

*AT Series Testers*

Application Note

# Laminate Transformer Testing





## 1. Introduction:

Laminate transformers are mostly used as line frequency, low frequency and low/high voltage step-up, step-down transformers. Two coils are wound over a core such that they are magnetically coupled. The two coils are known as the primary and the secondary. The core material tends to be constructed from thin sheets of a soft magnetic material (approx. 0.35mm thick), usually made of 4% silicon steel, called laminations, these are insulated from each other by varnish. These thin sheets reduce eddy currents by increasing the resistance to the flow of such currents. Eddy currents are one of the elements associated with overall core losses. Core loss is the sum of hysteresis and eddy current loss in a magnetic core. Hysteresis is the energy used up by changing the magnetic state of the core during each cycle and eddy currents are currents induced in the core by time varying fluxes. The core is partially assembled prior to the windings being inserted and once inserted the remaining laminate sheets are then interleaved to avoid all of the joints coming into one place, the joints are then staggered similar to laying bricks. Laminate transformers are used in most low frequency applications usually between 50Hz and 400Hz. The primary tends to have a high inductance this allows low frequency use with minimal core losses.

Laminate transformers provide the following: -

- High voltage step-up.
- Low voltage step-down.
- High current output.
- Isolation.

For the purpose of this document we will concentrate on a step-down laminate transformers. By designing the number of turns in the primary and secondary windings, any desired step-up or step-down transformer can be realised. The coupling between the primary and secondary must be 'tight' in a power transformer in order to reduce the leakage reactance, otherwise the drop in reactance will be considerable and will vary with secondary voltage and current. Therefore laminate transformers are wound with concentric windings (the primary and secondary are wound with half the turns onto the core limb, one over the other (to give a close coupling) with intervening insulation.



## 2. Applicable laminate tests.

The AT Series-testers currently has the ability to perform the following applicable laminate transformer tests: -

**CTY:** CTY is a continuity test designed to ensure that the transformer is correctly seated in its fixture and that all the winding termination integrity is good. The minimum resistance is 10KΩ up to 10MΩ.

**R:** R is the direct current, (DC) resistance offered by an inductor due to the resistance of the winding. The lower the resistance the more current an inductor will handle. Resistance is presented in  $\mu\Omega$  to MΩ.

**VOC:** Voltage open circuit, this test applies a voltage to the primary and reads the voltage induced in the secondary winding the results are presented as a secondary voltage from 100 $\mu$ V to 500V with a test voltage from 1V to 270V @ 20Hz to 1.5KHz. Phase is also measured as a polarity i.e. positive (in phase), negative (anti-phase).

**IR:** Insulation resistance tests are designed to check for poor shielding and insulation between windings. Voltage and current is measured and by dividing the voltage by the current insulation resistance measurements are presented in MΩ to GΩ with a test voltage from 100V to 7KV @ DC.

**MAGI:** Magnetising current is the combination of the current required to magnetise the core and the current required to supply the losses in the core. Results are presented as a current from 1  $\mu$ A to 2A (3A peak) with a test voltage from 1V to 270V @ 20Hz to 1.5KHz.

**STRW:** At no load and with the secondary open circuit a transformer will still draw current this current is proportional to the core losses (eddy currents and hysteresis). Faraday's law suggests that providing the voltage and frequency is increased proportionally core loss should remain the same. Therefore if a dramatic power increase is detected it would indicate a winding fault. Results are presented in watts from 1 mW to 40 watts with a test voltage from 1V to 270V @ 20Hz to 1.5KHz.

**HPAC:** Hi-pot AC tests are isolation safety tests, which tests the isolation between windings and between winding and core and winding to shield. Current flow is measured between each test point and is presented in  $\mu$ A to mA with a test voltage from 100V to 5.5KV @ 50Hz to 1KHz.

A typical laminate test sequence might be:

- CTY      Continuity.
- R         Resistance.
- VOC      Voltage open circuit.
- MAGI     Magnetising current.
- STRW     Stress watts.
- IR        Insulation resistance.
- HPAC     High potential AC. Safety-test.

### 3. CTY & R (continuity and resistance) testing.

Continuity is a simple test to ensure that the fixture as well as the transformer has been inserted correctly. The test parameters provided range from 10KΩ to 10MΩ, 10KΩ is generally used for speed and will test each winding and termination for a value less than 10KΩ.

