Chapter VI

TRANSFORMER TESTING

A transformer is tested to make certain that it has been properly designed and constructed to meet the specified requirement.

According to the specification No 76-1967 of IEC Recommendation Publication, the test schedules are listed as follows.

6.1 Measurement of winding resistance

6.2 Measurement of voltage ratio

6.3 Measurement of load loss and impedance voltage

6.4 Measurement of no-load loss and exciting current

6.5 Dielectric Test

6.5.1 Insulation-resistance Measurement

6.5.2 Induced-Potential Test (High frequency)

6.6 Measurement of secondary output voltage wave shape.

6.1 Measurement of winding resistance.

Resistance measurements precede all other tests because the other may possibly heat the windings slightly with a consequent change in resistance. It is most accurately measured by the Wheatstone bridge. The principal precaution to be taken is to make sure that the temperature of the winding is known. In oil-filled transformer the winding can usually be assumed to be at the oil temperature. The resistances of high and low winding with temperature are shown below.

Resistances of high voltage winding at 29°C = 23690 ohms

Resistances of low voltage winding at 29°C = 0.055 ohms

6.2 Measurement of Voltage Ratio

Ratio Tests are usually performed first since they determine whether or not the proper number of turns have been wound into a particular winding, and are made before the core and coils are assembled into the tank, since these tests can be made without oil. This, of course, saves the time and expense involved in dismantling a completed transformer if the ratio were incorrect. The connection for the ratio test is shown in Fig. 6.1.

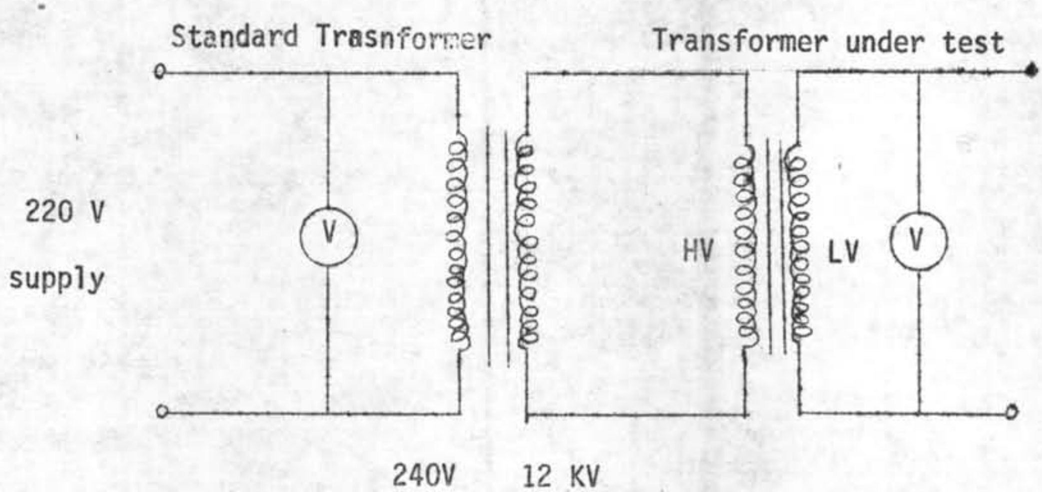

Fig 6.1 The connection for the ratio test

Test result

Voltages at primary low voltage = 26.6 volts

Voltages at secondary high voltage = 12,000 volts

From the rated voltage

Voltages at primary low voltage = 26.4 volts

Voltages at secondary high voltage = 12,000 volts

The slightly errors in ratio test is in limit of validity.

