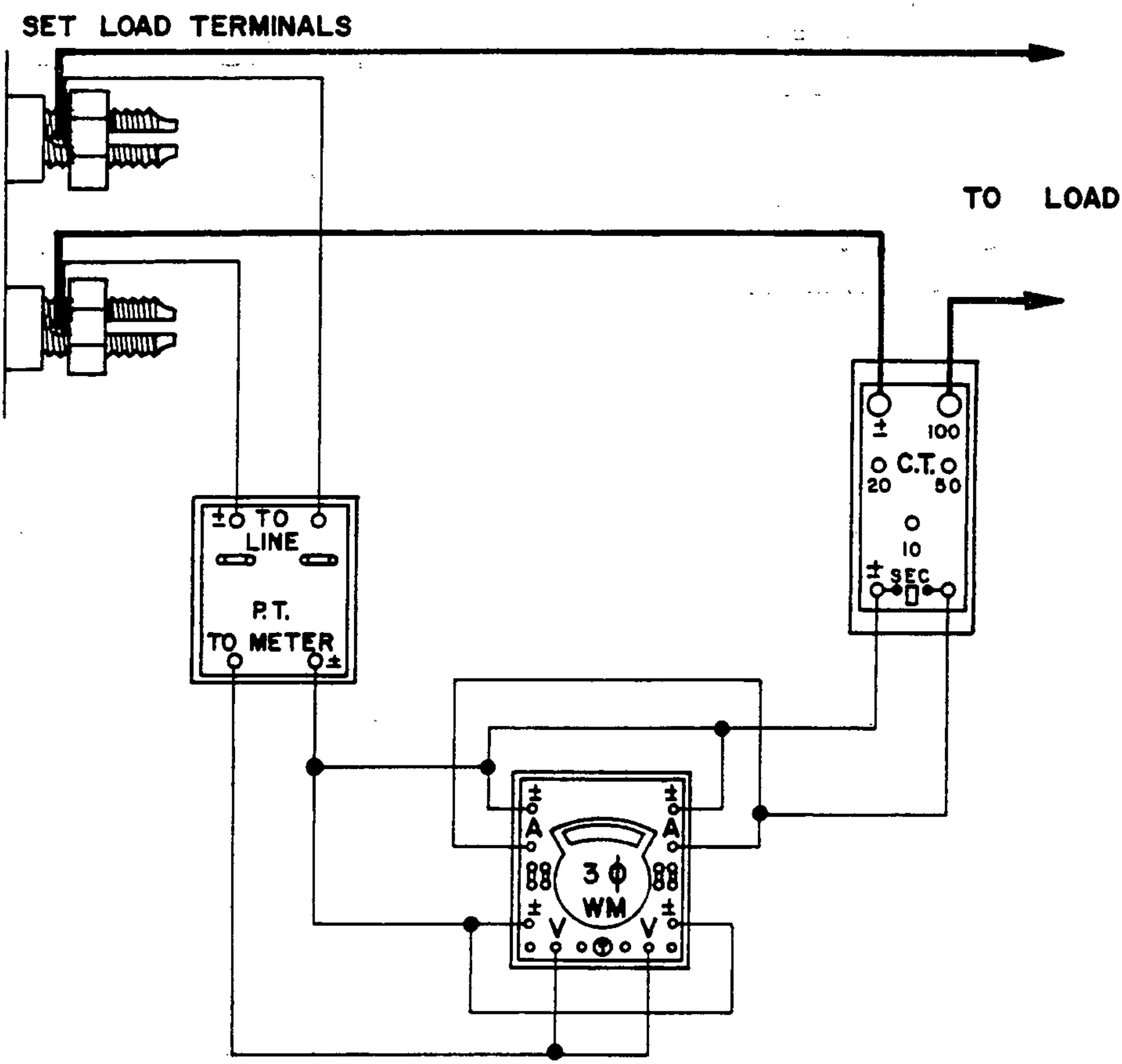


FIGURE 205.1-29. Polyphase wattmeter with current and potential transformers used as a single-phase instrument.

X-4242

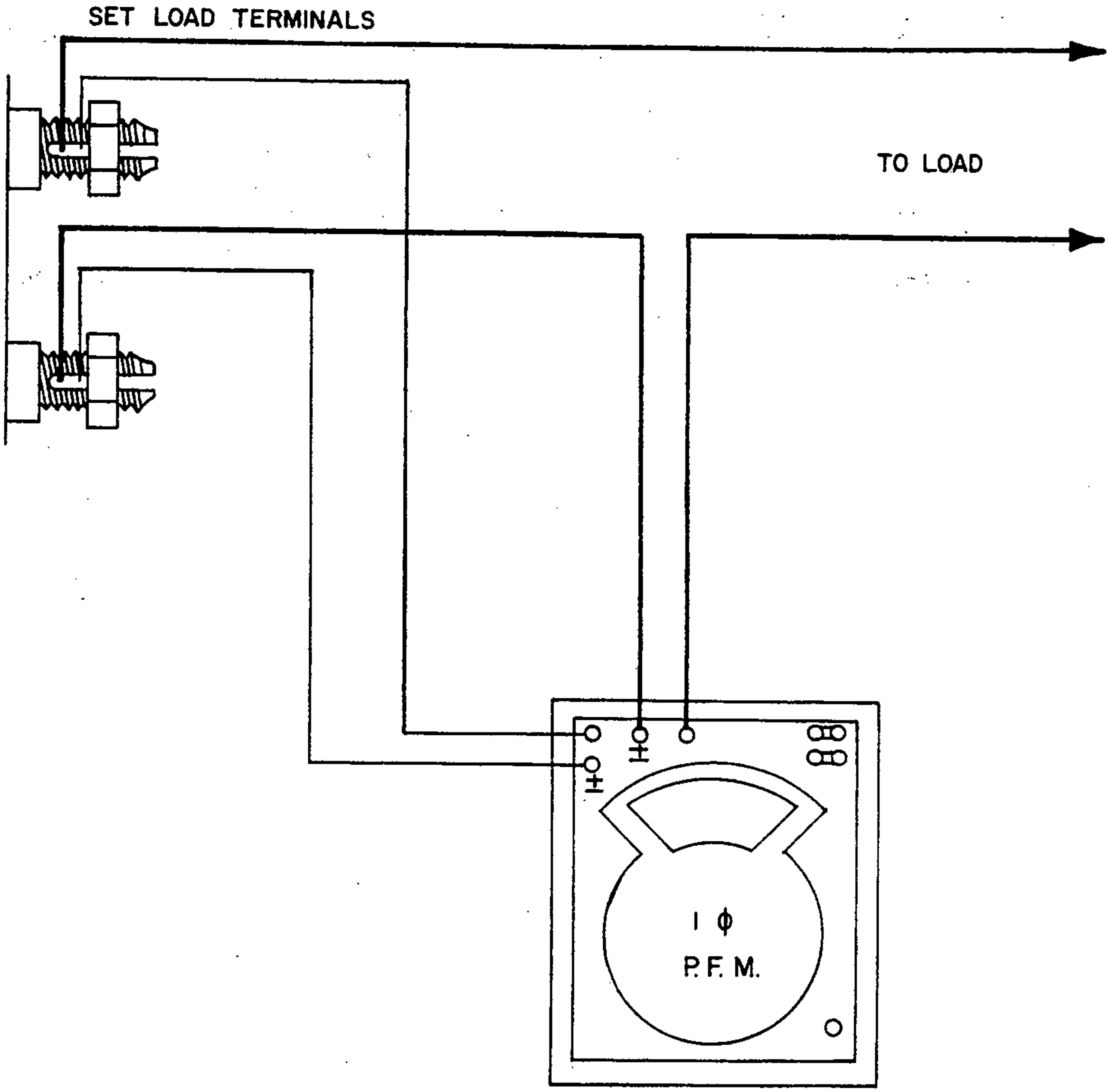


FIGURE 205.1-30. Single-phase power factor meter.

X-4243

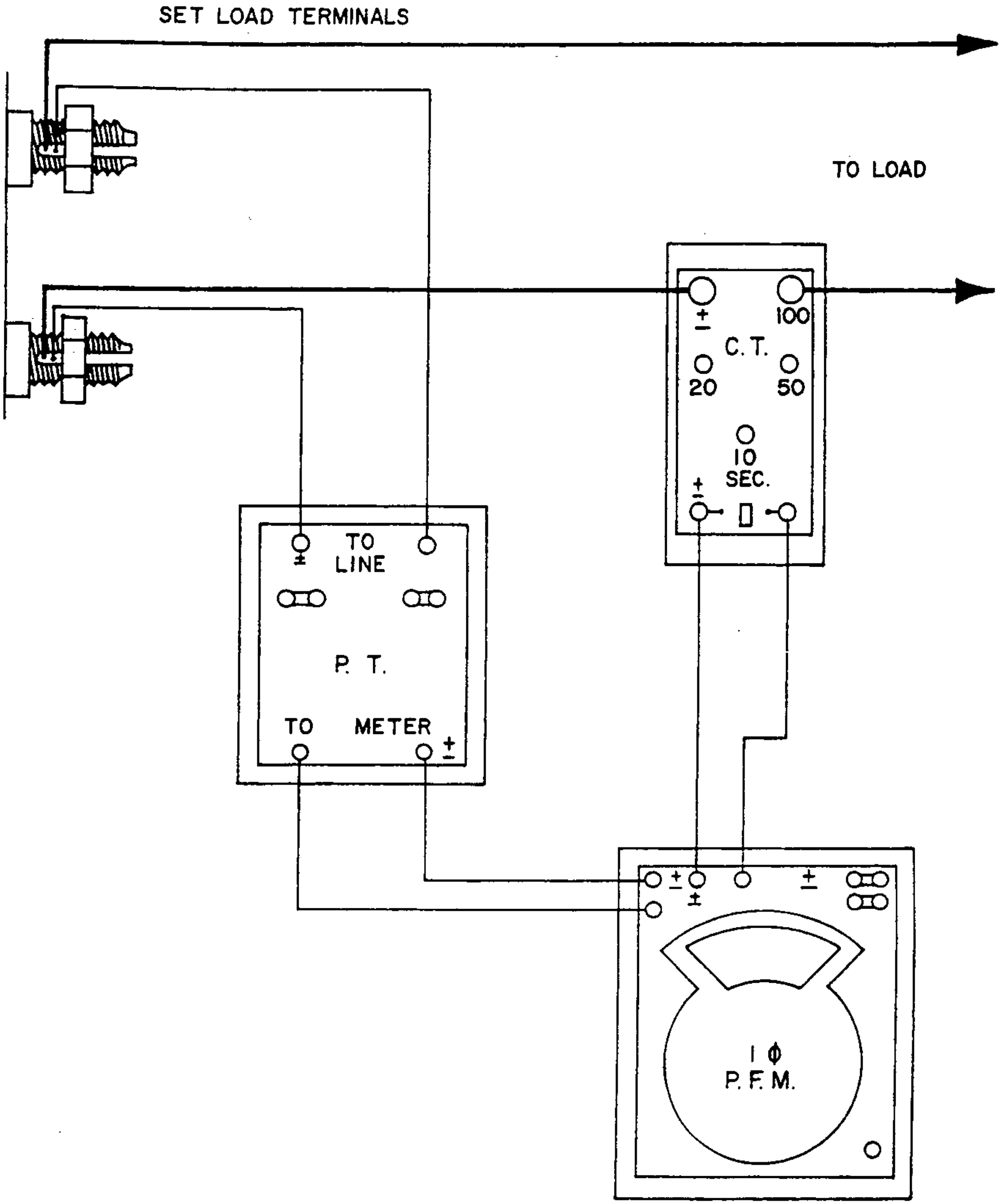


FIGURE 205.1-31. Single-phase power factor meter with potential and current transformers.

X-4244

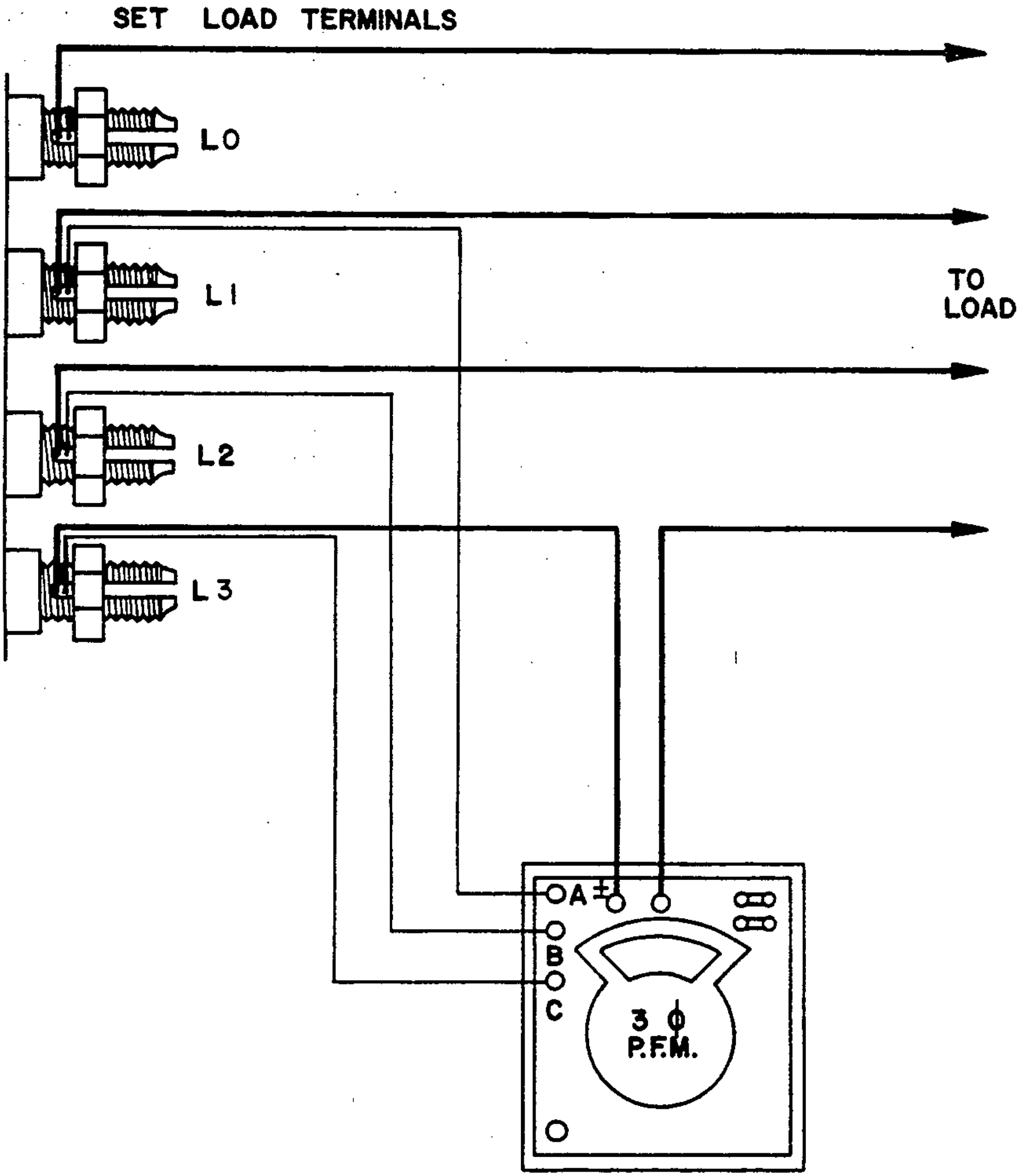


FIGURE 205.1-32. Three-phase power factor meter.