Resistance is the direct current (DC) resistance offered by an inductor due to the resistance of the magnetic wire used. Resistance is the undesirable characteristic, which is the by-product of the wire or conductive material used. Resistance measurement's are generally taken across all windings and is directly linked to the design of the transformer to carry a particular amount of current within that winding. The lower the resistance the higher the current carrying capabilities of the inductor.

FIGURE 1 (Typical laminate step-down transformer layout).

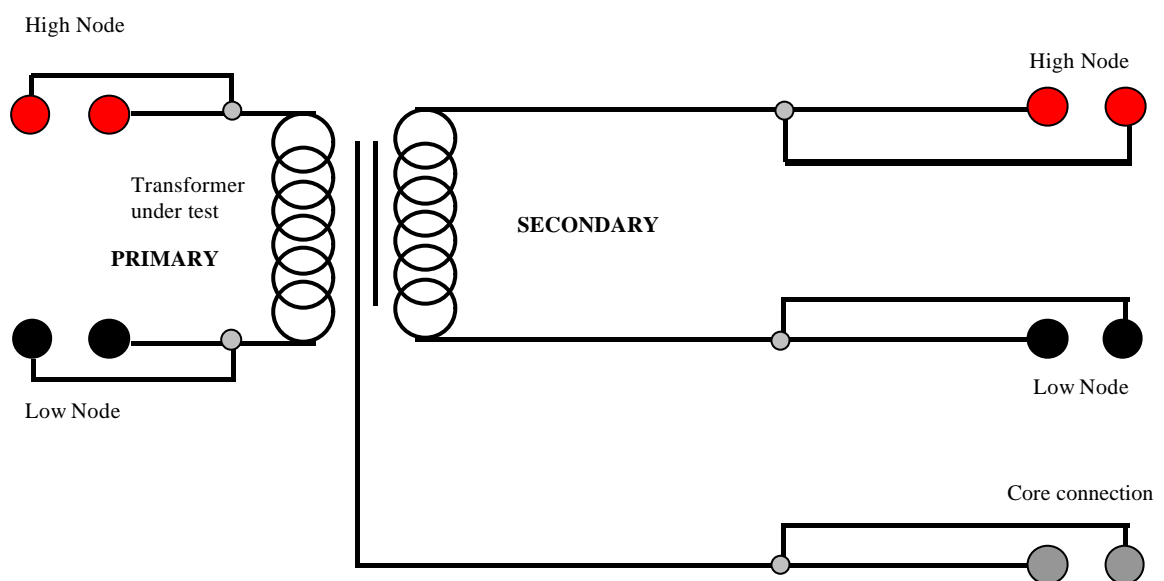


Figure 2 shows parameters required for R on the primary. The secondary winding would also be tested for resistance throughout the sample transformer.

Medium integration.