6.3 Measurement of load loss and impedance voltage.

Connections are made as shown in Fig. 6.2 . The low voltage side of the transformer is short-circuited through an ammeter. The reduced voltage on the input is varied until normal current flows through either side of the winding. Under these conditions the equivalent impedance of the transformer is equal to the ratio of $\frac{V_1}{I_1}$. In as much as any impedance in the secondary produces an effect on the magnitude of the short-circuit current, the impedance so determined is the equivalent value in terms of the input side. The resistance of the windings can be obtained roughly by measurement with direct current or from the readings of the wattmeter and ammeter. For the latter,

$$R_e' = \frac{\text{Watts}}{I_1^2}$$

Such a determination includes the stray losses; these are usually neglible. The total input for this test represents the copper losses in both windings.

With the equivalent impedance and resistance both determined in terms of the input, the equivalent reactance is

$$X_e' = \sqrt{(Z_e')^2 - (R_e')^2}$$

Or, from short-circuit data,

$$X_e' = \sqrt{\left(\frac{V_1}{I_1}\right)^2 - \left(\frac{W}{I_1^2}\right)^2}$$

This process considers the transformer in term of a simple, equivalent series circuit with no parallel magnetizing branch.

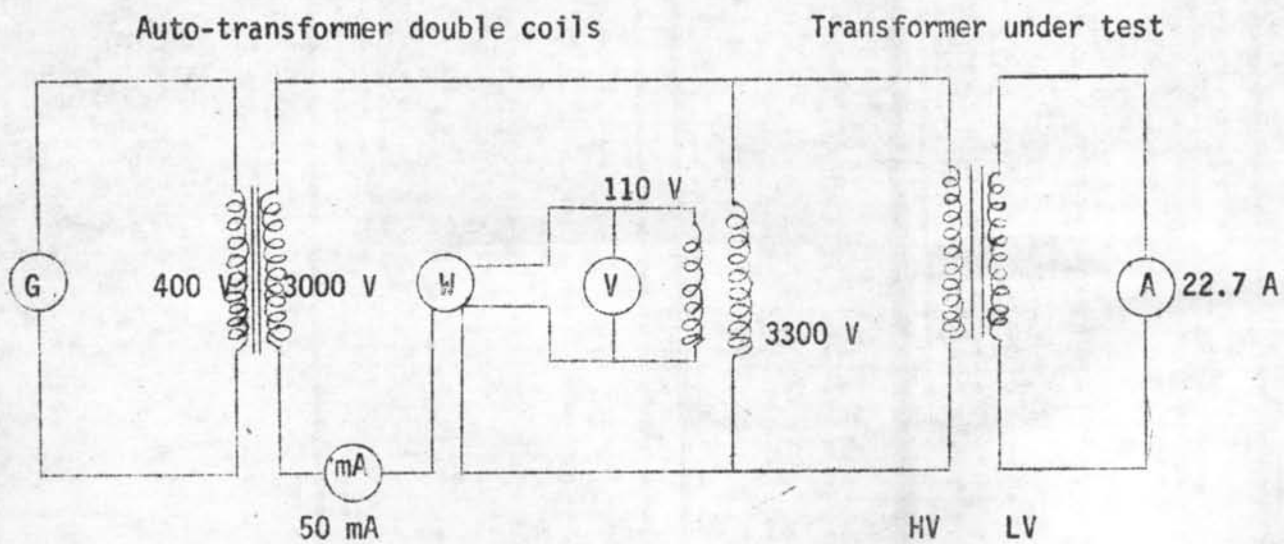

Fig. 6.2 Connection for the shortcircuit test.

Apparatus required

1. Auto-transformer double coil 300 KVA 400 V/300 V
2. Wattmeter
3. A.C. milliammeter
4. Voltmeter
5. Portable Potential Transformer 3300 V/110 V
6. A.C. ammeter

Test procedure

1. Connect the circuit as shown in Fig. 6.2
2. Short the low-voltage winding
3. Raise the voltage until the milliammeter read 50 mA