X-4245

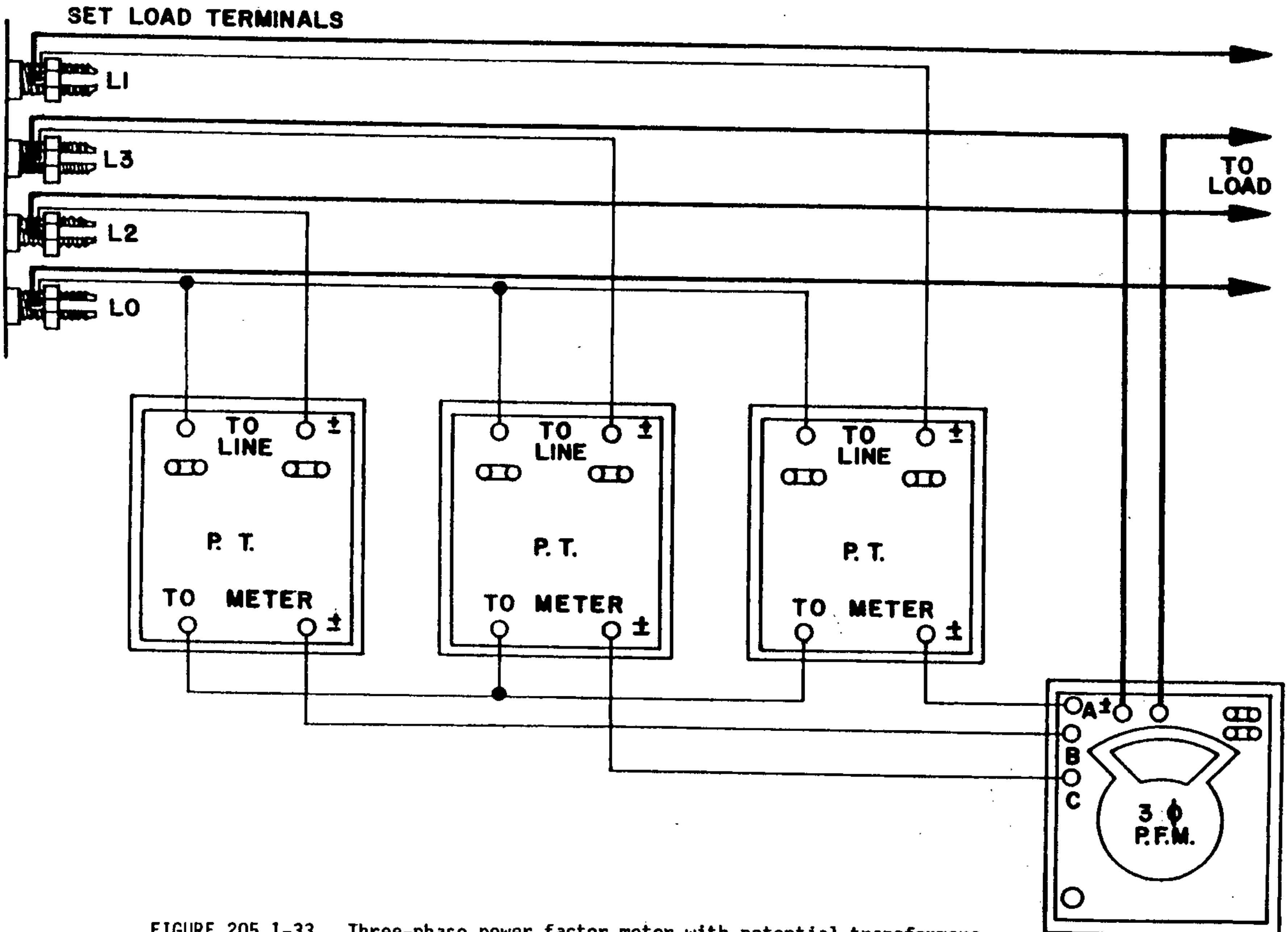


FIGURE 205.1-33. Three-phase power factor meter with potential transformers.

X-4246

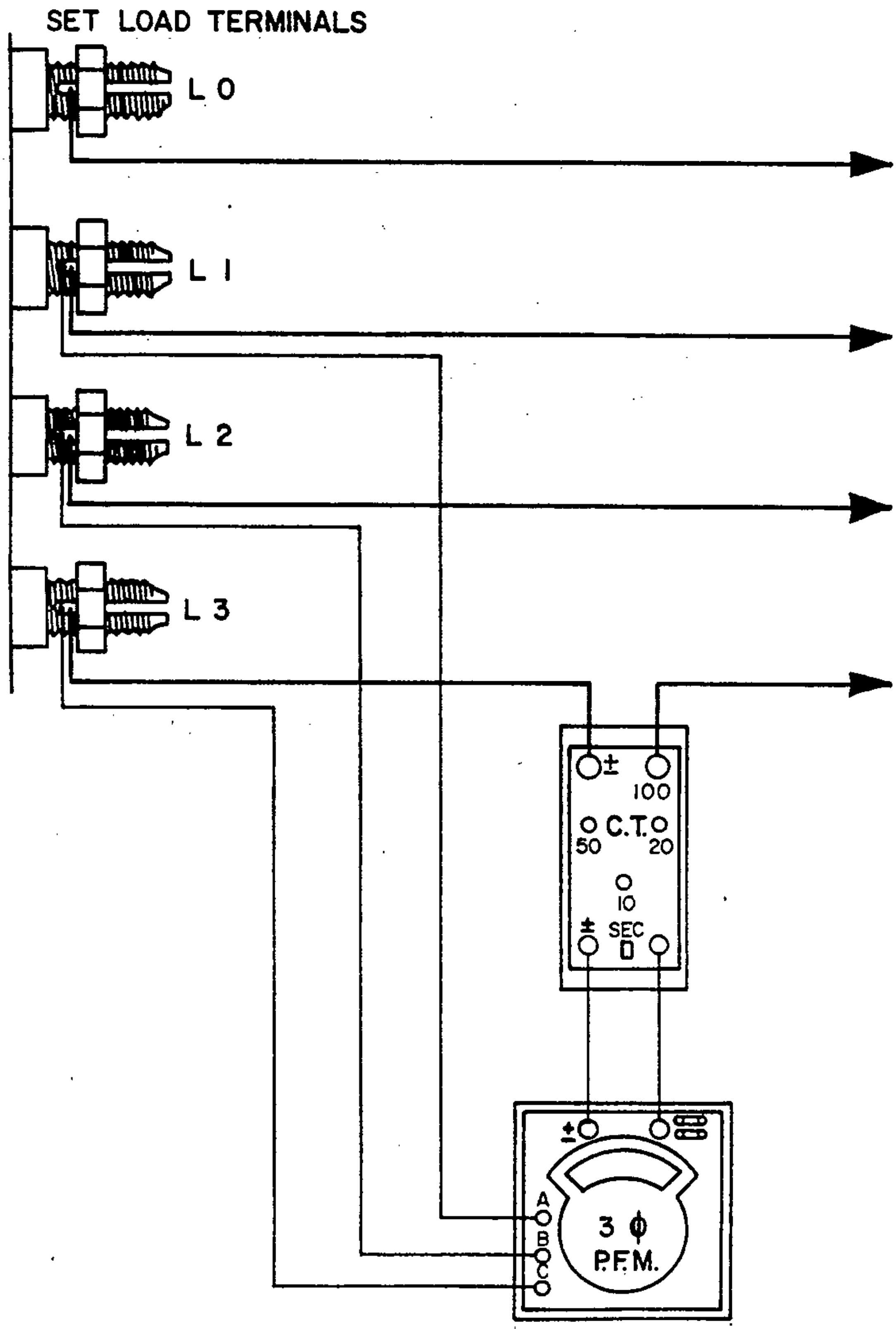


FIGURE 205.1-34. Three-phase power factor meter with current transformer.

X-4247

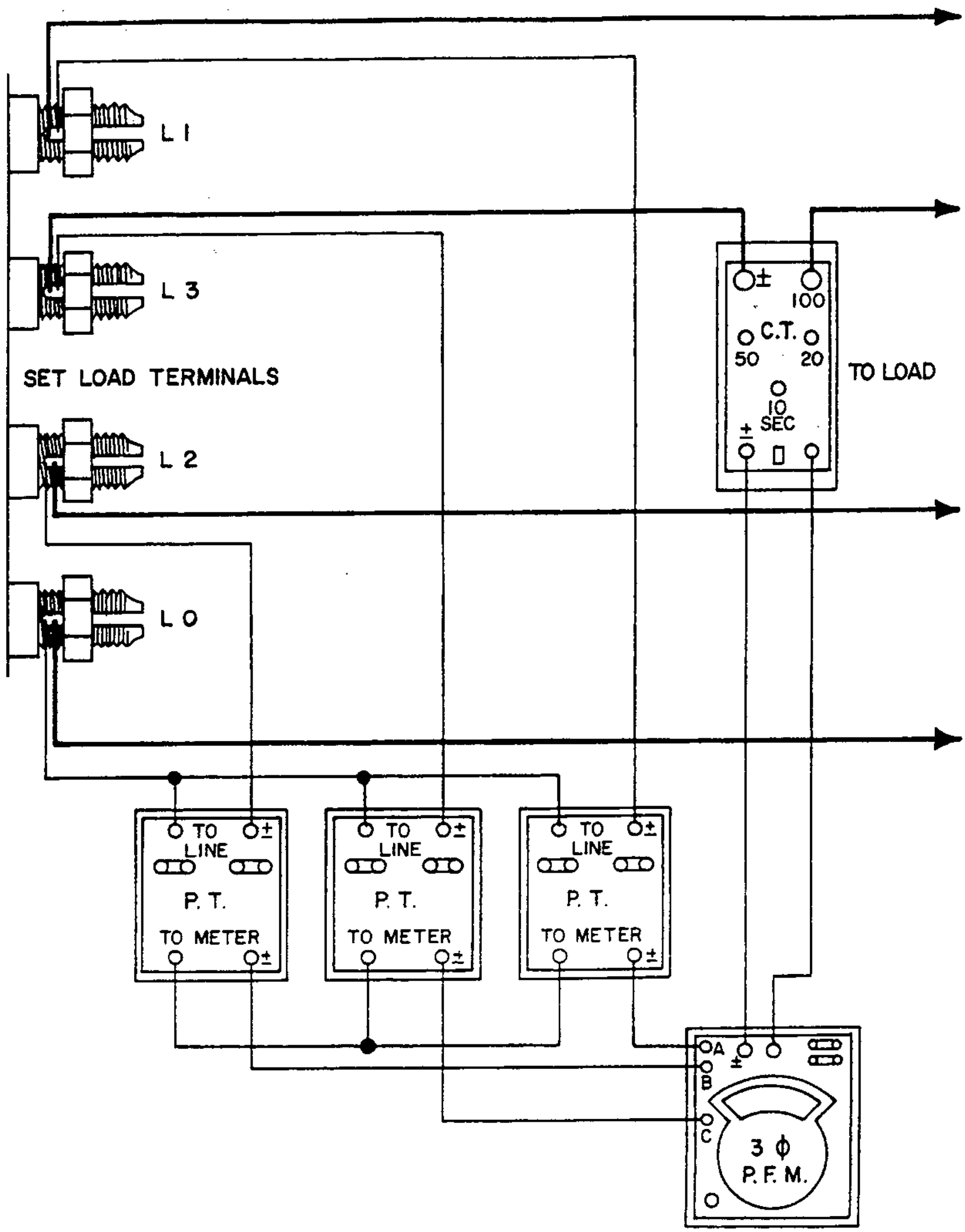


FIGURE 205.1-35. Three-phase power factor meter with potential and current transformers.

X-4248

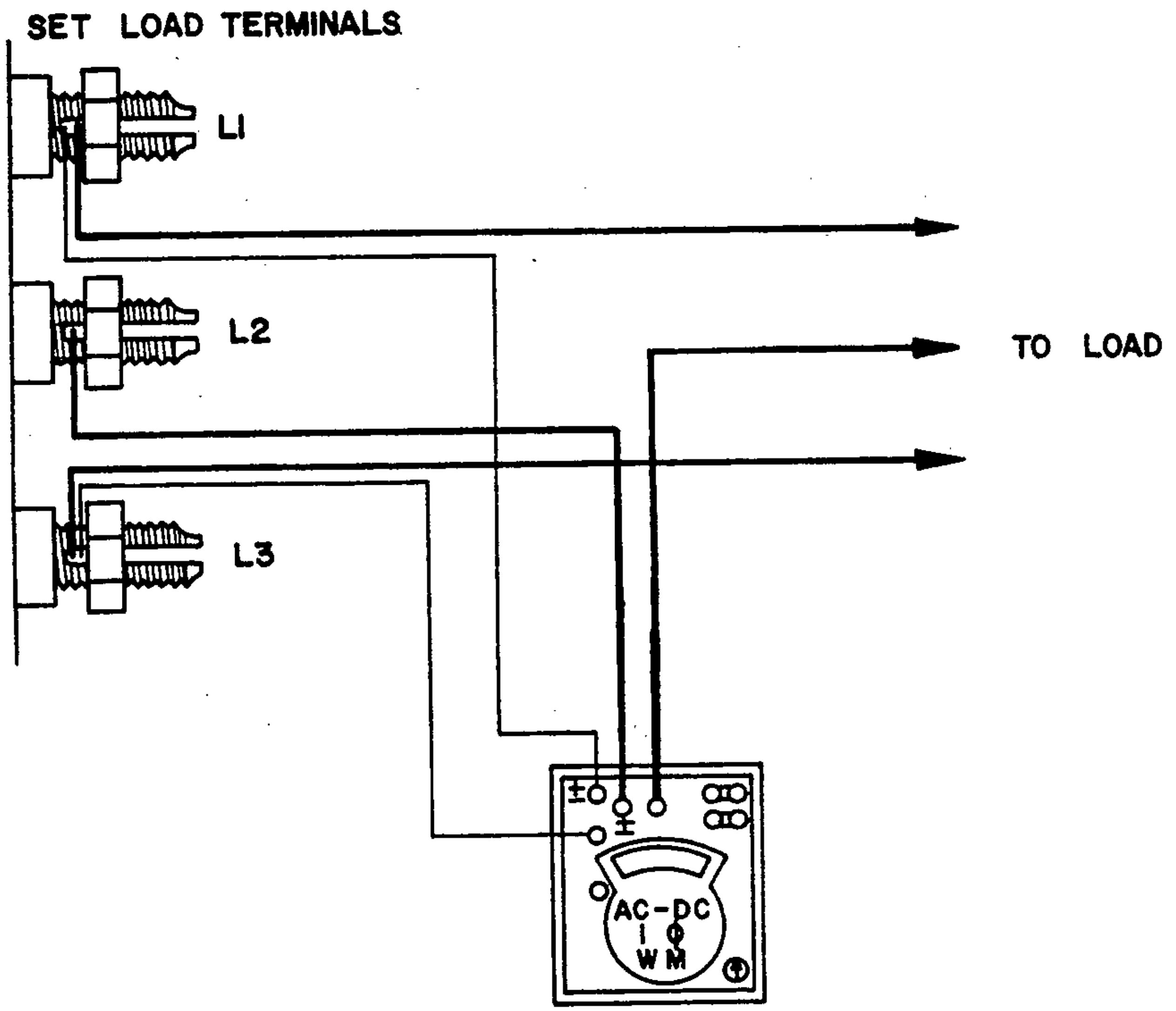


FIGURE 205.1-36. Single-element wattmeter used as a varmeter on three-phase balanced circuit.

