POWER TRANSFORMER TESTING SWP

1. PURPOSE AND SCOPE

The purpose of this Standard Work Practice (SWP) is to standardise and prescribe the method for testing power transformers.

Testing of current transformers, voltage transformers or auxiliary transformers internal to the power transformer are not included in this SWP.

2. STAFFING RESOURCES

Adequate staffing resources with the competencies to safely complete the required tasks as per MN000301R165: 8 Level Field Test Competency

These competencies can be gained from, but not limited to any or all of the following:-

- Qualifying as an Electrical Fitter Mechanic.
- Qualifying as a Technical Service Person.
- Training in the safe use of relevant test equipment.

Requirement for all live work:

- Safety Observer (required for all “live work” as defined in the ESO Code of Practice for Electrical Work).

All resources are required to:

- Have appropriate Switching and Access authorisations for the roles they are required to perform and have the ability to assess and maintain relevant exclusion zones from exposed live electrical apparatus.
- Hold current licences for any vehicles and equipment they may be required to operate.

Required Training

Staff must be current in all Statutory Training relevant for the task.

All workers must have completed Field Induction or have recognition of prior Ergon Energy Field Experience.

Contractors must have completed Ergon Energy's Generic Contractor Worker Induction.

3. DOCUMENTATION

CS000501F115. Daily/Task Risk Management Plan

ES000901R102. Health and Safety Risk Control Guide

SP0504R01. Power Transformer Testing Job Safety Analysis

SP0504C01R01. Power Transformer IR and DDF Temperature Correction

SP0504C04. Power Transformer No Load Loss Test Report

SP0504C05. Power Transformer Load Loss Test Report

SP0504C06. Power Transformer Load Loss and Impedance Calculation

SP0504C08. Power Transformer Testing Competency Assessment

SP0504C13. Construction Tool – Power Transformer

SP0504C12. Commissioning Tool – Power Transformer

SP0506. Substation Primary Plant and Secondary Systems Field Testing SWP

SM0701. Power Transformer Oil Sampling

SM0701R01. Power Transformer Oil Sampling Job Safety Analysis

SM0701R02. Maintenance Instruction for Power Transformer Oil Sampling

STNW1162. Standard for Managing Insulating Oil Sampling, Testing and Actioning the Results

STNW1160. Standard for Maintenance Acceptance Criteria

MN000301R172. Doble DLA Testing

DIRANA User Manual

Doble 5200 User Guide

MPD 600 Test Procedure

P53. Operate the Network Enterprise Process

AS 2374.1 Power Transformers

AS 2374.3.0 Power Transformers – Insulation levels and dielectric tests – General requirements

Test Equipment Manuals

Transformer Manual / Manufacturer's Drawings

J and P Transformer Book

4. KEY TOOLS AND EQUIPMENT

Test Equipment within calibration date, tested and tagged: Insulation Resistance tester, High Voltage test set, Digital Voltmeter, Ratiometer or Primary Injection Voltage source, Phase Angle meter and Ohmmeter.

Additional test equipment: Shorting leads, Multimeters, Surface thermometer, Oil sample test equipment and Oil Spill kit.

Load Loss test equipment: Supply source capable of supplying at least 50% of winding Full Load Current (FLC), RMS Voltmeter, Measuring VTs, Ammeter, Metering CTs, Wattmeter, (These meters may be replaced by power analysers or other appropriate meters) and shorting bars capable of full rated current of the winding to be shorted.

No Load Loss test equipment: Voltage source capable of rated voltage of transformer under test, average and RMS Voltmeters and measuring VTs, Ammeters, Metering CTs, Wattmeter, (These meters may be replaced by power analysers or other appropriate meters).

Power Frequency Withstand test equipment: Suitable single-phase test transformers of sufficient voltage and VA, voltage and current measuring equipment, ammeter with parallel spark gap and measurement VT and voltage meter.

Over-potential Withstand tests equipment: A three phase high frequency generator, three phase interposing test transformer, voltage and current measuring equipment suitable for use at the test frequency:

Voltage meters to measure test voltage (with input impedance to match voltage divider).