4. Record the voltage and watt from voltmeter and wattmeter respectively.

Test result

Ambient temperature	= 29°C
Short-circuit test voltage (V_1)	= 2631 volts
Short-circuit test current (I_1)	= 50 mA
Short-circuit test watt (W)	= 73 watts

equivalent resistance at 29°C

$$= \frac{W}{I_1^2}$$

$$= \frac{73}{(50 \times 10^{-3})^2}$$

$$= 29{,}200 \text{ ohms}$$

and equivalent impedance at 29°C

$$= \frac{V_1}{I_1}$$

$$= \frac{2631}{50 \times 10^{-3}}$$

$$= 52{,}630 \text{ ohms}$$

and equivalent reactance at 29°C

$$= \sqrt{(Z_{tp})^2 - (R_{tp})^2}$$

$$= \sqrt{(5.26 \times 10^4)^2 - (2.92 \times 10^4)^2}$$

$$= 43{,}800 \text{ ohms}$$

Impedance voltage at 29°C

$$= \frac{I_1 Z_{tp}}{E_p} \times 100 \%$$

$$= \frac{50 \times 10^{-3} \times 52{,}630}{100{,}000}$$

$$= 2.63 \%$$

6.4 Measurement of no-load loss and exciting current

If normal voltage and frequency are applied to one winding of a transformer and if the other winding or windings are "open-circuited", the watts input represent hysteresis and core eddy-current losses, I^2r loss in the winding to which the voltage is applied, and dielectric losses in the insulation. Since the no-load current is relatively small, it is usually unnecessary to substract the I^2rloss which it causes; consequently the no-load input can be taken as a measure of the core loss with fair accuracy. This loss remains constant at all loads. A diagram of connections is shown in Fig. 6.3 . On this connection the wattmeter reads the loss in the voltage coil of its own meter and in the voltmeter. To eliminate this error, if the low voltage winding is opened and the wattmeter read, this second reading may be substracted from the previous reading to obtain the correct no-load loss. Such an error is appreciable in testing small transformers.

Apparatus required

1. Variac
2. Wattmeter
3. Ammeter
4. Voltmeter

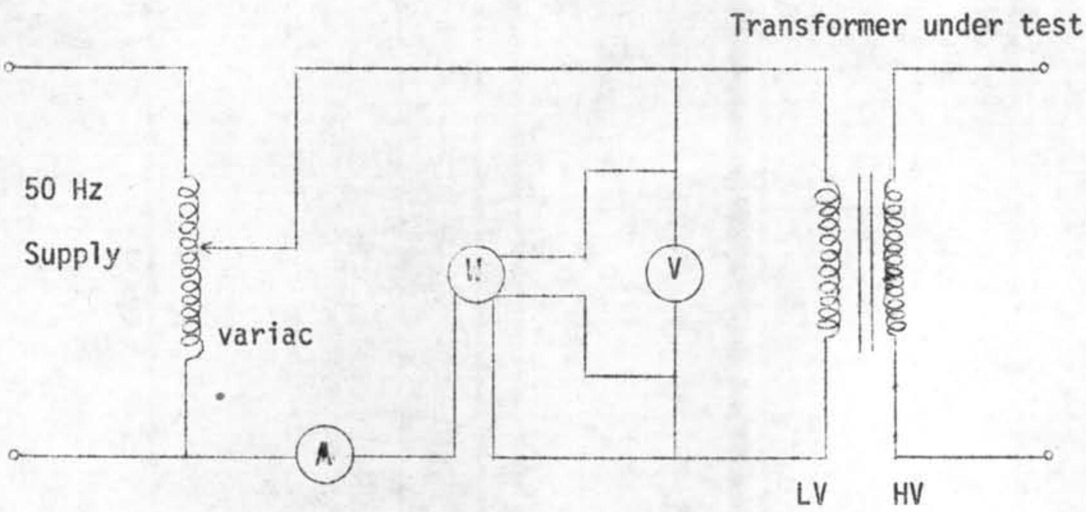

Fig. 6.3 Connection for the open-circuit test

Test procedure

1. Connect the circuit as shown in Fig. 6.3 .
2. Raise the voltage on low-voltage winding to 220 volts.
3. Read ampere, watt and voltage from ammeter, wattmeter and voltmeter respectively and then record.
4. Open the low-voltage winding to find the tare value of of wattmeter and ammeter.
5. To find the values of amperes and watts when varying the voltage, do as the previous method.