X-4249

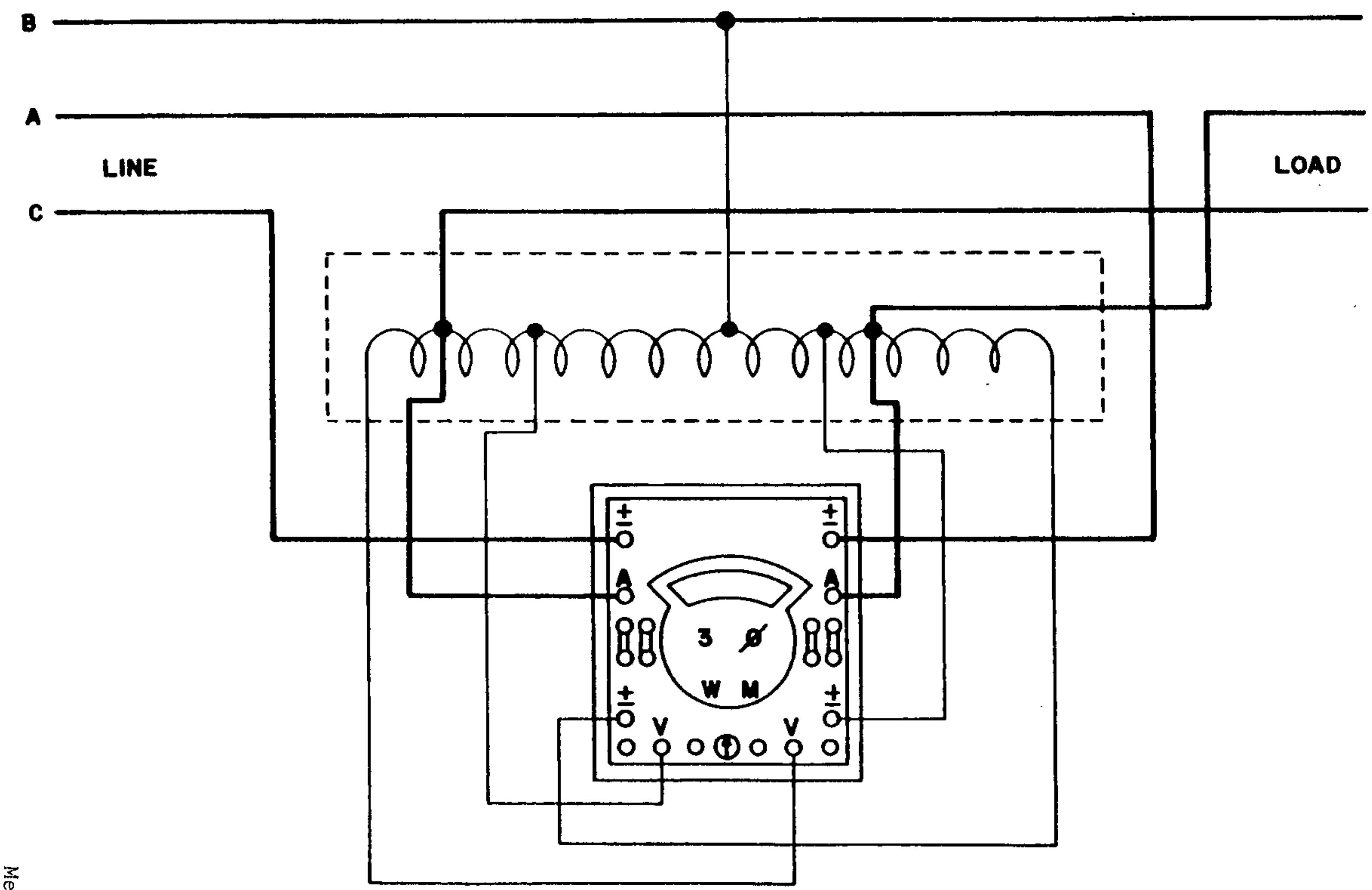


FIGURE 205.1-37. Polyphase varmeter circuit.

X-4250

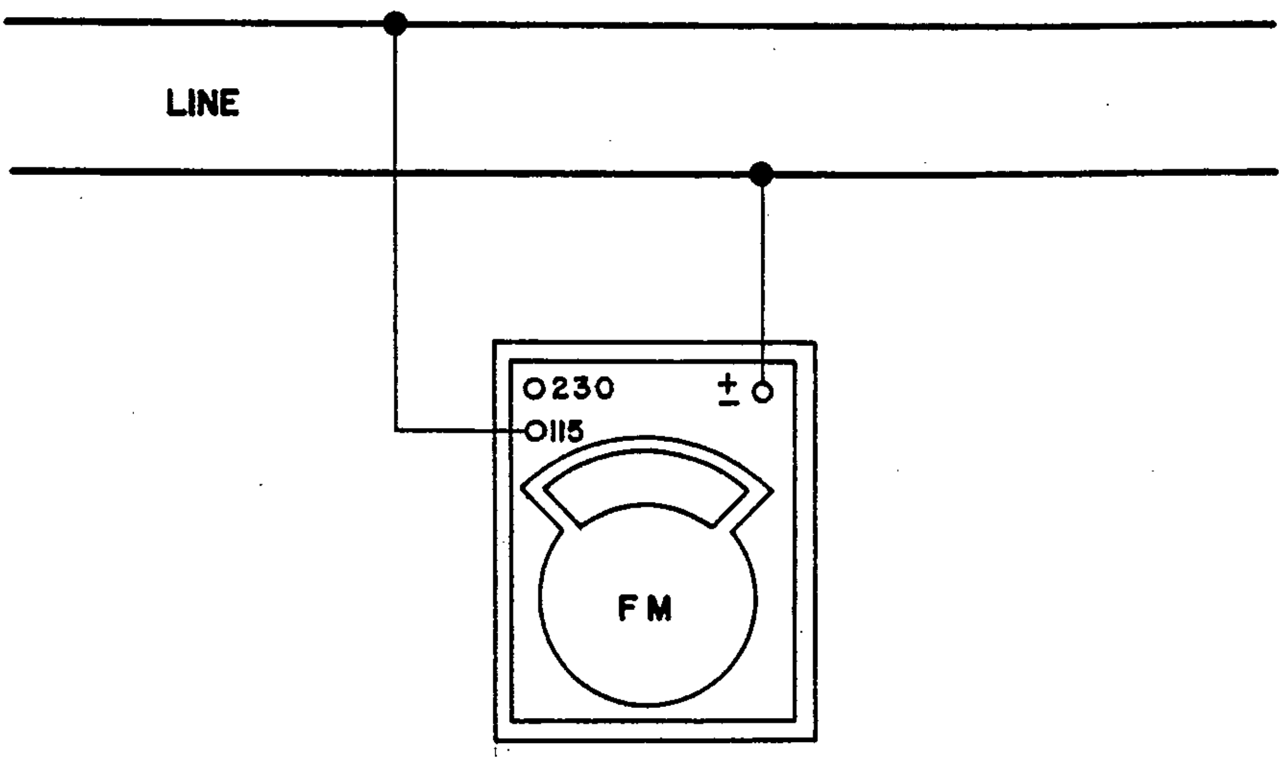


FIGURE 205.1-38. Frequency meter.

X-4251

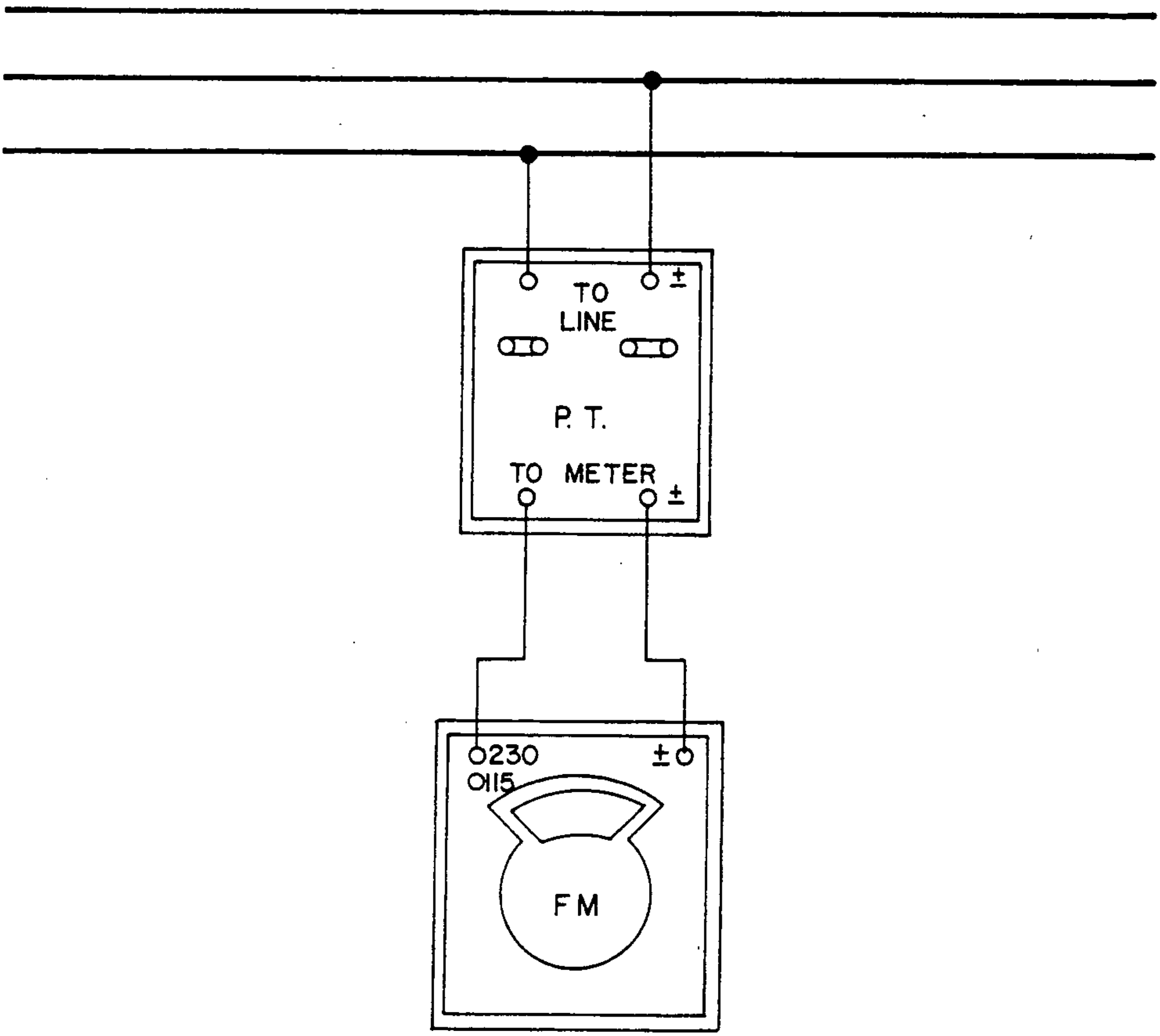


FIGURE 205.1-39. Frequency meter with potential transformer.