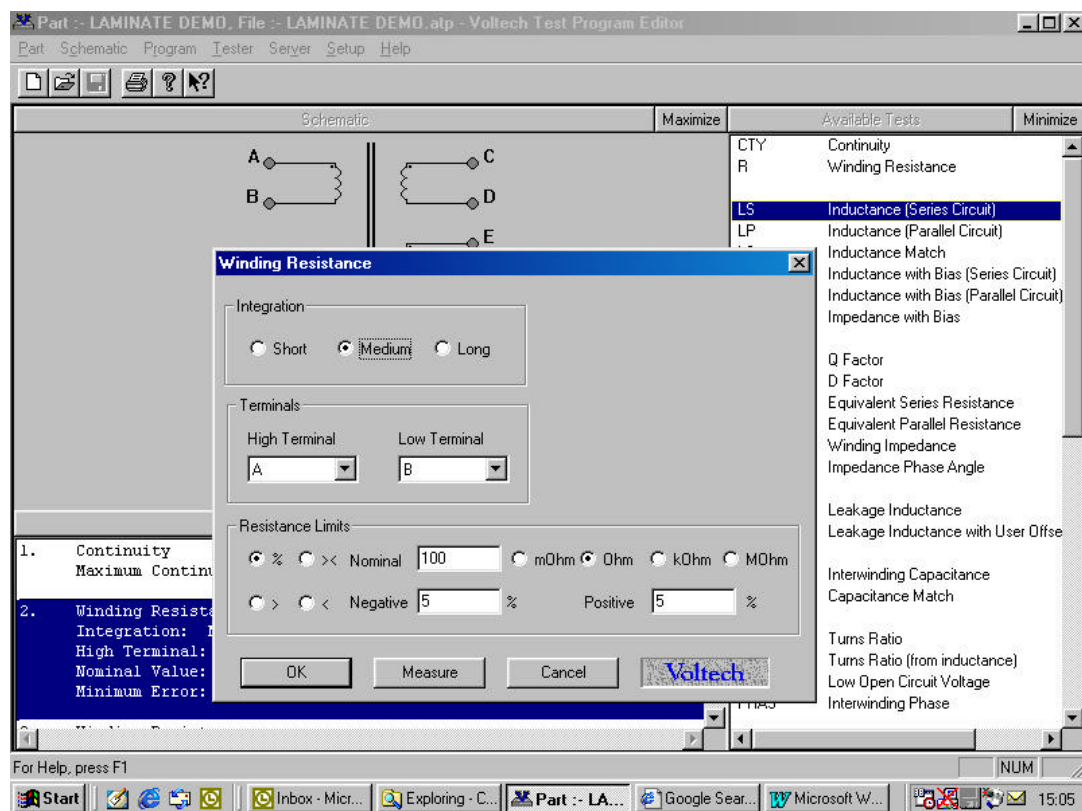
The resistance limits were chosen as a percentage of the nominal value of 100Ω +/- 5%.

Figure 2 shows parameters required for R on the primary. The secondary winding would also be tested for resistance throughout the sample transformer.

Medium integration.

The resistance limits were chosen as a percentage of the nominal value of 100Ω +/- 5%.

**FIGURE 2.**



## 4. VOC (voltage open circuit) testing.

Voltage open circuit testing is a high voltage version of the turns ratio test. Instead of returning a ratio result i.e. 2:1, 1:2 etc. a voltage result is returned that is proportional to the number of turns on the primary versus the number of turns on the secondary.

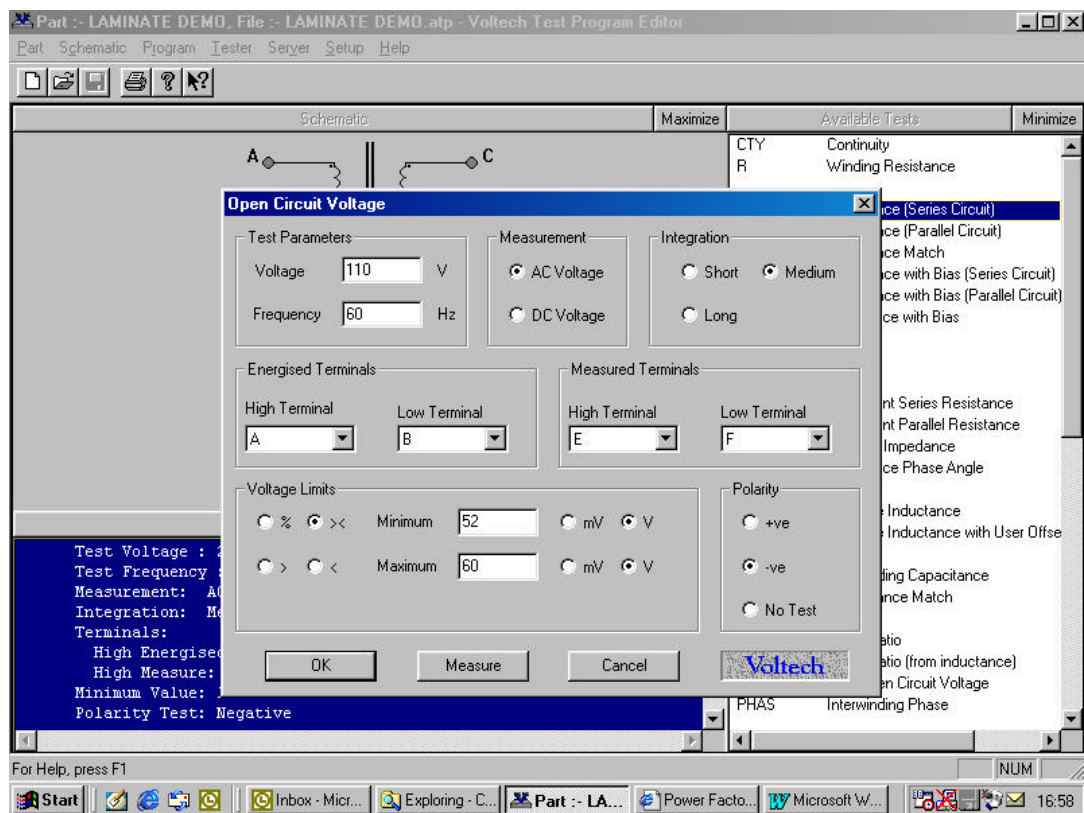
The test parameters provided range from 1V to 270V with a measurement range from 100µV to 500V. Phase is also catered for and can be selected as positive (in phase) or negative (anti-phase).

