

An American National Standard
**IEEE Standard Test Code
for Dry-Type Distribution and
Power Transformers**

Sponsor

**Transformers Committee of the
IEEE Power Engineering Society**

Approved June 16, 1978

IEEE Standards Board

Secretariat

**Institute of Electrical and Electronics Engineers
National Electrical Manufacturers Association**

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Foreword

(This Foreword is not a part of ANSI/IEEE C57.12.91-1979, American National Standard Test Code for Dry-Type Distribution and Power Transformers.)

This standard with its companion standards represents a new milestone in standards for dry-type transformers, which are becoming increasingly important with the elimination of askarel insulation in new transformers.

Dry-type transformers have been served in the past by a variety of documents including ANSI/IEEE C57.12.00-1973, ANSI/IEEE C57.12.90-1973, NEMA TR 27-1965 (R 1971, 1976), and ANSI/NEMA Pub No ST 20-1972. This standard is the result of an effort encompassing the interests of users, manufacturers, and others dedicated to produce voluntary consensus standards primarily for dry-type transformers.

This new series of standards encompasses dry-type transformers with a high voltage of 601 V and above and includes product standards through 34.5 kV and 7500 kVA (three phase, self-cooled). These new standards have various and significant changes including higher BILs (for most voltages), more stringent and meaningful short-circuit requirements, improved descriptions of usual and unusual service conditions, and numerous other improvements. The arrangement of this new standard should be easier and more efficient to use since its organization takes account of the sequence in which information is normally needed. ANSI/IEEE C57.12.91-1979 includes customary units and adds metric (SI) units in accordance with ANSI policy.

This standard was prepared by the Standards Preparation Working Group of the Dry-Type Transformer Subcommittee of the Transformers Committee of the Institute of Electrical and Electronics Engineers, following which it was approved by the IEEE Dry-Type Transformer Subcommittee, the IEEE Transformers Committee, the IEEE Standards Board, and the American National Standard C57 Committee for Distribution and Power Transformers and Regulators. The applicable rules and procedures of IEEE and ANSI for the preparation and approval of voluntary consensus standards were followed. These specify procedures for voting, review, and attempted reconciliation of dissenting viewpoints, a sixty day public review period, final review, and approval by the ANSI Board of Standards Review.

This American National Standard is a voluntary consensus standard. Its use may become mandatory only when required by a duly constituted legal authority, or when specified in a contractual relationship. To meet specialized needs and to allow innovation, specific changes are permissible when mutually determined by the user and the producer, provided such changes do not violate existing laws and are considered technically adequate for the function intended.

Suggestions for improvement of this standard will be welcome. They should be sent to:

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An American National Standard

IEEE Standard Test Code for Dry-Type Distribution and Power Transformers

1. Scope

1.1 This standard describes methods for performing tests specified in ANSI/IEEE C57.12.01-1979, General Requirements for Dry-Type Distribution and Power Transformers, and other referenced standards applicable to dry-type distribution and power transformers. It is intended for use as a basis for performance, safety, and the proper testing of dry-type distribution and power transformers.

1.2 This standard applies to all dry-type transformers except instrument transformers, step-voltage and induction voltage regulators, arc furnace transformers, rectifier transformers, specialty transformers, and mine transformers.

1.3 When this standard is used on a mandatory basis, the words *shall* and *must* indicate mandatory requirements; the words *should* or *may* refer to matters that are recommended or permissive, but not mandatory.

NOTE: The Foreword of this voluntary consensus standard describes the circumstances in which the standard may be used on a mandatory basis.

2. Terminology

Standard transformer terminology available in ANSI/IEEE C57.12.80-1978, Terminology for Power and Distribution Transformers, shall apply. Other electrical terms are defined in ANSI/IEEE Std 100-1977, Dictionary of Electrical and Electronics Terms.

3. References

3.1 Various American National Standards and Guides and other standards are listed below. When referred to in this standard, references are identified only by number and year. (Examples: ANSI/IEEE C57.12.01-1979, IEEE Std 1-1969.)

3.2 When the American National Standards and Guides referred to in this standard are superseded by a revision approved by the American National Standards Institute, Inc, the latest revision shall apply.