Test result

The exciting current and core loss from open circuit test are shown in table below and Fig. 6.4, 6.5

Input voltage (volts)	No-load current (amperes)	No-load loss (watts)
110	0.317	26.00
132	0.400	36.48
154	0.460	51.60
176	0.470	65.60
198	0.480	83.60
220	0.70	105.00
231	0.80	117.00
242	0.910	128.40
253	1.120	143.00
264	1.350	158.00
275	1.750	182.60
286	2.600	218.00
294	3.150	240.00

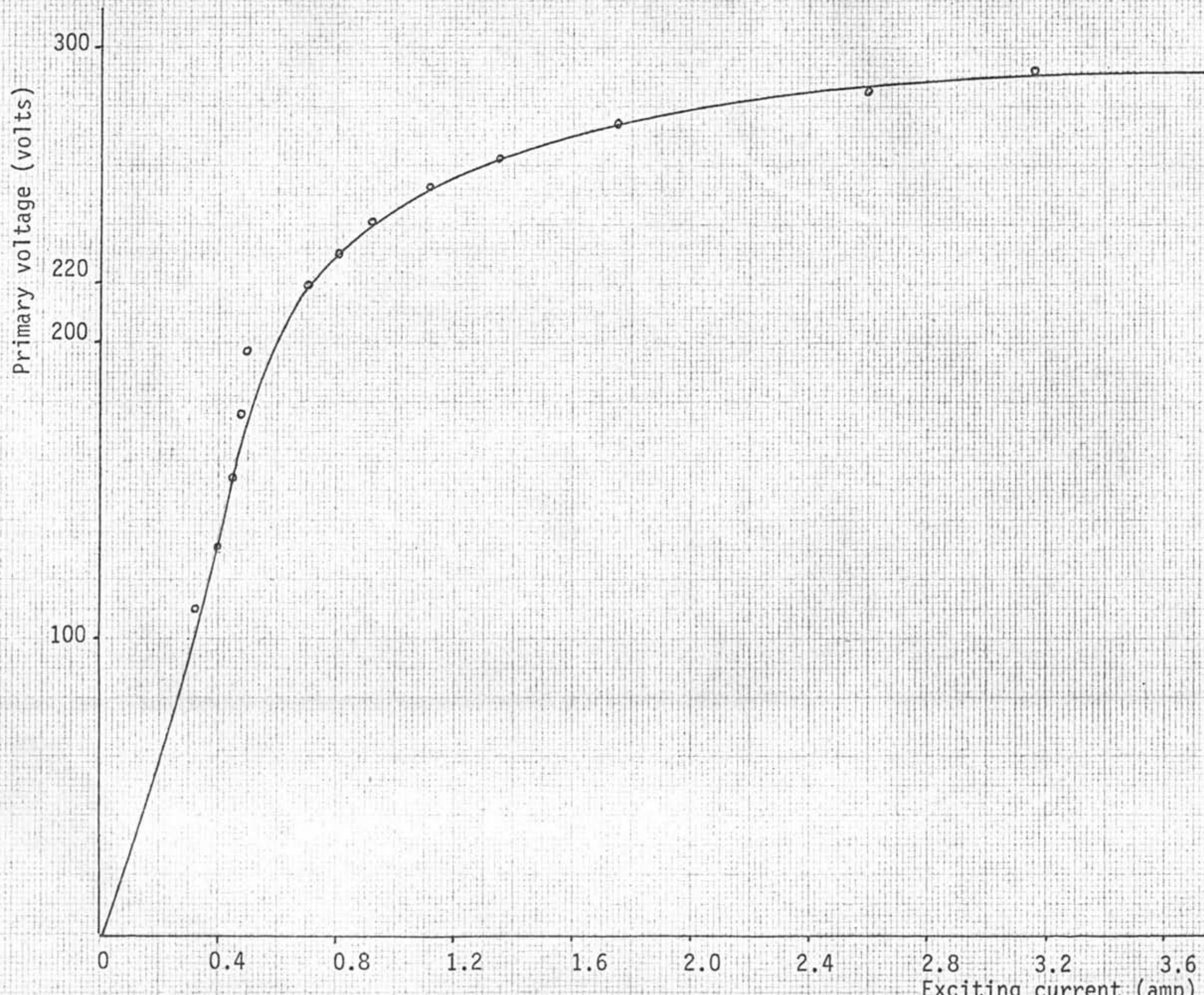

Fig. 6.4 Exciting Current Curve

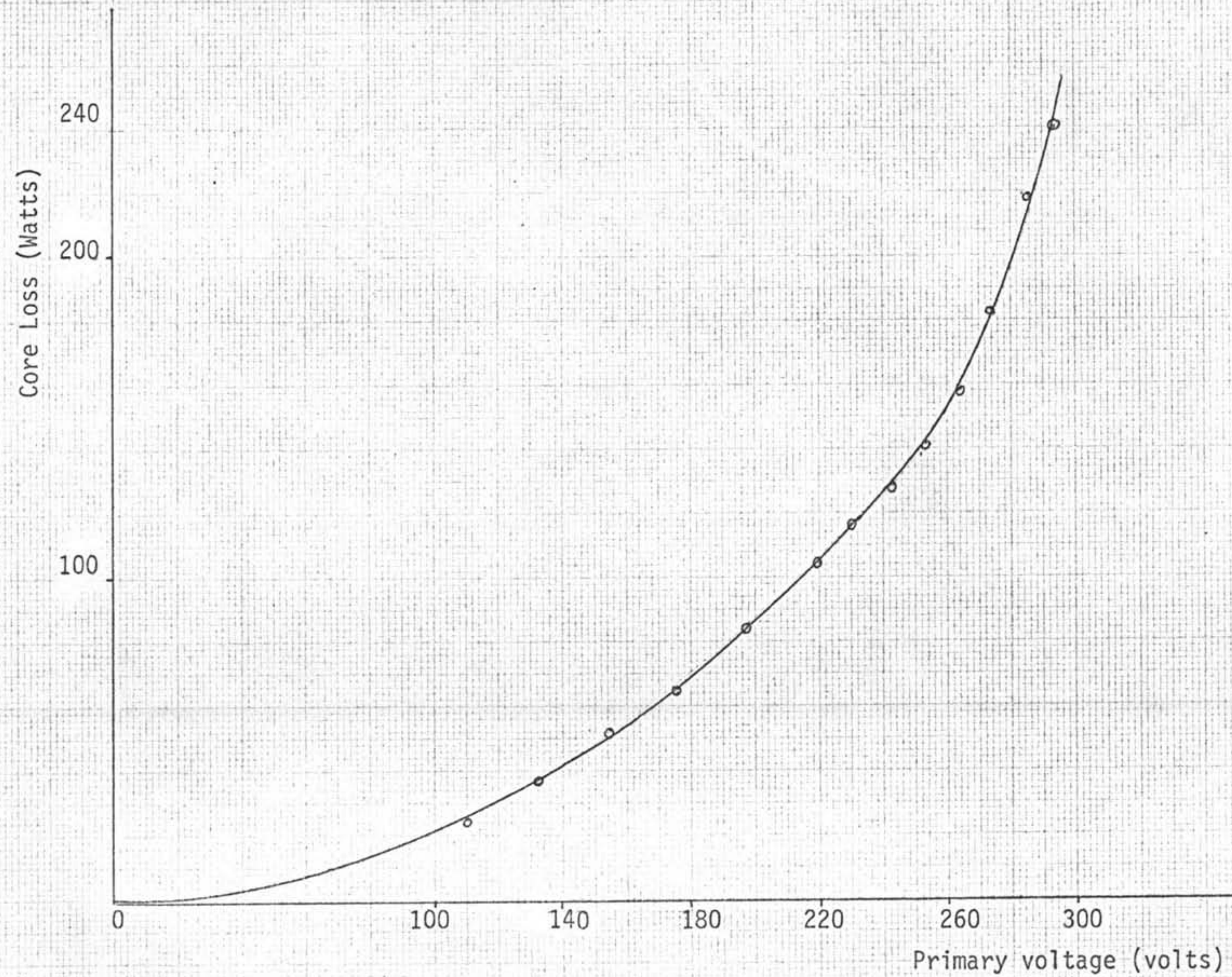

Fig. 6.5 Core Loss Curve

6.5 Dielectric Test

The object of these tests is to test the insulation between the phase windings, turns, coils and terminals and also between these parts and earth.

6.5.1 Insulation-resistance measurement

Before the dielectric tests are made, insulation-resistance measurements are made to be sure that the moisture has been removed from the insulation during the drying-out process. This test is made with a megger at 2500 V.d.c. . The insulation-resistances are shown in Table below

Terminal connection	Insulation-resistance (Mega-ohms)
High-voltage winding and ground	10,000
Low-voltage winding and ground	10,000
High-voltage and Low voltage winding	10,000

6.5.2 Induced-Potential Test (High frequency)

There are two kinds of high-voltage tests for transformer

a. Applied-Potential test

b. Induced-Potential test

In case of a winding which is constructed with one point of the winding permanently and solidly connected to the frame and case or for connection to earth, the applied potential test is not applicable and the induced-potential test alone shall be made.