Figure 3 shows the parameters required for VOC on the primary and secondary windings of the sample transformer.

Medium integration.

The voltage and frequency levels have been selected as U.S line frequency mains 110V @ 60Hz with the voltage limits selected as a minimum of 52V and a maximum of 60V. Phase has been set for a +ve.

**FIGURE 3.**



## 5. STRW (stress watts) testing.

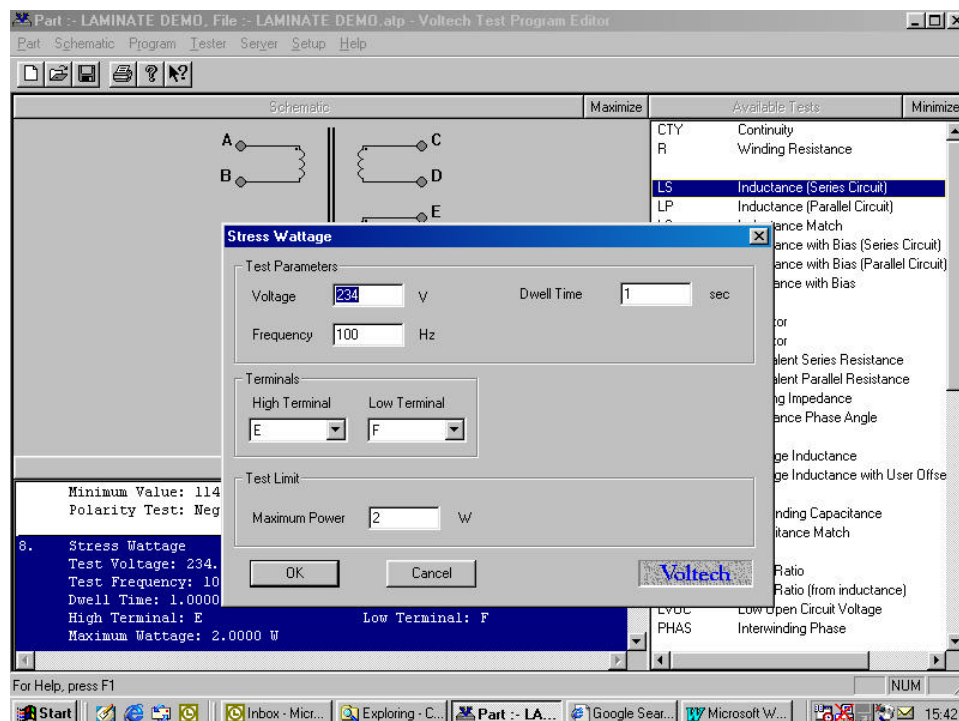
The primary role of stress watts testing is to indicate a fault in the inter-turn insulation of a winding. This test can be used on windings with very thin wire. At no load and with the secondary open circuit a transformer will still draw current this current is proportional to the core losses (eddy currents and hysteresis). Hysteresis is the energy used up by changing the magnetic state of the core during each cycle and eddy currents are currents induced in the core by time varying fluxes. Faraday's law suggests that providing the voltage and frequency is increased proportionally core loss should remain the same. Therefore if a dramatic power increase was measured it would indicate that a winding fault was present.