ANSI/IEEE Std 100-1977, American National Standard Dictionary of Electrical and Electronics Terms.

ANSI/IEEE C57.12.01-1979, American National Standard General Requirements for Dry-Type Distribution and Power Transformers.

ANSI/IEEE C57.12.70-1964 (R 1971), American National Standard Terminal Markings and Connections for Distribution and Power Transformers.

ANSI/IEEE C57.12.80-1978, American National Standard Terminology for Power and Distribution Transformers.

ANSI/IEEE C57.98-1968, American National Standard Guide for Transformer Impulse Tests, (Appendix to C57.12.90-1968).

ANSI S1.4-1971 (R 1976), American National Standard Specification for Sound Level Meters.

ANSI S1.11-1966 (R 1976), American National Standard Specifications for Octave, Half-Octave, and Third-Octave Band Filter Sets.

IEEE Std 4-1978, Standard Techniques for High Voltage Testing.

IEEE Std 99-1970, Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment.

3.3 Applicable Documents in Preparation¹

4. General

4.1 Test Definitions. Various types of tests ("routine," "design," "other," and "conformance" tests are defined in ANSI/IEEE C57.12.80-1978.

4.2 Test Requirements. A general summary of test requirements is included in ANSI/IEEE C57.12.01-1979, Table 7, which indicates by size (500 kVA and smaller, or 500 kVA and larger) which tests are normally considered as "routine," "design," or "other."

4.3 Purpose. The purpose of this standard is to provide test procedure information. Transformer requirements and specific test criteria are not a part of this standard but are contained in appropriate American National Standards, such as ANSI/IEEE C57.12.01-1979, or in user specifications.

4.4 Test Sequence. See 10.1.5.4 for sequence of dielectric tests when lightning impulse or switching impulse tests are specified.

NOTE: If it is desired to minimize potential damage to the transformer during testing, the resistance, polarity, phase-relation, ratio, no-load-loss and excitation current, impedance, and load-loss tests and temperature-rise tests (when applicable) should precede dielectric tests. When this sequence is used, the beginning tests involve voltages and currents that are usually reduced compared to rated values, thus tending to minimize damaging effects to the transformer.

¹ When the following documents are completed, approved and published, they become a part of this listing.

[1] Distribution and Power Transformer Short-Circuit Test Guide. (To be published in the ANSI C57 Series.)

[2] Requirements for Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase; and 15 to 500 kVA, Three-Phase; with High-Voltage 2400–34 500 Volts, C57.12.50.

[3] Requirements for Ventilated Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase, with High-Voltage 2400–34 500 Volts, C57.12.51.

[4] Requirements for Sealed Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase; with High-Voltage 2400–34 500 Volts, C57.12.52.

4.5 Instrumentation. Although the figures in this standard show conventional meters, adequate digital-readout measuring devices are considered as satisfactory alternatives.

5. Resistance Measurements

5.1 Importance of Measurements. Resistance measurements are of fundamental importance for three purposes:

- (1) For the calculation of the I^2R component of conductor losses
- (2) For the calculation of winding temperatures at the end of a temperature test
- (3) As a base for assessing possible damage in the field

5.2 Determination of Cold Temperature. The cold temperature of the winding shall be determined as accurately as possible when measuring the cold resistance. The precautions given in 5.2.1 and 5.2.2 shall be observed.

5.2.1 General. Cold-resistance measurements shall not be made on a transformer when it is located in drafts or when it is located in a room in which the temperature is fluctuating rapidly.

5.2.2 Transformer Windings. The temperature of the windings shall be recorded as the average readings of several thermometers or thermo-couples inserted between the coils, with care used to see that their measuring points are as nearly as possible in actual contact with the winding conductors. It should not be assumed that the windings are at the same temperature as the surrounding air.

5.2.2.1 The temperature of the windings may be considered equal to the ambient air temperature provided the transformer has been in a draft-free area for 24 hours and provided that neither voltage nor current has been applied to it for 24 to 72 hours, depending on size.