X-4252

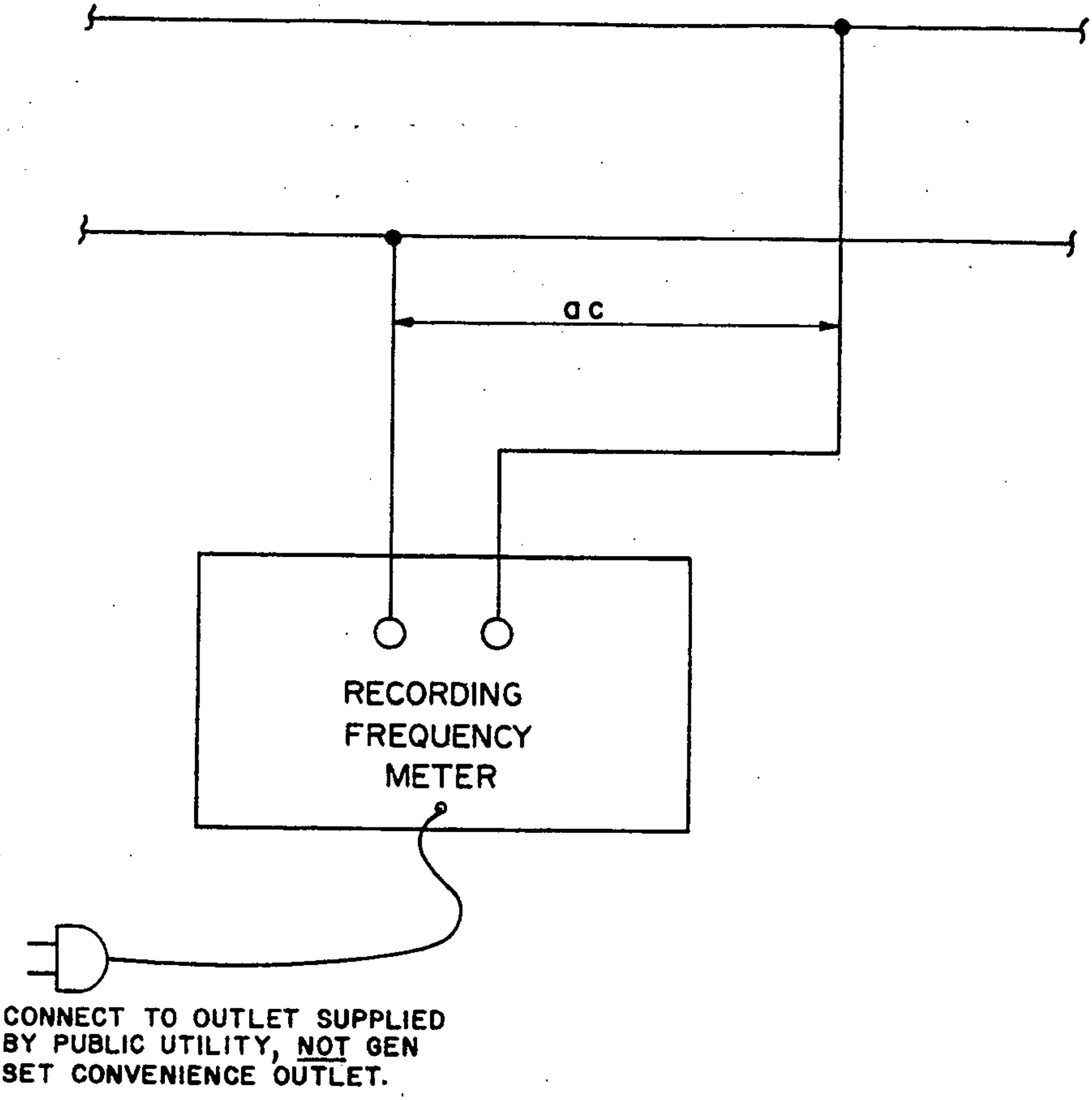
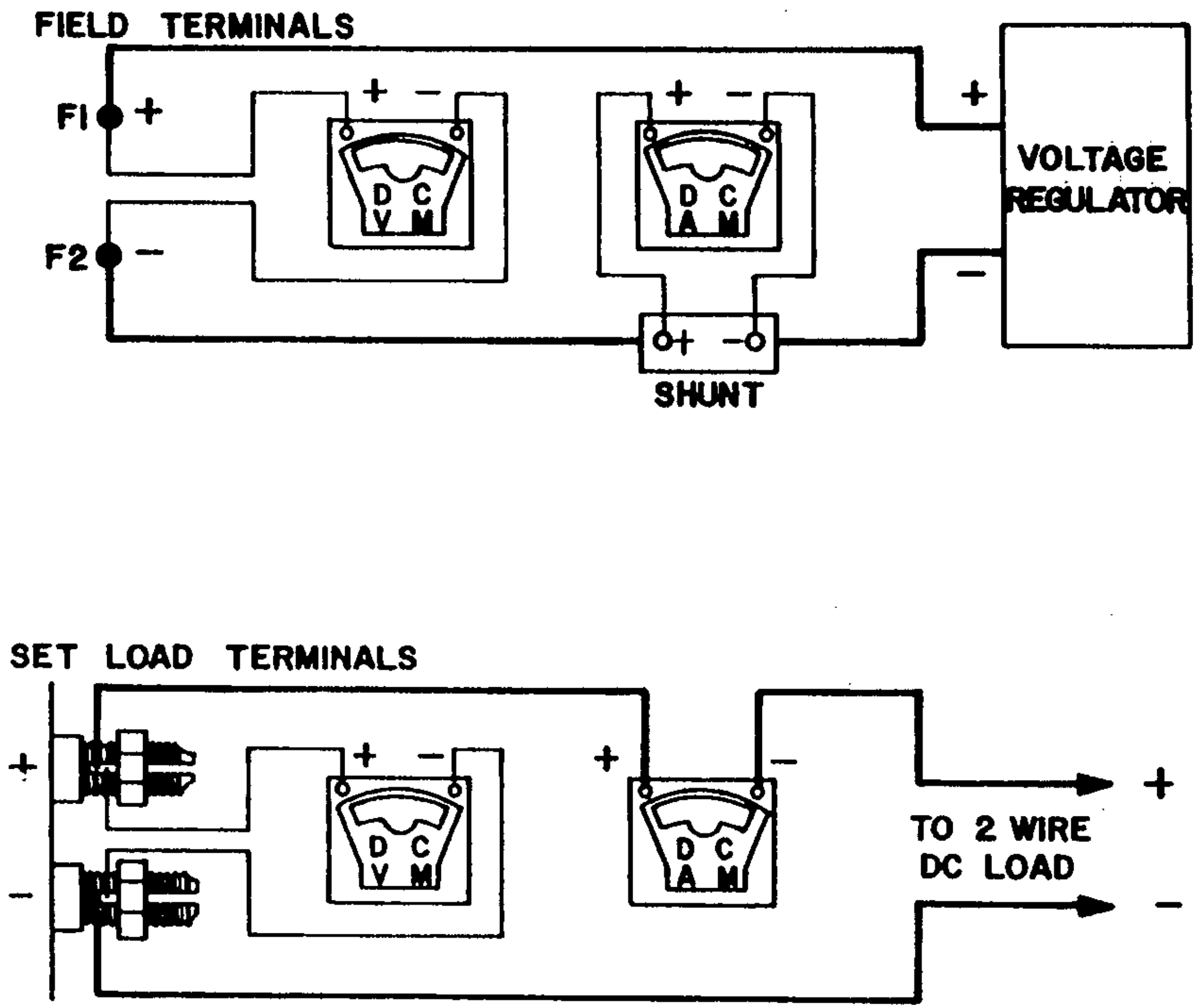


FIGURE 205.1-40 Recording frequency meter.

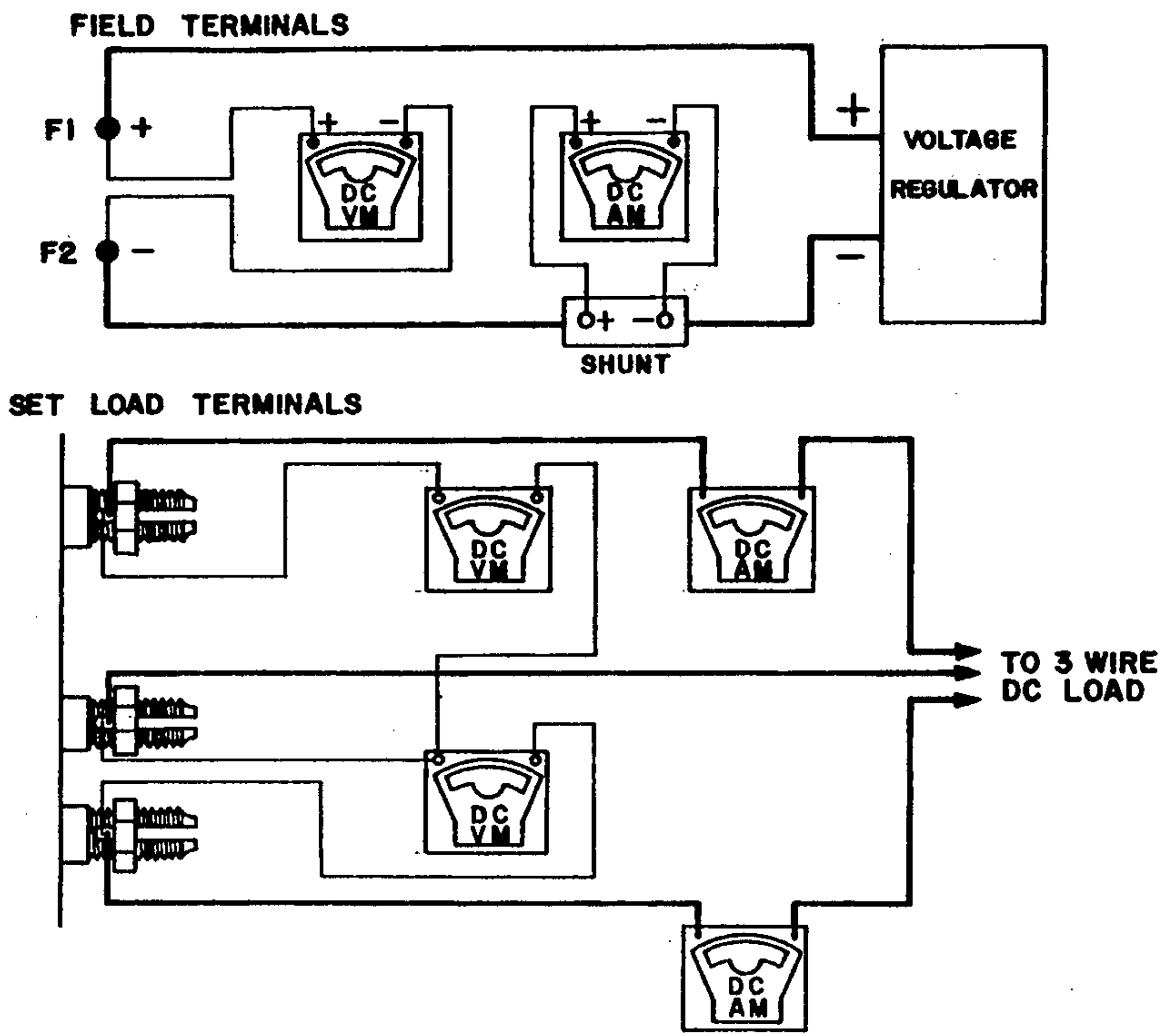
X-4253



NOTE: A TACHOMETER FOR DETERMINING THE GENERATOR SPEED IS REQUIRED BUT NOT SHOWN.

FIGURE 205.1-41. Load instrumentation for two-wire dc generator set.

X-4254



NOTE: A TACHOMETER FOR DETERMINING THE GENERATOR SPEED IS REQUIRED BUT NOT SHOWN.

FIGURE 205.1-42. Load instrumentation for three-wire dc generator set.

X-4255

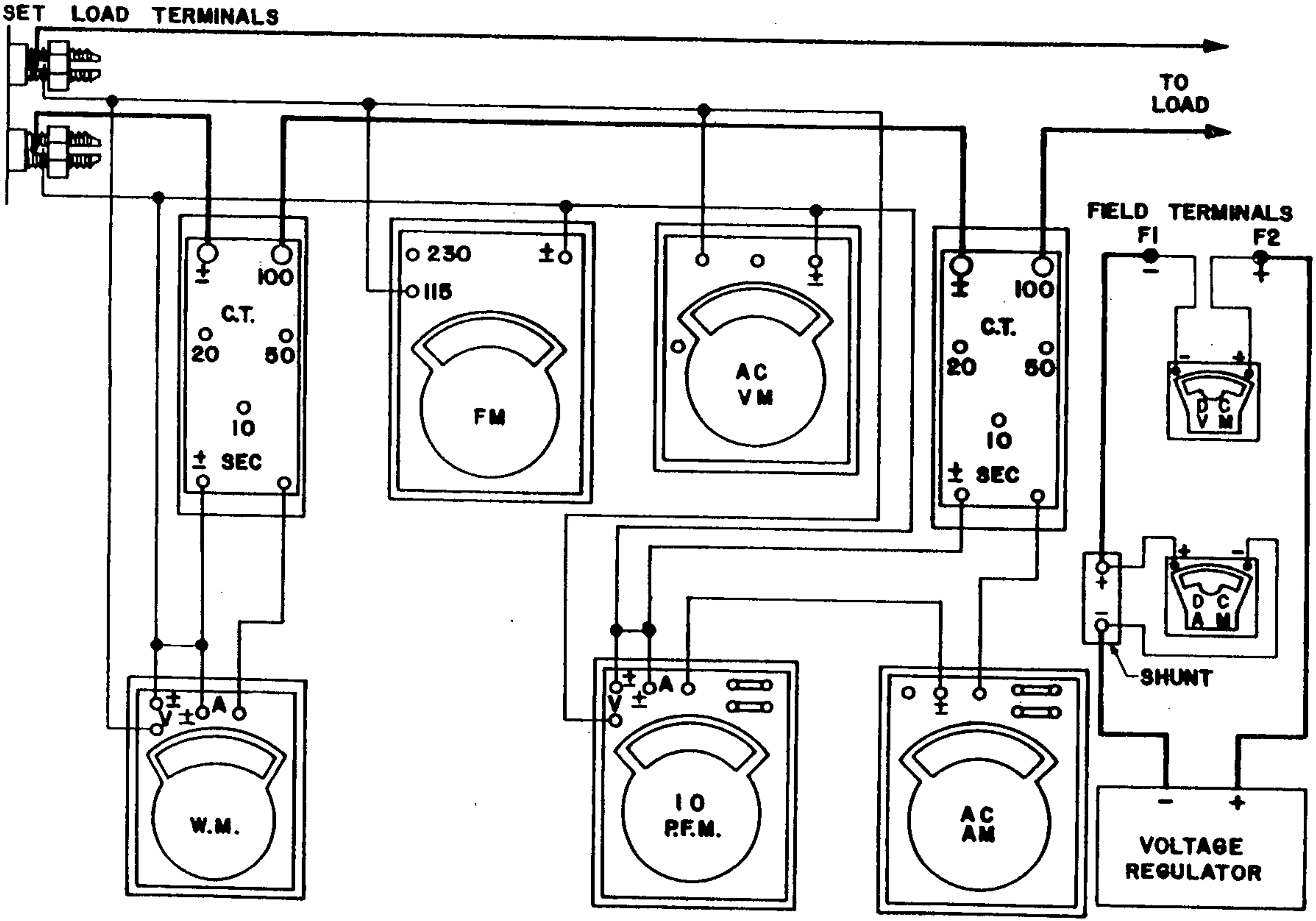


FIGURE 205.1-43. Load instrumentation for single-phase, two-wire ac generator set.