Stress watts testing allows a line frequency transformer of 110V @ 60Hz to be tested at 220V @ 120Hz according to Faraday's law as discussed above the core losses should not change from 110V @ 60Hz to 220V @ 120Hz allowing double the voltage stress testing on the windings.

Figure 4 shows the parameters required for STRW on the secondary winding of the sample transformer.

The voltage and frequency levels have been selected as double the induced voltage and frequency with the maximum power set at 2 watts for a dwell period of 1 second.

FIGURE 4.



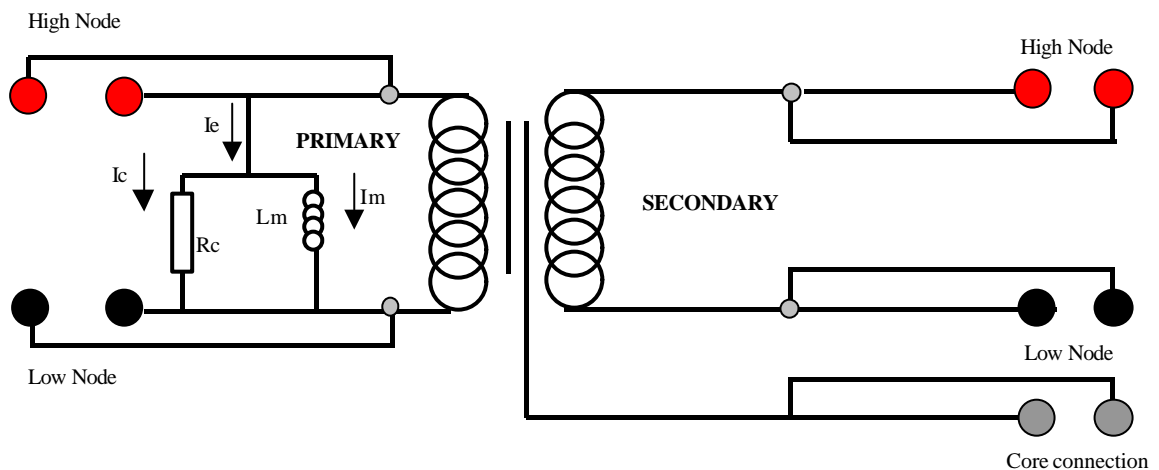
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Core losses are caused by the magnetising of the core and are always present. The way they are measured is by running full primary voltage with no load on the transformer.

## 6. MAGI (magnetising current) testing.

A magnetising current test is usually performed on transformers using laminate cores, which are designed to operate over the full extent of the B-H curve. The B-H curve shows the characteristics of a magnetic material, in terms of magnetising force (H) and resulting flux density (B). Magnetising current is the current needed to establish core flux, which results in the combination of current required to magnetise the core and current required to supply the losses in the core comprising of hysteresis and eddy currents. Hysteresis is the energy used up by changing the magnetic state of the core during each cycle and eddy currents are currents induced in the core by time varying fluxes.

FIGURE 5: Magnetising current equivalent circuit.



- $L_m$  = the magnetisation inductance.
- $I_m$  = the magnetising current.
- $I_e$  = the excitation current.
- $I_c$  = the core loss component of the excitation current.
- $R_c$  = the core loss resistance.