5.3 Conversion of Resistance Measurements. Cold winding resistance measurements are normally converted to a standard reference temperature equal to rated average winding temperature rise plus 20°C. In addition, it may be necessary to convert the resistance measurements to the temperature at which the impedance-loss measurements were made. The conversions are accomplished by the following formula:

$$R_s = R_m \left(\frac{T_s + T_k}{T_m + T_k} \right)$$

where

- R_s = resistance at desired temperature T_s
 R_m = measured resistance
 T_s = desired reference temperature
 T_m = temperature at which resistance was measured
 T_k = 234.5 for copper
 T_k = 225 for aluminum, EC

NOTE: The value of T_k may be as high as 230 for alloyed aluminum.

5.4 Resistance Measurement Methods

5.4.1 Bridge Method. Bridge methods (or high-accuracy digital instrumentation) are generally preferred because of their accuracy and convenience, since they may be employed for the measurement of resistances up to 10 000 Ω . They should be used in cases where the rated current of the transformer winding to be measured is less than 1 ampere.

NOTE: For resistance values of 1 Ω or more a Wheatstone bridge (or equivalent) is commonly used; for values less than 1 Ω a Kelvin bridge (or equivalent) is commonly used. Some modern resistance bridges have capability in both ranges.

5.4.2 Voltmeter–Ammeter Method. The voltmeter–ammeter method is sometimes more convenient than the bridge method. It should be employed only if the rated current of the transformer winding is 1 ampere or more. Digital voltmeters and digital ammeters of appropriate accuracy are commonly used in connection with temperature-rise determinations.

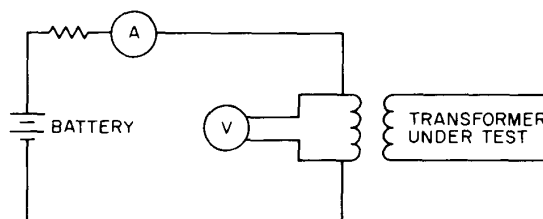
5.4.2.1 Measurement is made with direct current, and simultaneous readings of current and voltage are taken using the connections of Fig 1. The required resistance is calculated from the readings in accordance with Ohm's law. A battery or filtered rectifier will generally be found to be more satisfactory as a dc source than will a commutating machine. The latter may cause the voltmeter pointer to vibrate because of voltage ripple.

5.4.2.2 In order to minimize errors of observation:

- (1) The measuring instruments shall have such ranges as will give reasonably large indication.
- (2) The polarity of the core magnetization shall be kept constant during all resistance readings.

NOTE: A reversal in magnetization of the core can change the time constant and result in erroneous readings.

Fig 1
Connections for the Voltmeter–Ammeter Method of Resistance Measurement



5.4.2.3 The voltmeter leads shall be independent of the current leads and shall be connected as closely as possible to the terminals of the winding to be measured. This is to avoid including in the reading the resistances of current-carrying leads and their contacts and of extra lengths of leads.

To protect the voltmeter from injury by off-scale deflections, the voltmeter should be disconnected from the circuit before the current is switched *on* or *off*. To protect test personnel from "inductive kick," the current should be switched off by a suitably insulated switch.

If the drop of voltage is less than 1 volt, a potentiometer or millivoltmeter shall be used.

5.4.2.4 Readings shall not be taken until after the current and voltage have reached steady-state values.

When measuring the cold resistance preparatory to making a heat run, the time required for the readings to become constant should be noted. The period thereby determined should be allowed to elapse before taking the first reading when final winding hot-resistance measurements are being made.

In general, the winding will exhibit a long dc time constant. To reduce the time required for the current to reach its steady-state value, a noninductive external resistor should be added in series with the dc source. The resistance should be large compared to the inductance of the winding. It will then be necessary to increase the source voltage to compensate for the voltage drop in the series resistor. The time will also be reduced by operating all other transformer windings open circuited during the tests.

5.4.2.5 Readings shall be taken with not less than four values of current when deflecting instruments are used. The average of the resistances calculated from these measurements shall be considered to be the resistance of the circuit.

The current used shall not exceed 15 percent of the rated current of the winding whose resistance is to be measured. Larger values may cause inaccuracy by heating the winding and thereby changing its temperature and resistance.

If the current is too low to be read on a deflecting ammeter, a shunt and digital millivoltmeter or potentiometer shall be used.