Apparatus required

1. High-frequency generating set (200 Hz.).
2. Timing clock.

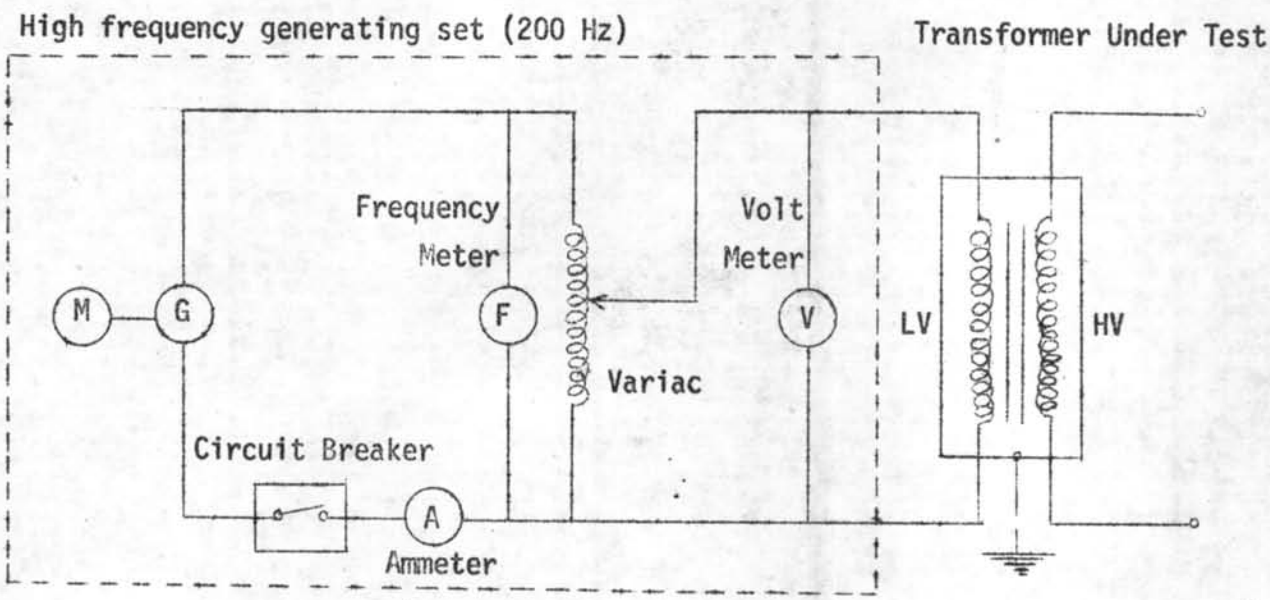

Fig. 6.6 Connection for the Induced-Potential Test

Test procedure

1. Connect the circuit as shown in Fig. 6.6 .
2. Earth the transformer tank.
3. Generate the voltage at 200 Hz. to 135 volts and then increased gradually to 407 volts. The voltage and frequency increased above the rated value in order to avoid excessive exciting current during the test.

4. After holding for 30 seconds at 407 volts 200 Hz., reduced the voltage gradually to 135 volts before switching off.

The duration of test could be derived from the equation;

$$\text{Duration of test frequency} = \frac{\text{twice the rated frequency} \times 60 \text{ seconds.}}{\text{test frequency}}$$