X-4256

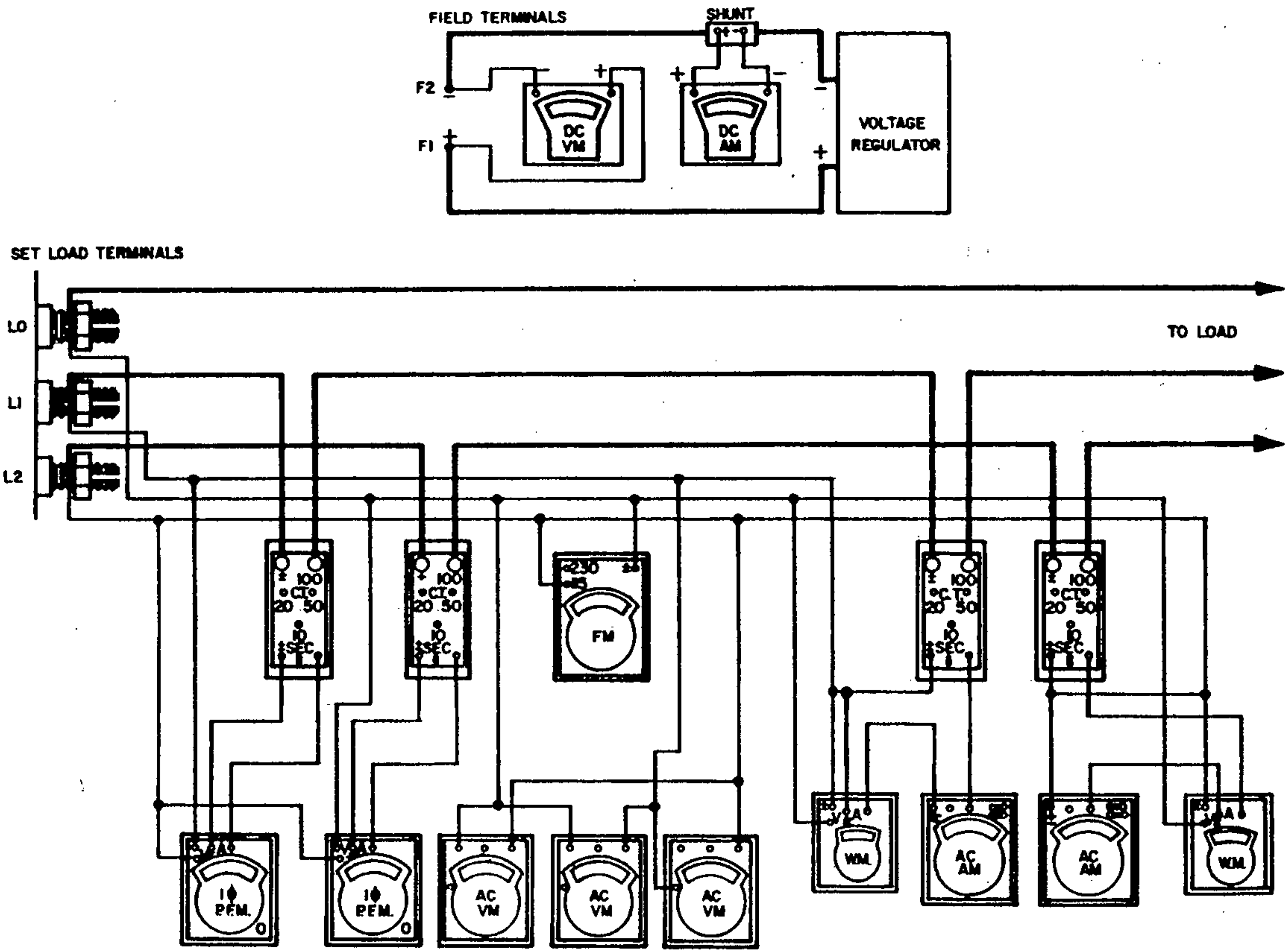


FIGURE 205.1-44. Load instrumentation for single-phase, three-wire ac generator set.

X-4257

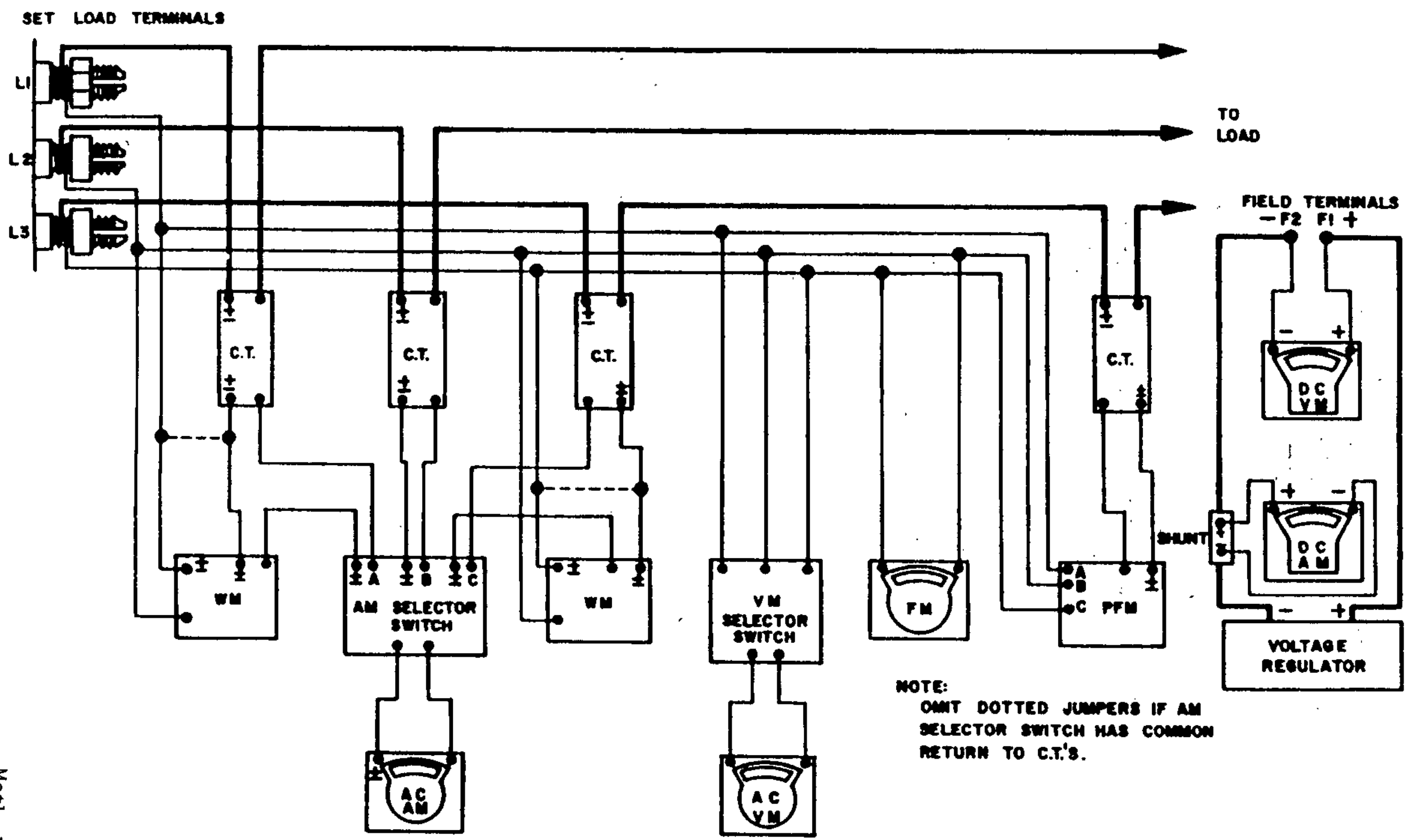


FIGURE 205.1-45. Load instrumentation for three-phase, three-wire ac generator set.

V-4258

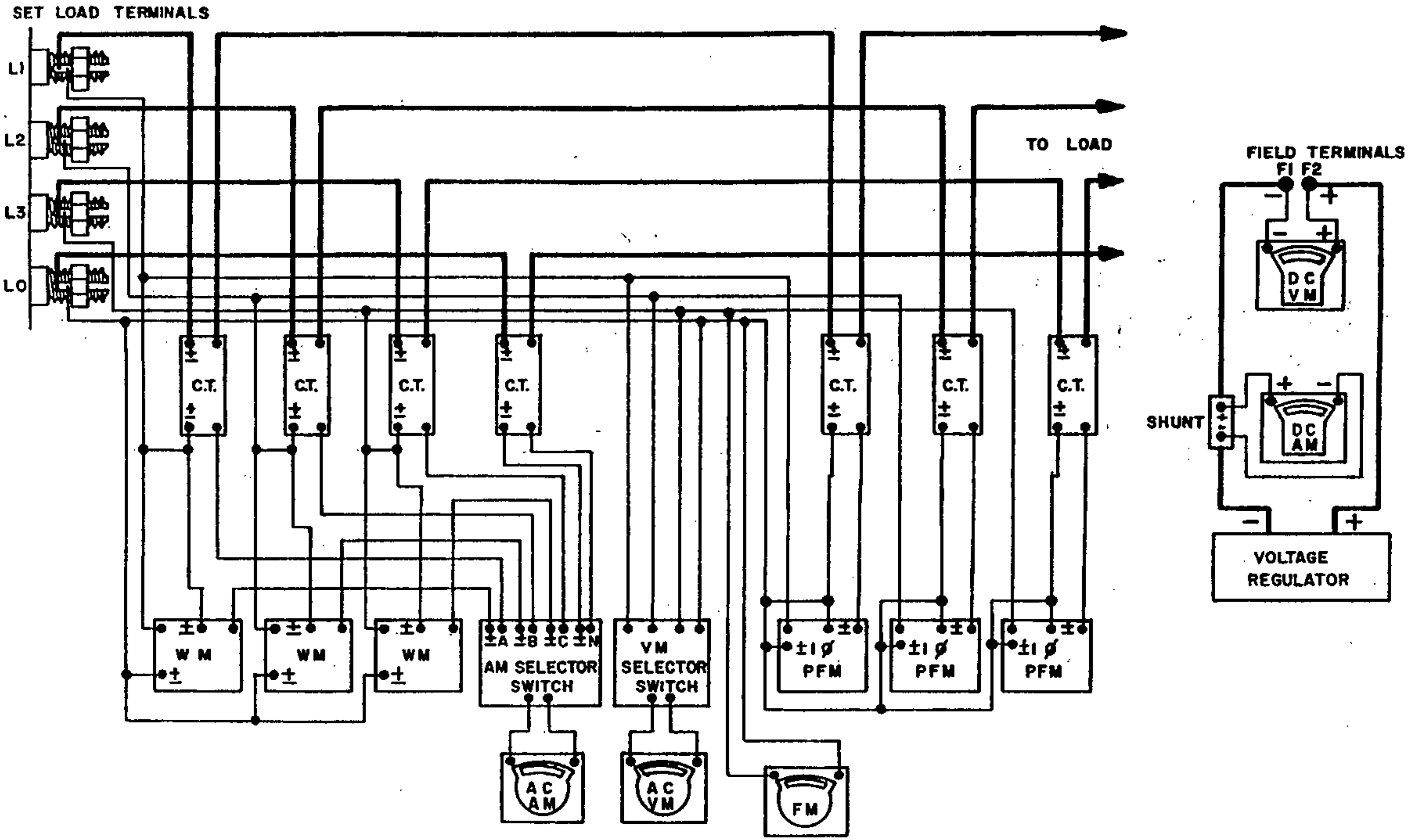


FIGURE 205.1-46. Load instrumentation for three-phase, four-wire ac generator set.

X-4259

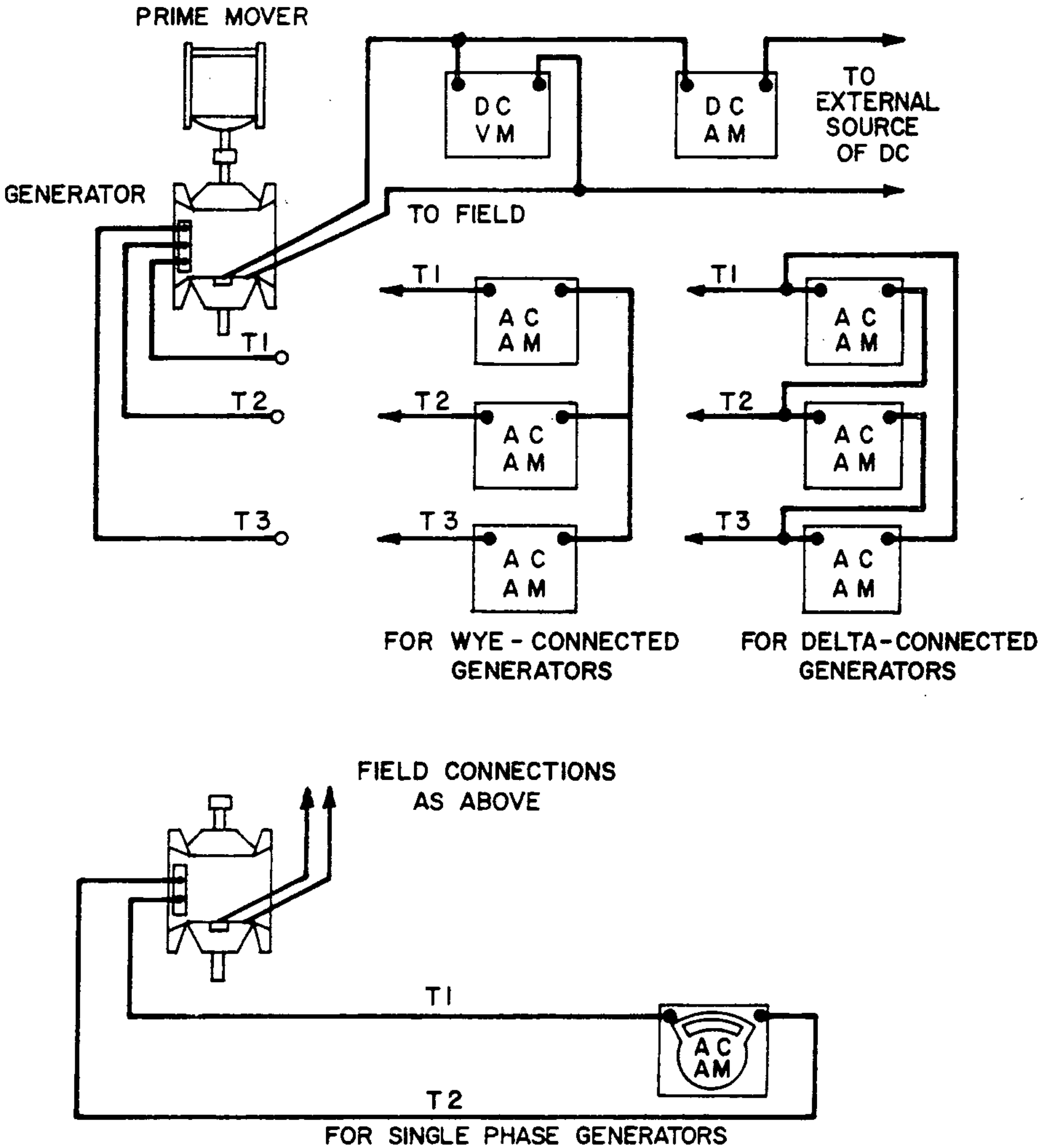


FIGURE 205.1-47. Load instrumentation for short circuit currents.