6. Polarity and Phase-Relation Tests

6.1 **General.** Polarity and phase-relation tests are of interest primarily because of their bearing on paralleling or banking two or more transformers. Phase-relation tests are made to determine angular displacement and relative phase sequence.

6.2 Polarity Tests -- Single-Phase Transformers

6.2.1 **Polarity Tests.** Polarity tests on single-phase transformers are commonly made in accordance with one of the following methods:

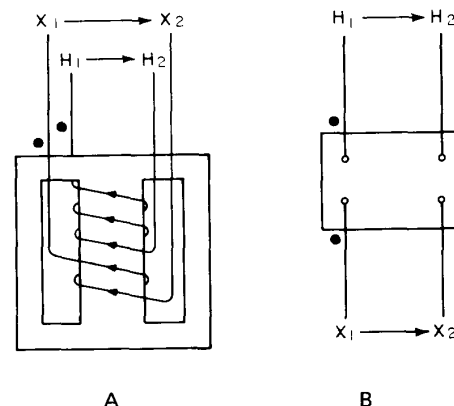
- (1) Inductive kick
- (2) Alternating voltage
- (3) Comparison
- (4) Ratio bridge

6.2.2 **Polarity by Inductive Kick.** The polarity of transformers with leads arranged as shown in Fig 2, A and B, may be determined at the time of making the resistance measurements as follows:

(1) With direct current passing through the high-voltage winding, connect a high-voltage direct-current voltmeter across the high-voltage winding terminals so as to get a small deflection of the pointer.

(2) Transfer the voltmeter lead connected to H_1 to X_1 and that connected to H_2 to X_2 .

Fig 2
Polarity by Inductive Kick Test



(3) Break direct-current excitation, thereby inducing a voltage in the low-voltage winding (inductive kick) that will cause a deflection in the voltmeter, which is interpreted in (4) and (5) below.

(4) If the pointer swings in the opposite direction (negative), the polarity is subtractive.

(5) If the pointer swings in the same direction as before (positive), the polarity is additive.

6.2.3 Polarity by Alternating-Voltage Test.

For transformers having a ratio of transformation of 30 to 1 or less, the H_1 lead shall be connected to the adjacent low-voltage lead. (In Fig 3, this will be X_1 .) Any convenient value of alternating voltage shall be applied to the full high-voltage winding and readings taken of the applied voltage and the voltage between the right-hand adjacent high-voltage and low-voltage leads.

If the latter reading is greater than the former, the polarity is additive.

If the latter voltage reading is less than the former (indicating the approximate difference in voltage between that of the high-voltage and low-voltage windings), the polarity is subtractive.

6.2.4 Polarity by Comparison. When a transformer of known polarity and of the same ratio as the unit under test is available, the polarity can be checked by comparison, as follows, similar to the comparison method used for the ratio test. (See Figs 6 and 7.)

(1) Connect the high-voltage windings of both transformers in parallel by connecting similarly marked leads together.

(2) Connect also the low-voltage leads, X_2 , of both transformers together, leaving the X_1 leads free.

(3) With these connections, apply a reduced value of voltage to the high-voltage windings and measure the voltage between the two free leads.

A zero or negligible reading of the voltmeter will indicate that the relative polarities of both transformers are identical.

An alternative method of checking the polarity is to substitute a low-rated fuse or suitable lamps for the voltmeter.

This procedure is recommended as a precautionary measure before connecting the voltmeter.

6.2.5 Polarity by Ratio Bridge. The ratio bridge described in Section 7 can also be used to test polarity.

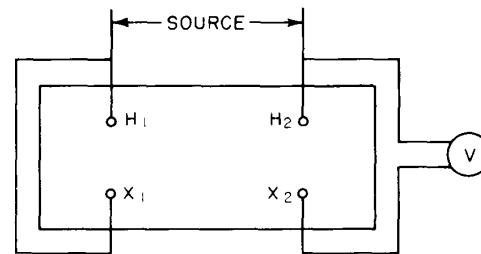


Fig 3
Polarity by Alternating-Voltage Test

6.3 Polarity and Phase-Relation Tests -- Polyphase Transformers

6.3.1 Polarity of Polyphase Transformers.

Each phase of a polyphase transformer shall have the same relative polarity when tested in accordance with one of the methods described for single-phase transformers.