Ammeters to measure the phase current.

Safety Barriers and warning signs.

HVIA Operating Equipment: PEDs, Live Line Tester, Class 0 gloves. All equipment to be inspected and confirmed within test date prior to use.

Standard PPE: Full-length high visibility protective cotton clothing, safety footwear and helmet.

Additional PPE as required: Leather work gloves, class 00 gloves, hearing protection, safety eyewear. All PPE to be inspected and confirmed within test date (where applicable) prior to use.

Sun protection to be used when working outdoors.

5. WORK PRACTICE STEPS

5.1. Carry out an On Site Risk Assessment

Prior to performing this activity any hazards associated with prerequisite tasks at the worksite shall be identified and assessed with appropriate control measures implemented and documented in accordance with the **Daily / Task Workplace Risk Management Plan** (CS000501F115) and using the **Health and Safety Risk Control Guide** reference document (ES000901R102).

If any risks cannot be managed or reduced to an acceptable level, do not proceed with the task and seek assistance from your Supervisor.

5.2. All Work To Be Done With Power Transformer De-Energised

All of the tests described in this SWP should be carried out with the transformer de-energised and appropriate control measures in place (e.g. barriers, matting) to prevent inadvertent contact with adjacent live plant or breaching exclusion zones. Furthermore, the P53 Operate the Network Process is applicable at all times for isolation and earthing.

Issue a Test Permit and follow the requirements of P53 Operate the Network Process.

As described in Substation Primary Plant and Secondary Systems Field Testing SWP SP0506 particular safety risks applicable to bus assemblies include:

- Contact with high voltage at the transformer primary connections.
- High fault current at the transformer primary connections.
- Unearthed CT and VT secondary winding.
- Open circuit CT secondary terminals.
- Open DLA test terminal on transformer bushing.
- Stored energy in the transformer magnetic field (refer to winding resistance testing).
- Induced voltages and currents from nearby energised / loaded plant.
- Working at height hazards.

5.3. Assessment Criteria

Unless stated, refer to STNW1160 Standard for Maintenance Acceptance Criteria for minimum acceptance values for each test.

5.4. Record Identification Details

Record identification details:

- Manufacturer's name and manufacturer's serial number.
- Plant/Asset number.
- Power ratings.
- Cooling configurations, e.g. ONAN, ODAF.
- Number of windings.

- Rated voltage.
- Vector group.
- Tap-changer range and tap size.

5.5. Visual Inspection of Power Transformer Condition

Inspect the transformer for any sign of damage or leaks. Confirm oil level is correct before testing commences, assembly is complete and no transport bracing has been left in place.

Inspect the external surfaces and ensure the transformer is clean and dry.

Check all connections for adequate labelling. The connections should be unambiguous, legibly and adequately marked.

5.6. Preliminary Steps

Identify transformer to be tested.

In a substation:

- Ensure the transformer windings to be tested are de-energised, tested and proved dead and earthed.
- Erect Safety barriers and warning signs and issue Test Permit if applicable.

In a workshop:

- Testing should be within designated test bays or barricaded and warning signed test areas.

Disconnect the transformer windings from overhead bus, pothead etc. Depending on exposure to nearby energised plant and location of earths, induced voltages may be present on disconnected conductors or the test object. Check for presence of induced voltages and apply temporary earth when making or removing test connections.

A common mistake when testing transformers is to have test results influenced by external equipment such as surge diverters or internal equipment such as VTs or auxiliary transformers.

Plan test connections so that clearances are greater than minimum withstand:

- Between high voltage test leads.
- Between high voltage test leads and equipment under test, other apparatus or earth.

5.7. Carry out Auxiliary and Control Circuit Voltage Withstand.

The power transformer auxiliary and control circuitry shall be subjected to a 1 minute power frequency withstand test at 2kV to confirm insulation integrity.

a) If the transformer is new and HV testing has been verified as satisfactorily completed at the manufacturer's works – No HV withstand test.

b) If the transformer is new and HV testing has not been verified as satisfactorily completed at the manufacturer's works – HV withstand test.

c) If the transformer is aged or refurbished and minimal wiring changes have occurred – No HV withstand test.

d) If the transformer is aged or refurbished and the wiring has been substantially modified – HV withstand test.