X-4260

METHOD 220.1b

ENGINE PRESSURE MEASUREMENTS

220.1.1 GENERAL. The location of the pressure tap is of importance in the repeatability of engine pressure measurements.

220.1.2 AIR INTAKE PRESSURE.

220.1.2.1 SPARK IGNITION ENGINES. The intake manifold pressure shall be measured by a manometer connected to a pressure tap located approximately 2 inches from the carburetor flange. On small engines where a pressure tap may interfere with carburetion, the intake manifold pressure data may be omitted at the descretion of the testing agency. The pressure shall be measured in inches of water H_2O or mercury (Hg).

220.1.2.2 COMPRESSION IGNITION ENGINES. Pressure of the intake air in the manifold for naturally aspirated engines shall be measured by a manometer connected to a pressure tap near the inlet flange of the manifold. For engines with scavenging air blowers, turbocharges, or supercharges, the air pressure shall be measured by a manometer connected to a pressure tap located on the discharge side of the blower. The pressure shall be measured in inches of water (H_2O) or mercury (Hg).

220.1.3 EXHAUST GAS PRESSURE. The mean exhaust gas pressure shall be measured by a manometer connected to a tap located approximately 2 inches beyond the outlet flange of the exhaust manifold or turbocharger. The pressure shall be measured in inches of mercury (Hg) or water (H_2O). The back pressure imposed by the laboratory or manufacturer's plant exhaust system during tests at rated net continuous load and speed shall not be less than that existing at the same load and speed with the set exhausting directly to the atmosphere through its own exhaust system, and will be increased above this minimum value if a higher test pressure is specified in the procurement documents.

Method 220.2b

PRESSURE AND TEMPERATURE CORRECTIONS TO
(SPARK AND COMPRESSION IGNITION) ENGINE DATA

220.2.1 GENERAL. Ambient air pressure, water vapor pressure and the intake air temperature variations have considerable effect on the operational characteristics of engines. It is necessary to correct for these variations in order to assure that engine output data is uniform.

220.2.2 MEASUREMENT OF ATMOSPHERIC MOISTURE. The quantity of moisture mixed with the air under different conditions of temperature and degrees of saturation may be measured in several distinctly different ways. Many of these, however, are not practicable methods for daily observations, or are not sufficiently accurate. Probably the most convenient of all methods and the one most generally employed is to observe the temperature of evaporation--that is, the difference between the temperatures indicated by wet-bulb and dry-bulb thermometers. One of the most commonly used instrument for this purpose is the sling psychrometer (also called "whirled psychrometer"). In special cases, rotary fans or other means may be employed to move the air rapidly over the thermometer bulbs. In any case, satisfactory results cannot be obtained from observation in relatively stagnant air. A strong ventilation is absolutely necessary to accuracy.

Additional information on atmospheric moisture measurement can be found in ANSI/ASHRAE 41.6 and in the ASHRAE brochure on psychrometry.

220.2.3 SLING PSYCHROMETER DESCRIPTION. This instrument consists of a pair of thermometers, provided with a handle as shown in figure 220.2-1, which permits the thermometers to be whirled rapidly, the bulbs being thereby strongly affected by the temperature of and moisture in the air. The bulb of the lower of the two thermometers is covered with thin muslin, which shall be wet at the time an observation is made.

220.2.3.1 MAINTENANCE OF THE WET BULB. The muslin covering for the wet bulb shall be kept clean and in good condition. The evaporation of the water from the muslin always leaves in its meshes a small quantity of solid material, which eventually stiffens the muslin so that it does not readily become wet after being dipped in water. To minimize this problem, use pure distilled water and renew the muslin frequently. New muslin must always be washed to remove sizing (starch) and other potential contaminants before being used. A small rectangular piece of muslin wide enough to go one and one-third times around the bulb, and long enough to cover the bulb and that part of the stem below the metal back, shall be thoroughly wetted in clean water, and neatly fitted around the thermometer. It shall then be tied first around the bulb at the top, using suitably strong thread, then looped to form a knot around the bottom of the bulb, just where it begins to round off. As this knot is drawn tighter and tighter the thread will slip off the rounded end of the bulb and neatly stretch the muslin covering with it, at the same time securing the latter at the bottom.

220.2.4 MAKING AN OBSERVATION USING THE SLING PSYCHROMETER. The wet bulb shall be thoroughly saturated with water by dipping it into a small cup or wide-mouthed bottle. The thermometers shall then be whirled rapidly for 20 seconds; stopped and quickly read, the wet bulb first. These readings shall be recorded, the psychrometer immediately whirled again and a second set of readings taken. This is repeated three or four times, or more, if necessary, until at least two successive readings of the wet bulb agree, thereby showing that it has reached its lowest temperature.

A minute or more is generally required to secure the correct temperature. When the air temperature is near the freezing point, the temperature of the wet bulb may fall several degrees below freezing point, but the water will still remain in the liquid state. No error results from this, provided the minimum temperature is reached. If, however, as frequently happens, the water suddenly freezes, a large amount of heat is liberated, and the temperature of the wet bulb immediately becomes 32°. In such cases it is necessary to continue the whirling until the ice-covered bulb has reached a minimum temperature.

220.2.4.1 WHIRLING AND STOPPING THE PSYCHROMETER. It is difficult to effectually describe these movements. The techniques can only be learned by practice. The arm is held with the forearm about horizontal, and the hand well in front. A peculiar swing starts the thermometers whirling, and afterward the motion is kept up by only a slight but very regular action of the wrist, in harmony with the whirling thermometers. The rate should be a natural one, so as to be easily and regularly maintained. If too fast, or irregular, the thermometers may be jerked about in a violent and dangerous manner. The stopping of the psychrometer, even at the very highest rates, can be perfectly accomplished in a single revolution, when one has learned the technique. This can only be acquired by practice. It consists of a quick swing of the forearm by which the hand also describes a circular path and follows after the thermometers in a peculiar manner that wholly overcomes their circular motion without the slightest shock or jerk. As an alternative stopping method, the thermometers may, without very great danger, be allowed simply to stop themselves; the final motion in such a case will generally be quite jerky, but, unless the instrument is allowed to fall on the arm, or strikes some object, no injury should result.

220.2.4.2 SPECIAL PROCEDURES FOR USING THE PSYCHROMETER IN SUNLIGHT. While the psychrometer will give quite accurate indications, even in the bright sunshine, observations made in the sunshine are not without some error, and, where greater accuracy is desired, the psychrometer should be whirled in the shade of a building or tree, or, as may sometimes be necessary, under an umbrella. In all cases there should be perfectly free circulation of the air, and the observer should face the wind, whirling the psychrometer in front of his body. It is a good plan, while whirling, to step back and forth a few steps to further prevent the presence of the observer's body from giving rise to erroneous observations.

220.2.5 CORRECTING INTAKE MANIFOLD PRESSURE OBSERVATIONS. The moisture vapor pressure for a given combination of temperature and relative humidity shall be determined by obtaining wet-bulb and dry-bulb temperatures with a sling psychrometer. The psychrometer shall be operated near the engine air intake and the readings obtained shall be used in conjunction with the ASHRAE Handbook 1981 Fundamentals, chapter 5 and the Psychrometric Tables of chapter 6 therein, to obtain the moisture vapor pressure. Subtract the moisture vapor pressure from the observed value of the manifold pressure to obtain the dry absolute manifold pressure at the observed temperature. The dry absolute manifold pressure at the observed temperature shall be converted to a dry absolute manifold pressure at the standard carburetor inlet temperature of 60 °F (15.5 °C) by applying the following formula:

$$\text{D.A.M.P. at } T_S = \text{D.A.M.P. at } T_O \left[\frac{460 + 60}{T_O + 460}\right]$$

Where:

D.A.M.P. is the Dry Absolute Manifold Pressure.

T_S is the standard carburetor inlet air temperature (60 °F).

T_O is the observed temperature in ° F.

220.2.6 CORRECTING MAXIMUM POWER VALUES. All values of observed maximum engine generator set output power shall be corrected to standard conditions of pressure and temperature (sea level and 60 °F), unless otherwise specified in the procurement document. Correct the observed engine generator set output value by applying the following formula:

$$\text{Corrected watts} = (\text{Observed watts}) \frac{29.92}{B-E} \sqrt{\frac{460+T}{460+60}} \quad (\text{For sea level and } 60° \text{ F})$$

Where: B is the barometer inches of mercury (corrected for temperature).

E is the water vapor pressure (inches of mercury).

T is the intake air temperature (° F).

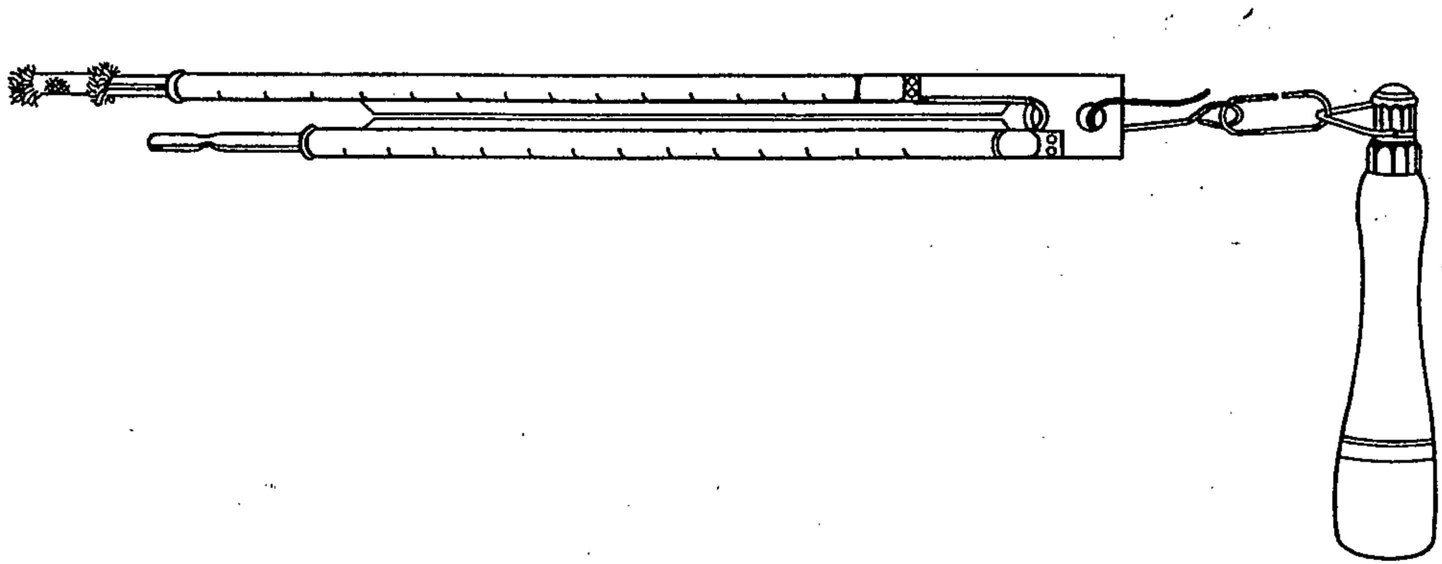


FIGURE 220.2-1. Sling psychrometer.

X-4261A

METHOD 221.1a

TEMPERATURE CORRECTIONS TO RESISTANCE MEASUREMENTS

221.1.1 GENERAL. The resistance of a conductor varies with the temperature. The resistance of metals and most alloys increases with the temperature, while the resistance of carbon and electrolytes decreases with the temperature.

221.1.2 PROCEDURE. When the resistance R_t of a winding has been determined by test at a winding temperature T_t, the resistance may be corrected to a specified temperature T_s by the following equation:

$$R_s = R_t \left(\frac{T_s + k}{T_t + k}\right) \text{ ohms.}$$

where R_s = winding resistance, corrected to specified temperature, T_s

T_s = specified temperature, ° Celsius

R_t = test value of winding resistance

T_t = temperature of winding when resistance was measured, ° Celsius

k = characteristic constant for the winding material

NOTE: k for 100 percent pure copper = 234.5; k for hard drawn 97.3 percent copper = 241.5. Data for different materials may be found in various standard engineering handbooks.

For MIL-STD-705 testing all values of observed resistance of windings shall be corrected to a standard temperature of 25 °C (77 °F) unless otherwise specified in the procurement document.

Method 222.1a

BATTERY SERVICING AND CONDITION ASSURANCE
PRIOR TO "COLD STARTING" TESTS

222.1.1 GENERAL. Lead-acid or nickel-cadmium (NI-CAD) batteries are used to start some engine-driven electrical power generator sets. One of the purposes of MIL-HDBK-705 is to provide guidance to assure that proper test conditions and preparations are accomplished prior to commencing any of the MIL-STD-705 tests.

When provisions are made in advance to assure that adequate facilities, equipment and personnel will be available, battery servicing and condition assurance can usually be accomplished within a normal 5-day work-week. Planning and scheduling for MIL-STD-705 testing should allow sufficient pre-test time for these tasks.

The tests of MIL-STD-705, when used for first article or production acceptance, are to verify that generator sets have been properly manufactured, not to test batteries. Batteries are multi-use items tested and qualified under their own separate programs, prior to being specified for use on generator sets or various other equipment. Batteries that are used during MIL-STD-705 first article or production acceptance testing are, in essence, "test support equipment". If full battery output capability is not assured prior to generator set testing, inadequate battery performance may cause abortion of an otherwise valid test sequence; this can result in waste of test facility and personnel resources, and risk failure to meet contract or program schedules. Operational experience with the procedures below is that they are highly effective in preventing such problems.

When the tests of MIL-STD-705 are used for evaluation during equipment research and development, the use or non-use of the procedures below depends upon the purpose for which the test data will be used. For example, total system reliability or operational readiness assessments, evaluations of component compatibilities, standardization studies and so forth, would probably not require the use of these battery conditioning procedures.

222.1.2 PREPARATION OF BATTERIES FOR CHARGING. It is strongly recommended that new batteries be used for the cold starting tests of MIL-STD-705, to further minimize possibilities of test abortions due to improper battery conditions. Extreme care must be exercised to insure that NI-CAD batteries are not contaminated by tools, equipment, solutions or gases from lead-acid batteries. Such contamination can destroy NI-CAD batteries. Refer to the NI-CAD battery technical manual or manufacturer's data for further guidance about this.