6.3.2 Phase-Relation Tests

6.3.2.1 Test for Phasor Diagram for Transformers with a Ratio of Transformation of 30 to 1 or Less. The phasor diagram of any three-phase transformer, defining both the angular displacement and phase sequence, can be verified by connecting the H_1 and X_1 leads together, exciting the unit at a suitably low, three-phase voltage, taking voltage measurements between various pairs of leads, and then either plotting these values or comparing them for their relative order of magnitude with the help of the corresponding diagram in Fig 4 or 5, in which typical check measurements to be taken and their relative magnitudes are also indicated.

6.3.2.2 Test of Phase Relation with Ratio Bridge. The ratio bridge described in Section 7 can also be used to test phase relationships.

6.3.3 Phase-Sequence Test. The phase-sequence indicator may incorporate either a three-phase induction motor or a split-phase circuit.

It should be connected first to the higher voltage leads, the transformer excited three-phase at a low voltage suitable for the indicator, and the direction of rotation of the indication of the instrument noted.

The indicator is then transferred to the low-voltage side of the transformer, connecting to

X_1 the lead that was connected to H_1 , connecting to X_2 the lead that was connected to H_2 , and connecting to X_3 the lead that was connected to H_3 .

The transformer is again excited at a suitable voltage (without changing the excitation connections) and the indication again noted.

The phase sequence of the transformer is correct if the indication is the same in both cases.

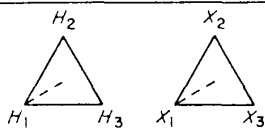
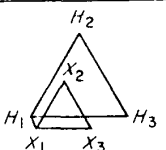
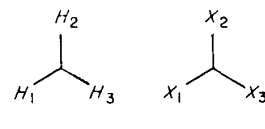
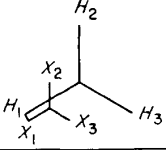
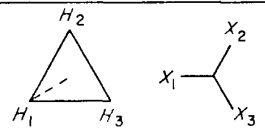
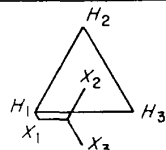
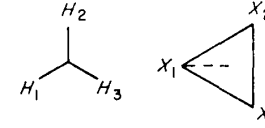
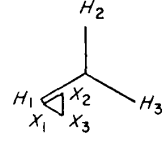
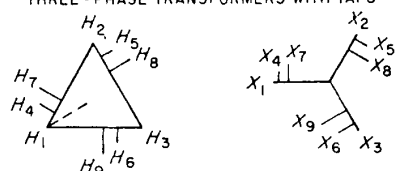
Six-phase secondaries, having no neutral connection, have to be connected temporarily in delta (Δ) or wye (Y) for this test also. If a six-

phase neutral is available, the phase-sequence indicator leads should be transferred from H_1 to X_1 , from H_2 to X_3 , from H_3 to X_5 , respectively, and the direction of rotation noted. The tests should then be repeated by transferring from H_1 to X_2 , from H_2 to X_4 , and from H_3 to X_6 , respectively, and noting the indication, which should be the same as before.

6.3.3.1 The preceding method (phase-sequence test) does not disclose the angular displacement of the transformer.

6.3.3.2 The ratio bridge described in Section 7 can also be used to test phase-sequence.

Fig 4
Transformer Lead Markings and Voltage-Phasor Diagrams for
Three-Phase Transformer Connections