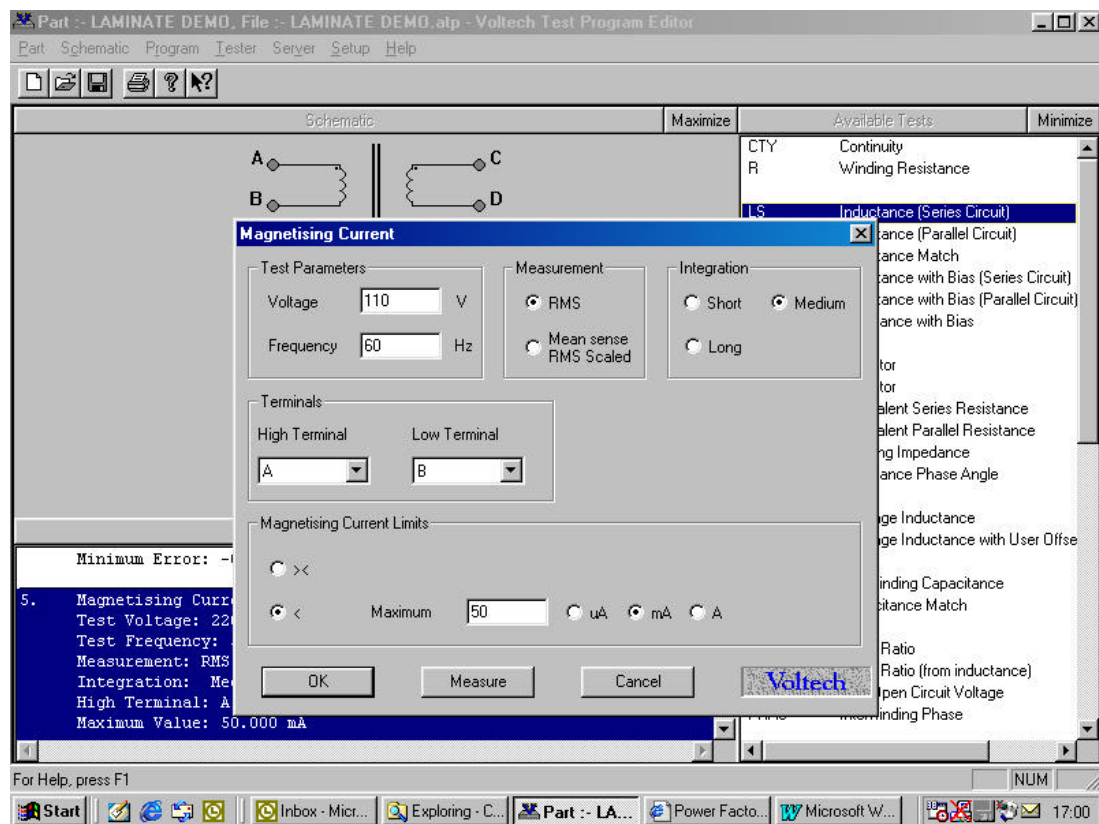


Figure 6 shows the parameters required for MAGI on the primary winding of the sample transformer.

Integration, medium

The voltage and frequency levels have been selected for U.S. line voltage and frequency (RMS) 110V @ 60Hz with the maximum current draw set at 50mA.

**FIGURE 6.**



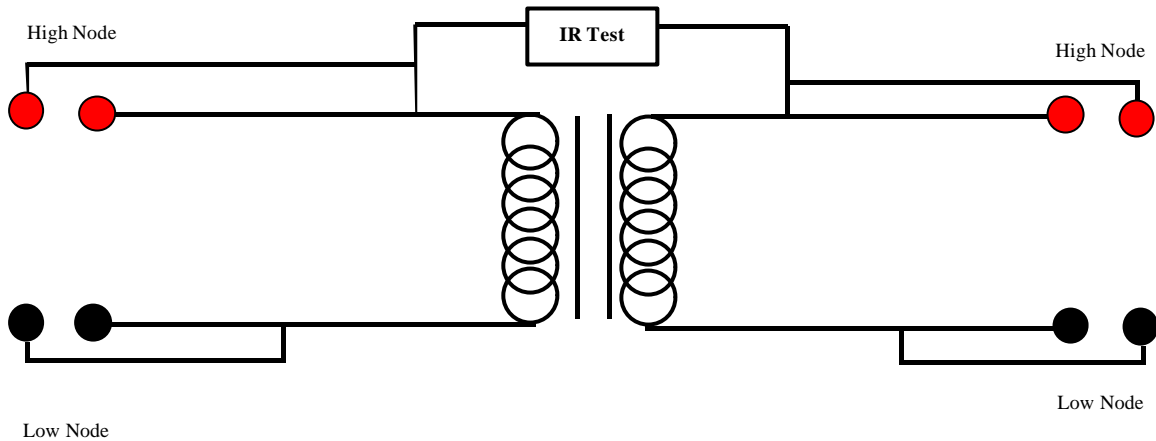
Core losses are caused by the magnetising of the core and are always present. The way they are measured is by running full primary voltage with no load on the transformer.

## 7. IR (insulation resistance) testing.

Insulation resistance testing is a means of checking winding insulation and winding to core insulation. The quality of the insulation can be checked by applying a DC voltage across the insulation and measuring its resistance.