Batteries may be received in either the "wet" or "dry" condition. Wet battery cells already contain the electrolyte solution, whereas dry batteries require filling with electrolyte solution after receipt. Some batteries may have sealing devices over each cell for shipment and storage, which must be dislodged (and can be discarded or left inside the cells) prior to filling. Wet batteries may require "topping off" with distilled water to bring the electrolyte to its correct level, but neither topping off of wet batteries nor filling of dry batteries should be attempted until the battery has stabilized at a temperature between 60 °F (15.6 °C) and 100 °F (37.8 °C). Stabilization should be verified by 3 consecutive checks of the battery or electrolyte temperature, 10 minutes apart and varying within ±5 °F (2.8 °C) of each other, within the 60 °F to 100 °F range. Final check and adjustment of the electrolyte level should then be made 30 minutes after any previous additions of distilled water or electrolyte.

The electrolyte for dry lead-acid batteries is a solution of sulfuric acid (H_2SO_4) and distilled water having a specific gravity between 1.260 and 1.280 at 80 °F (26.7 °C). Wet lead-acid batteries contain the same solution, but normally only distilled water is added to them after receipt. For temperatures below 0 °F (-17.7 °C), battery performance is better when 1.280 specific gravity solution is used.

NI-CAD batteries use potassium hydroxide (KOH) electrolyte. Unlike lead-acid battery electrolyte, the specific gravity of potassium hydroxide in NI-CAD batteries does not vary with the state of charge of the battery; however, the level of the electrolyte in NI-CAD batteries does vary extremely with the state of charge. NI-CAD batteries normally are shipped with the proper amounts of electrolyte already in the cells, but if the battery is in the discharged state when received, it may appear to be dry or low on electrolyte because the liquid has been absorbed by the cell plates. Because of this phenomenon, neither electrolyte nor distilled water should be added to NI-CAD batteries until they have been fully recharged (see 222.1.3 below). After recharging, the level may continue to vary for another two hours; therefore, final level determination should be made two hours after completion of recharging. Distilled water may then be added if needed. If it is suspected that a totally dry NI-CAD battery has been received, the condition can be confirmed by checking for absence of voltage across the individual cells or between the terminal posts, or by observing the charger meter immediately after charging current is applied to the proper connections; if there is no electrolyte in the battery, it will not take a charge, and the charger should be stopped. Electrolyte should then be added, not to full level, but to just above the plates in each cell. Charging may then be resumed and continued, provided battery temperature does not rise above that specified in the battery Technical Manual or manufacturer's data, and the charger meter or other device indicates the battery is taking the charge. Final electrolyte level should be verified or corrected two hours after completion of charging.

All battery electrolytes are highly corrosive and can severely damage human eyes, skin, and other body tissues; therefore, protective clothing, gloves and goggles should be worn when handling these chemicals and while near any battery charging operations.

After adjusting electrolyte levels, battery tops and cases should be thoroughly washed, neutralized and dried. Use washing and neutralizing solutions recommended in the applicable technical manuals or manufacturer's data. Do not allow washing or neutralizing solutions to enter the battery cells. After drying, the battery should be placed on a dry wooden board or similar material that will electrically and chemically isolate the battery case from ground and surrounding material. The battery should remain so insulated throughout charging and storage operatins prior to use for the cold starting tests of MIL-STD-705. Avoid allowing sparks, lighted cigarettes, pipes, cigars, excessive heat, or flame near batteries, especially during charging operations. Hydrogen and oxygen gases from the batteries can ignite and explode. Charging and storage areas must allow for adequate ventilation and dilution of these gases.

222.1.3 BATTERY CHARGING EQUIPMENT AND CONNECTIONS. Charging equipment for lead-acid batteries can consist of any suitable DC power source with the necessary metering and instrumentation. NI-CAD batteries generally require their own special charging equipment as well as special discharging fixtures, which will be identified in the applicable technical manual or manufacturer's data. Improper charging or discharging of NI-CAD batteries can result in a condition called "thermal runaway", which is dangerous to personnel and destructive to the battery.

When more than one battery is to be charged or discharged simultaneously, connect the batteries in series or use isolated circuits. Do not connect the batteries in parallel because the charge or discharge rate of an individual battery is extremely difficult to control that way.

222.1.4 STANDARD BATTERY RATING VERSUS "8 HOUR RATE". "Battery Rating" normally means the total number of ampere-hours that can be expended during a specified period of continuous discharging at a specified constant temperature and at a specified constant discharge rate. This rate, also referred to as "rated output", is not the maximum discharge rate; most batteries used to start engines are required to discharge at rates many times their standard rated output. When the actual hourly rate of a battery is unknown, an 8 hour rate must be assumed; for example, a 32 amp-hour battery is capable of supplying 32 - 8 = 4 amps to the load for 8 hours before becoming fully discharged. Additional examples for two commonly used lead-acid batteries are given in the table below.

Battery Designation	Ampere-hour Rating	Calculation	8 Hour Rate
MS3500-1 Type 2HN	45 Ampere-hours	45 - 8 = 5.62	5.62 Amperes
MS3500-3 Type 6TN	100 Ampere-hours	100 - 8 = 12.5	12.5 Amperes

"Rated capacity" of a battery is the number of amps the battery will supply at a specified temperature. The capacity of lead-acid batteries decreases with temperatures below 80 °F (26.7 °C). At -40 °F (-40 °C), the loss can be as much as 75 percent. Capacity can be improved and returned to normal, but only by increasing the temperature.

222.1.5 STATE-OF-CHARGE ASSURANCE. The state-of-charge of a battery at any point in time may be determined by various methods, but these methods may not accurately establish the length of time the battery will continue to operate at that state. Presently, the best assurance that a battery is in its optimal state-of-charge is obtained by subjecting the battery to cycles of charging and discharging (preconditioning) determined from previous experience to produce maximum output for the longest period of time. A general rule is to charge or recharge a battery in the final cycle so that the ampere hours put into the battery by charging are at least 1.25 times the battery's rated capacity in ampere-hours.

222.1.5.1 PRECONDITIONING OF LEAD-ACID BATTERIES.

a. Charge the batteries with a constant current* at the 8 hour rate (see 222.1.3) until the specific gravity of the electrolyte becomes constant for three consecutive 30-minute readings. Use a suitable hydrometer or optical tester to obtain the readings of each cell. A difference in readings between any two cells of .05 or more indicates a battery usually unsuitable for MIL-STD-705 cold starting tests.

   * Constant potential may be used provided battery electrolyte temperature is maintained below 130 °F (54.7 °C), or provided violent gassing is controlled by interrupting charging or by lowering the charging voltage. Violent gassing is evident if bubbles in the electrolyte occur at a rate of more than two per second, or if the diameter of any bubble exceeds 1/8 inch (3.2 mm).

b. The batteries shall then be discharged continuously at the 8 hour rate to a final terminal voltage equivalent to 1.75 volts per cell (1.75 x 6 = 10.5 volts for a 12-volt battery). At this point, specific gravity of each of the cells should be checked again, and readings should not differ by more than .05.
c. Repeat a.
d. Repeat steps b and a two additonal times.

222.1.5.2 PRECONDITIONING OF NI-CAD BATTERIES. NI-CAD Batteries generally are not affected by lower temperatures as much as lead-acid batteries are; however, NI-CAD batteries have other characteristics that, without preconditioning, can significantly reduce their performance at all temperatures.

Preconditioning of NI-CAD batteries prior to MIL-STD-705 testing differs considerably from the procedures used for lead-acid batteries. NI-CAD preconditioning consists of assuring that the process commonly referred to as "equalization" has been performed immediately prior to charging or recharging. Equalization corrects the condition referred to as "memory effect" and also corrects any imbalance among individual cells allowed or caused by the memory effect. Any voltage difference between cells of more than 0.10 volts indicates that equalization is not accomplished and may indicate the need for battery repair or replacement, if subsequent or repeated equalization does not correct the imbalance.

NI-CAD equalization procedures, as well as charging and discharging rates and equipment, differ among the models, types and styles of batteries. The applicable technical manual(s) or manufacturer's data or both should be consulted to determine proper procedures and equipment.

222.1.6 STABILIZATION PERIOD AFTER CHARGING. Batteries should be allowed to "sit" for approximately 24 hours after final charging and prior to use. Final state-of-charge determinations should also not be made until after this stabilization period. Throughout the stabilization period, the battery should be kept on a dry wooden board or similar material that electrically and chemically isolates the battery case from ground and surrounding material; battery terminals should be kept covered with suitable plastic caps, grease or wax; temperatures around the battery should be kept between 60 °F (15.6 °C) and 80 °F (26.7 °C); the battery exterior should remain dry, and the relative humidity around the battery should not exceed 65 percent.

222.1.7 INSTALLING BATTERIES IN GENERATOR SETS. Clean the battery posts and cable terminals thoroughly in accordance with the applicable technical manual(s) or manufacturer's data. Do not use a wire brush or other metal cleaning tools on NI-CAD battery posts. Nylon brushes, sand paper or emery cloth are recommended for cleaning NI-CAD battery posts.

After installation, apply approximately 1/8" (3 mm) thick coating of petroleum jelly, GAA compound or similar, completely covering the battery posts and cable terminals.

222.1.8 SOURCES OF ADDITIONAL INFORMATION ON BATTERIES. The following publications contain additional information and guidance on battery installation and maintenance. They are listed here for information only; they are not required for this MIL-HDBK-705 and are outside its scope.

- DA Pamphlet 750-34 Preventive Maintenance of Lead-Acid Batteries
- TM 11-6140-203-14-3 Technical Manual Nonaircraft Nickel-Cadmium Batteries

6. NOTES AND CONCLUDING MATERIAL

6.1 Notes. Not Applicable.

Custodians:
Army - ME
Navy - YD
Air Force - 99

Preparing activity:
Army - ME

Project 6115-0214

Review activities:
Army - CE, TE
Navy - AS

User activities:
Army - AT, ER
Navy - MC
Air Force - 11

LOAD BANKS

10. GENERAL

10.1 Scope. This appendix contains no mandatory requirements. It only provides general information and additional sources of information about load banks, mainly of the types used for evaluation and testing of electrical generator sets.

20. SOURCES OF ADDITIONAL INFORMATION

20.1 Government publications. The following documents contain information on some representative types of single-function (resistive and dual-function (combination resistive and reactive) load banks and their uses:

SPECIFICATIONS

MILITARY

MIL-T-4709	- Load Bank, Type A-1.
MIL-T-26922	- Test Set, Electrical Power A/M24T-8().
MIL-L-52366	- Load Bank, AC, 0-33KW Resistive.
MIL-D-82134	- Dummy Loads, Electrical 60/100 KW, 55/90 KVAR, 3 Phase, 60/400 Hertz, AC.

(Copies may be requested from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120).

20.2 Other publications.

Avtron Model T508E746 Load Bank Installation and Operation Instructions.

(Copies may be requested from Avtron Manufacturing, Inc., 10409 Meech Avenue, Cleveland, OH 44105) (FSCM 01014).

Manufacturers' data on load banks may also be requested from (but is not limited to) the following:

Essex Electro Engineers, Inc. - Bensenville, IL (FSCM 21269).
Sun Electric Corporation - Chicago, IL (FSCM 82386).
Technical Services Laboratory, Inc. - Ft. Walton Beach, FL (FSCM 51283).
UMC Electronics Co. - North Haven, CN (FSCM 22680).

30. DEFINITIONS

30.1 Government recognized definitions. The following DoD formally accepted definitions should be helpful in understanding various terms applied or related to load banks, and to contrast load banks to similar types of equipment. The characters in parentheses following each definition indicate its source. (H6 indicates Federal Item Name Directory for Supply Cataloging - Handbook H6; H300 indicates Technical Information File of Support Equipment - MIL-HDBK-300; IEEE indicates Institute of Electrical and Electronics Engineers Standard Dictionary of Electrical and Electronics Terms - Publication IEEE 100). Although there have been many exceptions, present general practice is to distinguish between the terms "dummy load" and "load bank" by considering "dummy loads" to be for radio frequency and microwave requirements, and "load banks" to be for AC power frequency and DC requirements.

30.1.1 Artificial load. A dissipative but essentially nonradiating device having the impedance characteristics of an antenna transmission line, or other practical utilization circuit. (IEEE)

30.1.2 Dummy load, electrical. A specific electrical element or set of electrical elements that are connected together to form a fixed arrangement and used as a substitute load for terminating an electrical circuit. A dummy load contains all the essential electrical characteristics necessary to terminate the circuit but does not function in the same manner as the load which it replaces. Examples are resistors used to replace antennas, batteries, loudspeakers, or the like. Includes single port terminations or twin lead, coaxial and waveguide transmission lines as low power terminations of a section of a transmission system in a specified manner. Includes conversational terminology for non catalog items. Includes dummy loads when arranged in a group or bank. Excludes power absorbers. See also "Load bank, electrical". (H6)

30.1.3 Dummy load (radio transmission). A dissipative but essentially non-radiating substitute device having impedance characteristics simulating those of the substituted device. See also: "Artificial Load; radio transmission"* (IEEE)

(*Note: IEEE Dictionary has no entry for the combined terms "Artificial load; radio transmission" - see "Artificial load.")

30.1.4 Dummy load group, electrical. A collection of items, that provide electrical dummy load facilities. (H6)

30.1.5 Load, dummy (artificial load). See "Dummy load." (IEEE)

30.1.6 Load bank, electrical. A set (bank) of electrical elements that are passive (resistive, inductive, capacitive) or active (motors, batteries). They are usually located adjacent to each other to form a consolidated set of any of these elements or any combination of them. A load bank is used to replace distributed or dispersed load elements contained in a power distribution system or electrical network for the purpose of providing a concentrated load. A load bank contains all the essential electrical characteristics necessary to terminate the circuit and functions in the same manner as the load which it is intended to replace. This description necessarily includes a bank of light bulbs or cone heating elements where energy conversion is primarily in the form of heat, although visible radiant energy is the natural result of incandescent heating. Load banks are intended to cover a specific range of characteristics and normally operate at DC or at power frequencies 50, 60, or 400 Hz AC. Load banks may be uninstrumented or complete with integral instrumentation and may also be furnished as skid or trailer mounted. Excludes "Test set, electrical"*. See also "Dummy load, electrical". (H6)

(*Note: H6 has no entry for "Test set, electrical"; see "Test set, electrical power".)