	ANGULAR DISPLACEMENT	DIAGRAM FOR CHECK MEASUREMENT	CHECK MEASUREMENTS
GROUP 1 ANGULAR DISPLACEMENT 0 DEGREES	 DELTA-DELTA CONNECTION		CONNECT H_1 TO X_1 MEASURE $H_2-X_2, H_3-X_3,$ H_1-H_2, H_2-X_3 VOLTAGE RELATIONS (1) $H_2-X_3 = H_3-X_2$ (2) $H_2-X_2 < H_1-H_2$ (3) $H_2-X_2 < H_2-X_3$
	 Y-Y CONNECTION		
GROUP 2 ANGULAR DISPLACEMENT 30 DEGREES	 DELTA-Y CONNECTION		CONNECT H_1 TO X_1 MEASURE $H_3-X_2, H_3-X_3,$ $H_1-H_3, H_2-X_2, H_2-X_3$ VOLTAGE RELATIONS (1) $H_3-X_2 = H_3-X_3$ (2) $H_3-X_2 < H_1-H_3$ (3) $H_2-X_2 < H_2-X_3$ (4) $H_2-X_2 < H_1-H_3$
	 Y-DELTA CONNECTION		
	THREE-PHASE TRANSFORMERS WITH TAPS 		

7. Ratio Tests

7.1 General. The turn ratio of a transformer is the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding.

7.1.1 When a transformer has taps for changing its voltage ratio, the turn ratio is based on the number of turns corresponding to the normal rated voltage of the respective windings to which operating and performance characteristics are referred.

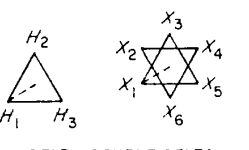
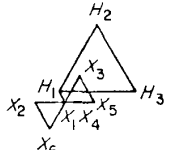
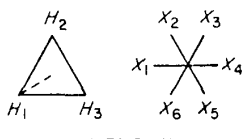
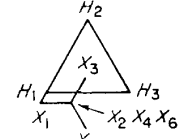
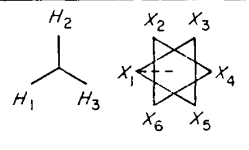
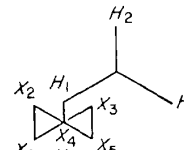
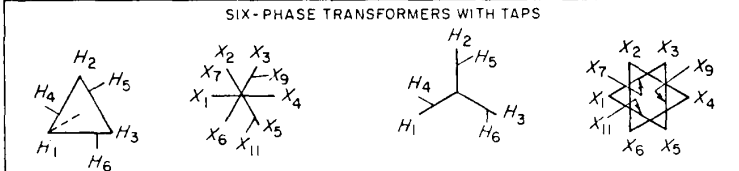
If the transformer has taps, the turn ratio shall be determined for all taps as well as for the full winding.

7.1.2 The ratio test shall be made at rated or lower voltage and rated or higher frequency.

7.1.3 In the case of three-phase transformers when each phase is independent and accessible, single-phase power should preferably be used, although when convenient, three-phase power may be used.

7.1.4 Transformers that have Y-diametric connections but do not have the neutral of the Y brought out shall be tested for ratio with three-phase power. Any inequality in the magnetizing characteristics of the three phases will then result in a shift of the neutral, thereby causing unequal diametric voltages. When such inequality is found, the diametric connection should be changed to either Δ or Y connection and the line voltages measured. If these are

Fig 5
Transformer Lead Markings and Voltage-Phasor Diagrams
for Six-Phase Transformer Connections

	ANGULAR DISPLACEMENT	DIAGRAM FOR CHECK MEASUREMENT	CHECK MEASUREMENTS
GROUP 1 ANGULAR DISPLACEMENT 0 DEGREES	 DELTA-DOUBLE DELTA		CONNECT H_1 TO X_1 TO X_4 MEASURE $H_2-X_3, H_1-H_2, H_2-X_5, H_2-X_6,$ $H_3-X_2, H_2-X_2, H_3-X_3$ VOLTAGE RELATIONS (1) $H_2-X_5 = H_3-X_3$ (4) $H_2-X_6 = H_3-X_2$ (2) $H_2-X_3 < H_1-H_2$ (5) $H_2-X_6 > H_1-H_2$ (3) $H_2-X_3 < H_2-X_5$ (6) $H_2-X_2 < H_2-X_6$
GROUP 2 ANGULAR DISPLACEMENT 30 DEGREES	 DELTA DIAM		CONNECT X_2 TO X_4 TO X_6 H_1 TO X_1 MEASURE $H_3-X_3, H_3-X_5, H_1-H_3, H_2-X_3,$ H_2-X_5 VOLTAGE RELATIONS (1) $H_3-X_3 = H_3-X_5$ (2) $H_3-X_3 < H_1-H_3$ (3) $H_2-X_3 < H_2-X_5$
	 Y-DOUBLE DELTA		CONNECT H_1 TO X_1 TO X_4 MEASURE $H_3-X_3, H_3-X_5, H_1-H_3, H_2-X_3,$ $H_2-X_5, H_3-X_2, H_3-X_6, H_2-X_2, H_2-X_6$ VOLTAGE RELATIONS (1) $H_3-X_3 = H_3-X_5$ (2) $H_3-X_3 < H_1-H_3$ (3) $H_2-X_3 < H_2-X_5$ (4) $H_3-X_2 = H_3-X_6$ (5) $H_3-X_2 > H_1-H_3$ (6) $H_2-X_2 < H_2-X_6$
SIX-PHASE TRANSFORMERS WITH TAPS 			