**FIGURE 7** (insulation resistance test circuit).

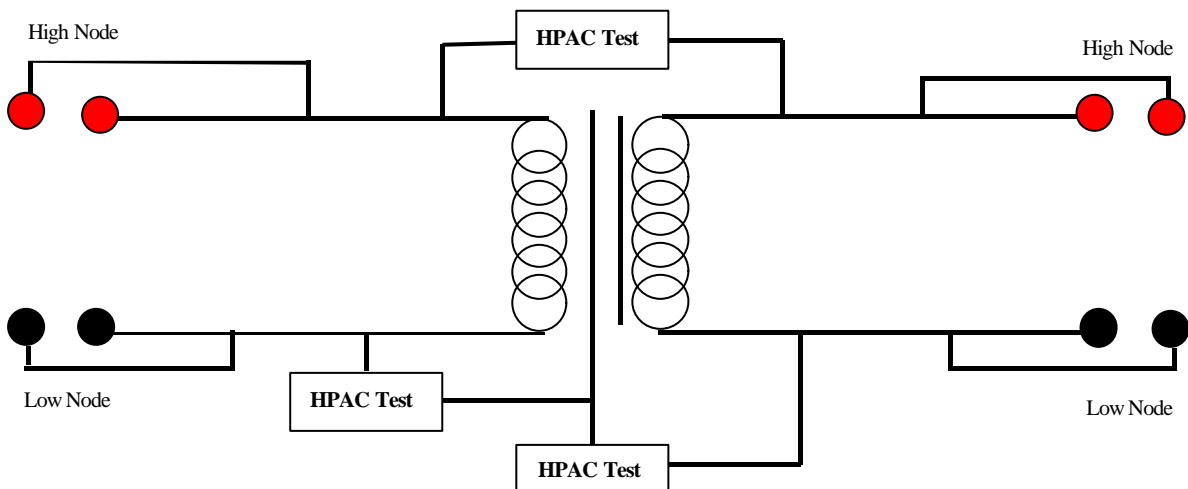


## 8. HPAC (high voltage safety) testing.

Hi-pot or flash is a safety isolation test and is applied to isolation transformers to ensure that the isolation between the windings does not break down. This guarantees the integrity of safety critical insulation in accordance with international standards. Where transformer provide isolation between dangerous line voltages and safe low level voltages is HPAC a critical test.

Tests are operated between windings and between windings and the core material.

**FIGURE 8** (Hi-pot AC test circuit).



## 9. Complete Laminate Testing Solution.

The following sample line frequency transformer specification will be used as a model to explain one method of a complete testing solution: -

- Continuity, maximum continuity resistance 10KΩ.
- DC winding resistance. primary nominal value 100Ω +/- 5%.
- Secondary nominal value 50Ω +/- 5%.
- Magnetising current 110V @ 60Hz maximum current 50mA.
- Voltage open circuit 110V @ 60Hz minimum voltage 52V, maximum voltage 60V.
- Stress watts, primary voltage 220 @ 120Hz maximum 2 watts.
- Insulation resistance @ 500VDC, Primary to secondary 1 minimum-resistance 10MΩ.
- Hi-pot primary to secondary 5KVAC / 1mA / 2 seconds.
- Hi-pot primary to core 5KVAC / 1mA / 2 seconds.



Two grayscale images of AT Series Testers are positioned on either side of the central text. They are industrial-looking devices with a complex, angular design and a central opening.

## *AT Series Testers*

### **VOLTECHNOTES**

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#### **Voltech Instruments Ltd**

148 Sixth Street,  
Harwell International Business Centre,  
Harwell, Didcot, Oxfordshire OX11 0RA, U.K  
Telephone: +44 (0) 1235 834555  
Facsimile: +44 (0) 1235 835016  
Email: [sales@voltech.co.uk](mailto:sales@voltech.co.uk)

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#### **Voltech Instruments Inc**

11637 Kelly Road, Suite 306  
Fort Myers FL 33908, U.S.A  
Telephone: +1 239 437 0494  
Facsimile: +1 239 437 3841  
Email: [sales@voltech.com](mailto:sales@voltech.com)



[www.voltech.com](http://www.voltech.com)

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