30.1.7 Simulator (1) (test, measurement and diagnostic equipment). A device or program used for test purposes which simulates a desired system or condition providing proper inputs and terminations for the equipment under test. (IEEE)

30.1.8 Support equipment. Support equipment is construed to include ground operation, handling, and servicing equipment. Support equipment is further defined as all equipment required in [on] the ground to make a weapon system operational in its intended environment. This includes all equipment required to install, launch, arrest (except Navy shipboard and shore based launching and arresting equipment), guide, control, direct, inspect, test, adjust, calibrate, appraise, gage, measure, assemble, disassemble, handle, transport, safeguard, store, actuate, service, repair, overhaul, maintain or operate the system, subsystem, or end item. (H300)

30.1.9 Support equipment (test, measurement and diagnostic equipment). Equipment required to make an item, system or facility operational in its environment. This includes all equipment required to maintain and operate the item, system or facility and the computer programs related thereto. (IEEE)

30.1.10 Test, measurement and diagnostic equipment (TMDE). Any system or device used to evaluate the operational condition of a system or equipment to identify and [or] isolate or both any actual or potential malfunction. (IEEE)

30.1.11 Test set, electrical power. A test set primarily designed for use in making examinations of electrical power generating or converting equipments and/or transmission systems. (H6)

30.2 Other terms and synonyms for load banks. Including most of the terms defined above, load banks have been cataloged under or as the following:

Artificial load
Dummy load, electrical
Dummy load group, electrical
Dummy load (radio transmission)
Load, test
Load test machine, generator
Load test set
Load, variable

Load assembly, simulated	Loadbank
Load bank, electrical	Test set, electrical
Load, dummy (artificial load)	Test set, electrical (load bank)
Load set	Test set, electrical power
Load simulator	Test set, electrical power (load bank)

40. GENERAL CHARACTERISTICS

40.1 Types of load banks associated with electrical power generators. Load banks can be appropriately categorized as "Support Equipment" and may be classified according to their principle(s) of operation as resistive, reactive or combination resistive and reactive.

Resistive type load banks directly convert all of the elctrical energy applied to them to heat.

Reactive types operate on the principle of either capacitance or inductance. (Reactive capacitance types of load banks create leading power factor conditions, and are not used with any MIL-HDBK-705 or MIL-STD-705 procedures or tests.) Reactive inductance types, also referred to as "impedence types", are used with MIL-HDBK-705 and MIL-STD-705 procedures and tests when lagging power factor conditions are required. Some of the electrical energy applies to reactive inductance load banks is converted to heat, but much of it is temporarily stored as magnetic energy, which can be reconverted to electrical energy and returned to the supply system.

Load banks vary from inexpensive, 2 cubic feet, under 100 pounds versions to high-value, 250 cubic feet, major equipment items weighing over 2000 pounds.

40.2 Uses of load banks. Load banks may be further classified according to their use or application as follows:

40.2.1 Parasitic load banks. Diesel engines with governors are used to drive some electrical generators and are selected according to the horsepower requirements and maximum thermal efficiency for generating at maximum electrical loads. Under conditions of less than maximum electrical loads, the governored engine's fuel burning efficiency declines and maintenance problems may occur due to lower engine temperatures, incomplete burning of fuel, and resulting carbon and sludge deposits. Parasitic load banks are used with diesel engine-driven generator sets to minimize these problems. These load banks are usually of the resistive type and are called "parasitic" because they are constantly connected to the output power circuit and are activated when actual power use requirements drop below pre-determined levels. Parasitic load banks may be either attached components of an electrical power generator set, or ancillary issued items which usually remain constantly with a particular generator set or group of sets. Parasitic loads may also be used during maintenance and service checks to verify generator set conditions under various load conditions.

40.2.3 Mobile load banks. These load banks may be resistive, reactive or combination resistive and reactive. Mobile load banks are mounted on wheeled, trailable carriages and are used for service and maintenance checks, inspection and testing. They may also be used as parasitic loads.

40.2.4 Portable and semi-portable load banks. Portable and semi-portable load banks may be resistive, reactive or combination resistive and reactive. Load banks such as the Avtron Model TE08E746 are generally used for evaluation and testing at designated power factors per MIL-HDBK-705 and MIL-STD-705, and are combination resistive and reactive semi-portable load banks. MIL-L-52366 "purely resistive" type portable load banks are also sometimes used, in conjunction with other "reactive only" types, for MIL-HDBK-705 and MIL-STD-705 evaluation and testing at power factors less than unity; MIL-L-52366 load banks are also used alone for MIL-HDBK-705 and MIL-STD-705 evaluation and testing at unity power factor. Portable and semi-portable load banks may be transported by man, vehicle, aircraft, railway car or marine vessel, depending on the size and weight of the load banks. They may also be used for the same purposes as parasitic and mobile load banks.

50. DETAIL CHARACTERISTICS

50.1 Load banks used for evaluation and testing per MIL-HDBK-705 and MIL-STD-705. Description, functional characteristics and quality assurance provisions extracted from a purchase description for a typical load bank used by the U.S. Government for generator set evaluation and testing are listed below. This information is intended to be an example and should be used only for guidance. Because generator set test conditions of "0.8 power factor, lagging" are required in many of the procedures, load banks used in conjuncton with those particular parts of MIL-HDBK-705 or MIL-STD-705 must provide reactive inductance loads. The capacity or load range of load banks must equal or be greater than the rated power output of the generator being evaluated or tested; therefore it is often necessary to connect load bank sections in series, parallel, or series-parallel to attain required loads. In three-phase circuits, balanced loading is provided by connecting equal load sections across the three generator line output terminals.

50.2 Description and funtional characteristics for a typical load bank.

50.2.1 Description. The load bank shall provide a 0 - 100% Kw resistive load and a 0 - 100% KVAR reactive load for each of the six conditions resulting from the connections of 120/208 volts or 240/416 volts at 50, 60, or 400 Hertz. A stepped selection of any balanced three phase load from 0 - 100% Kw and 0 - 100% KVAR shall be provided in addition to provisions for 100 percent unbalanced load on any phase. Additional infinite variation shall also be provided for the ranges between each of the steps. The load bank shall operate continuously without damage.

50.2.1.1 Load steps. The load bank steps shall be such that any load between 0 and 100% of the load bank rating can be obtained. An example of the steps of one phase of a typical load bank is as follows:

Step No.	Kw or KVAR (per phase).
1	0-3 1/3 (variable)
2	3
3	6
4	9
5	12
6	15
7	18
8	21
9	24
10	27
11	30
12	33
13	36

50.2.2 Operating environment temperatures and humidity. When equipped with all accessories and at specified loads within its rating, the load bank shall perform all its required functions at ambient temperatures of -54 °C and +52 °C at specified relative humidities.

50.2.3 Resistive elements. The resistive elements shall be fabricated from a corrosion-resistant, low resistance-temperature coefficient alloy wire having a change of cold to hot resistance as specified in the procurement document. The resistors shall be insulated from ground (1800 volts) and shall have a power factor greater than 0.995 at 400 Hertz. When individual coils are stretched to their installed length, there shall be at least three wire diameters clearance between adjacent coil turns.

50.2.4 Reactive elements. The reactors shall be of iron core construction with clearances which limit the flux density in the iron to at least fifty percent below the saturation point. Wave form distortion shall be less than one half of one percent. Power factor of the reactors shall be less than 0.05 at 400 Hertz. Reactor coils shall be tapped for use at 60 and 400 Hertz.

50.2.4.1 Temperature rises. Allowable temperature rise of windings shall not exceed the following:

Method	Type of Insulation per MIL-E-917		
	Class A	Class B	Class F
By thermometer	65 °C	75 °C	85 °C
By rise in resistance	75 °C	95 °C	105° C

50.2.5 Load tolerances. When rated voltages at 60 or 400 Hertz are applied, in each of the cases the resistive load shall be within two percent and the reactive load shall be within five percent of the control switch settings. Corresponding loads in each of the individual phases shall be balanced within three percent of each other (based on current).

50.2.6 Dielectric strength and insulation resistance. Reactive and resistive load elements shall withstand 1800 volts at a frequency of 60 Hertz applied between the member and ground for one minute. All other circuits shall withstand 1000 volts at 60 Hertz applied between the circuit and ground for one minute. The insulation resistance shall not be less than one megohm.

50.3 Quality assurance of reactive modes of a typical load bank for use in evaluation or acceptance testing of military generator sets. Accuracy and consistency of the load bank described in 50.2 above may be determined using the following equipment and methods. This equipment and these methods may also be used for assurance of similar reactive types or modes of load banks. Strict adherence to the applicable technical manual or load bank manufacturer's operating instructions should assure consistent test results.

50.3.1 Test instruments. Test instruments for measurement of load bank performance shall be accurate within plus or minus 0.0075 times the applicable U.S. National Bureau of Standards (NBS) reference or "master". Certification of this accuracy must be traceable to NBS. Evidence of calibration within 180 days or less prior to the completion date of the load bank testing, for which the instrument is to be (or was) used, shall be available for examination by the Government's inspection representative. Recalibration may be required for reasonable cause at any time by the Government's inspection representative. If immediately following a test, an instrument is determined to be "out of calibration", or to be not calibrated, the Government's inspection representative may require repetition of the test or portions thereof.

50.3.2 Tests. Each load bank shall be subjected to the following tests:

a. Insulation resistance and ability to withstand high voltage.
b. Reactor saturation.
c. Load balance.
d. Load control switch step markings.
e. Harmonic content.
f. Full load run.

50.3.2.1 Insulation resistance and ability to withstand high voltage. For this test, all over-voltage and frequency protection devices shall be disconnected. With all load contactors closed, measure the resistance with a standard megohm meter from each of the four load terminals to the ground. Ohmic resistance values of less than five megohms shall constitute failure of this test. A 60 Hertz potential of 1800 volts shall then be applied from each load terminal to ground (load bank ground connection); after one minute, then while still maintaining the 60 Hz, 1800 v potential, the leakage current shall be measured. Measurements obtained that are not within specified limits shall constitite failure of this test, as will any other evidence of insulation failure or damage. (ANSI or IEEE insulation "hi-pot" tests may be substituted for 50.3.2.1 if approval is obtained from the cognizant Government contracting officer.)

50.3.2.2 Reactor saturation. One of each size reactor used in the load bank shall be subjected to the following saturation test at 60 and 400 Hertz: Apply voltage to the reactor in steps of 20 volts from 0 - 160 volts. Record voltage applied and current drawn by the reactor. Plot voltage versus current. Any evidence of saturation (departure from a straight line voltage - current relationship) that is not within the specified limits shall constitute failure of this test.

50.3.2.3 Load balance. With the load bank connected for 120/208 volts, 60 Hertz, check the current balance for each load step of each reactive element. Vernier load is to be set at maximum value for each step. At each load step, determine by use of the vernier load if an overlap exists on the preceding load (line currents must be balanced). When this test is complete, reconnect the load bank for 240/416 volts, 60 Hertz and repeat the test. Repeat the test for both voltage connections using a 400 Hertz source. Under any of the load conditions, a difference in current between any two phases exceeding three percent of the lowest phase current, shall constitute failure of this test. Non-overlapping of load steps shall constitute failure of this test. This test may be conducted in conjunction with the test specified in 50.3.2.4.

50.3.2.4 Load control switch step markings. With the load bank connected for 120/208 volts, 60 Hertz, check the control panel resistive control switch markings for each step against the actual KVAR load. The vernier step shall be checked at 0, 1, 2, and 3 KVAR points. When this test is complete, reconnect the load bank for 240/416 volts, 60 Hertz, and repeat the test. Repeat the test for both voltage connections, using a 400 Hertz source. Under any of the load conditions, a difference of five percent between the control switch markings and the actual load shall constitute failure of this test. This test may be conducted in conjunction with the tests specified in paragraph 50.3.2.3.

50.3.2.5 Harmonic content. With all reactive load elements energized at 120 volts, 60 Hertz, determine for each harmonic (1st through 15th) its percent with respect to the fundamental frequency. Repeat the test with all the reactive load elements energized at 120 volts, 400 Hertz. Any harmonic exceeding two percent of the fundamental shall constitute failure of this test. If this test has previously been performed on reactors of identical design, the contractor may submit certified test data to the contracting officer through the Government's inspection representative, and upon approval, be relieved of running this test.

50.3.2.6 Full load run. The complete load bank (all circuits operative) shall be connected for 120/208 volts, 60 Hertz and operated at rated capacity* continuously for twelve hours. Any failure or damage or evidence of impending failure or damage during or after the twelve hour run shall constitute failure of this test. Prior to the start of this twelve hour run, the contracting officer's representative shall select one reactive load element on which the temperature rise shall be determined. Failure to meet the limits specified in paragraph 50.2.4.1 shall constitute failure of this test.

(* Rated capacity is that load which is produced with all load circuits energized at their maximum values and at nominal voltage.)

60. NOTES

60.1 Procurement documents must specify the following:

a. Cold to hot resistance limits - para 50.2.3.
b. Leakage current limits - para 50.3.2.1.
c. Saturation limits - para 50.3.2.2.

60.2 Air cooled load banks potentially subject to coil over-heating and damage from thermal shock. Cooling fan systems in air cooled load banks may be powered from the generator set through the load bank's internal circuitry, or externally from local utility line power. After using a load bank for a sustained period of time, it is usually advisable to gradually reduce the load settings and run the fans long enough afterwards to assure gradual and sufficient "cool-down" of heat-sensitive components within the load bank.

60.3 Operator's manuals. U.S. Army Technical Manuals (TM's), Air Force Technical Orders (AFTO's), Navy and Marine Corps manuals exist for many types of load banks. When the National Stock Number (NSN) of a specific load bank is known, determination of a specific or related manual can be made by consulting MIL-HDBK-300 or Department of the Army Pamphlet DA PAM 310-4. In cases where Government operator's manuals are unavailable, the applicable load bank manufacturer's manual or instructions should be used.

(Copies of MIL-HDBK-300 may be requested from the Naval Publications and Forms Center, 5801 Tabor Ave., Philadelphia, PA 19120. Non-government requests for information from DA PAM 310-4 may be made to the applicable Government representative.)

60.4 Future status of this appendix, and load banks in general. It is anticipated that a future consolidation of MIL-HDBK-705 and MIL-STD-705 into a single document without this appendix will result in the issuance of this appendix as a separate handbook or standard on Load Banks. It is also anticipated that new Federal Stock Classification (FSC) under Federal Stock Group (FSG) 61 will be established solely for Load Banks, in order to consolidate item management, facilitate standardization and item reduction studies, reduce proliferation of Load Banks amoung other FSG's and FSC's, and to insure their entries in the Support Equipment Register (MIL-HDBK-300).

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-HDBK-705C	Generator Sets, Electrical, Measurement and Instrumentation Methods

3a. NAME OF SUBMITTING ORGANIZATION

b. ADDRESS (Street, City, State, ZIP Code)

4. TYPE OF ORGANIZATION (Mark one)

- [ ] VENDOR
- [ ] USER
- [ ] MANUFACTURER
- [ ] OTHER (Specify): ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER (Last, First, MI) – Optional

b. WORK TELEPHONE NUMBER (Include Area Code) – Optional

c. MAILING ADDRESS (Street, City, State, ZIP Code) – Optional

8. DATE OF SUBMISSION (YYMMDD)