found to be equal to each other and of proper value (1.73 times the diametric voltages if connected in Y), the ratio is correct.

7.2 Tolerances for Ratio. See ANSI/IEEE C57.12.01-1979, Section 9.

7.3 Ratio Test Methods

7.3.1 Voltmeter Method. Two voltmeters shall be used (with voltage transformers if necessary), one to read the voltage of the high-voltage winding, the other that of the low-voltage winding. The two voltmeters shall be read simultaneously.

A second set of readings shall be taken with the instruments interchanged, and the average of the two sets of readings taken to compensate for instrument errors.

Voltage transformer ratios should be such as to yield about the same readings on the two voltmeters; otherwise compensation for instrument errors by an interchange of instruments will not be satisfactory, and it will be necessary to apply appropriate corrections to the voltmeter readings.

Tests shall be made at not less than four voltages in approximately 10 percent steps, and the average result shall be taken as the true value. These several values should check within 1 percent. Otherwise, the tests shall be repeated with other voltmeters.

If appropriate corrections are applied to the voltmeter readings, tests may be made at only one voltage.

When several transformers of duplicate rating are to be tested, work may be expedited by applying the foregoing tests to only one unit and then comparing the other units with this one as a standard, in accordance with the comparison transformer method discussed in 7.3.2.

7.3.2 Comparison Method. A convenient method of measuring the ratio of a transformer is by comparison with a transformer of known ratio.

The transformer to be tested is excited in parallel with a transformer of the same nominal ratio, and the two secondaries are connected in parallel but with a voltmeter or detector in the connection between two terminals of similar polarity (Fig 6). This is the more accurate method because the voltmeter or detector indicates the difference in voltage.

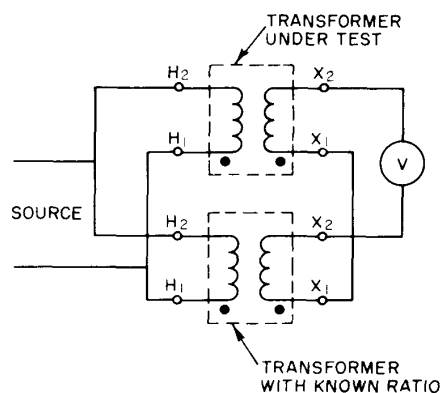
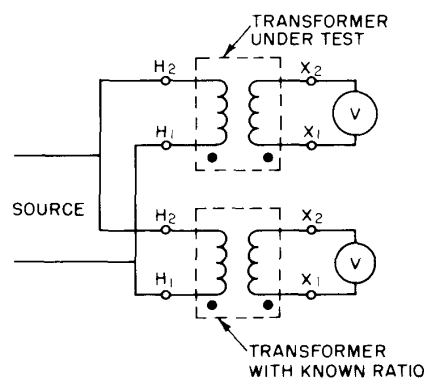


Fig 6
Voltmeter Arranged to Read the Difference
between the Two Secondary Voltages



(Readings are repeated after interchanging voltmeters.)

Fig 7
Voltmeters Arranged to Read the Two
Secondary Voltages

7.3.2.1 For an alternate method the transformer to be tested is excited in parallel with a transformer of known ratio, and the voltmeters are arranged to measure the two secondary voltages (Fig 7).