$$= \frac{2 \times 50}{200} \times 60 = 30 \text{ seconds}$$

Test result

After the test, all parts of the transformer under test are in normal condition. The result shows that the insulation are adequate.

6.6 Measurement of Secondary Output Voltage Wave Shape

One of the important characteristic of the high voltage testing transformer is the ability to generate high voltage output with approximately sinusoidal wave shape. The connection for the measurement is shown in Fig. 6.7

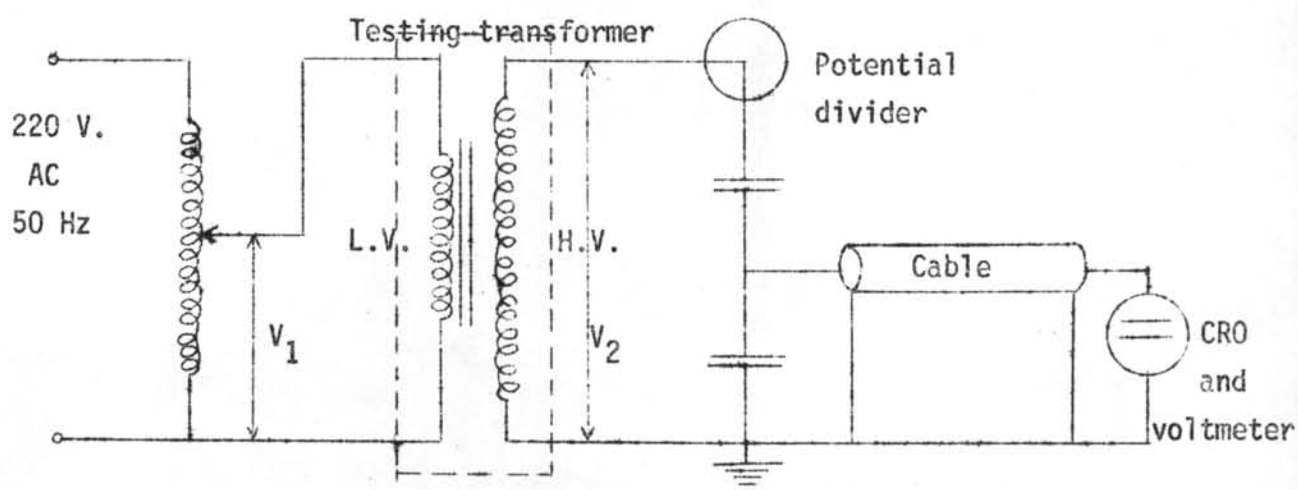

Fig. 6.7

Test result

The secondary output voltage wave shape at rated voltage are shown in Fig. 6.8. The wave shapes are purely sinusoidal.