The circuitry shall be considered to have passed if no disruptive discharge occurs during the test.

Consideration shall be given where electronic components are used in the auxiliary and control circuitry. Different testing

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procedures and values may be adopted subject to agreement by the Commissioning Engineer.

5.8. Measure Insulation Resistance

DC insulation tests are to be carried out between terminals of the transformer as detailed below. The voltage applied will be as per Table 1 for a duration of 1 minute.

Preliminary steps:

- Short the phases of the winding to be tested together.
- Short circuit CT secondary windings and connect to earth.
- Short one side of all VT secondary windings to earth.
- Short all other windings (i.e. excluding the winding under test) together and to earth.
- Connect Insulation Resistance test equipment as required by the instrument manufacturer's manual.

Test each winding in turn keeping clear of live test leads.

- HV to all other windings and Earth.
- LV to all other windings and Earth.
- TV to all other windings and Earth, if applicable.

Warning: Before removing test leads from the transformer winding and discharge the winding under test for minimum of 30 seconds or until the insulation resistance test set indicates no charge.

Measure the winding temperature, where possible, and oil temperature at the time of the test.

Primary Voltage Rating	Test Voltage in kV (DC)
Up to 1kV	1
Above 1kV to 3.6kV	2
Above 3.6kV to 12kV	5

Table 1: Applied Voltages for IR Tests

As a rule of thumb, an IR of 1,000MΩ or greater is expected for new transformers.

For aged transformers, use the formula:

IR = 10 * kV / √MVA

If a Polarisation Index is required an Insulation Resistance reading must be recorded at 1 minute and 10 minutes. If only Insulation Resistance is required a 1 minute reading is sufficient.

Note: A Polarisation Index measurement is required prior to commissioning of any transformer.

To calculate the Polarisation Index:

PI = 10 minute IR / 1 minute IR

Note: The PI, being a ratio of IR values, is less susceptible to variation with temperature than IR and is therefore a useful tool in determining insulation quality. For new transformers, a PI of 2 or more is expected. However, a PI measurement is only an indication for non-rigid insulation. As such, lower PI values may still be acceptable. Refer to STNW1160 Standard for Maintenance Acceptance Criteria for minimum acceptance values.

Remove all shorts from the windings and wiring under test.

5.9. Carry out Power Transformer Oil Sampling

The power transformer shall have the integrity of its oil insulation confirmed prior to energisation.

a) If the transformer is new, not filled at site and manufacturer results are verified as satisfactory – No oil sampling required, verify manufacturer results only.

b) If the transformer is new and filled at site – Onsite oil sampling required.

c) If the transformer is refurbished and filled in the workshop – Workshop oil sampling required.

d) If the transformer is refurbished and filled on site – Onsite oil sampling required.

Carry out an oil sample of the transformer as per SM0701 Power Transformer Oil Sampling and STNW1162 Standard for Managing Insulating Oil Sampling, Testing and Actioning the Results.

New transformer oil is expected to have a breakdown voltage of at least 60kV. Refer to AS 1767 for acceptance criteria on other oil properties (eg water content, neutralisation value etc).

The recommended limits for breakdown voltage of transformer oil in service are listed below. Refer to AS 1883 for other acceptance criteria.

Highest Voltage of Equipment (kV)	Breakdown Voltage (kV)
<72.5kV	40kV
72.5kV to 170kV	50kV
>170kV	60kV

Table 2. Breakdown voltage levels

5.10. Measure Winding Resistance

Connect DC Resistance test equipment as required by the instrument manufacturer's manual.

Test each winding as required in the scope of works.

Ensure that the winding is fully charged before taking the reading. On large transformers the charge time can be minimised by passing the DC current through the HV and LV winding of the phase under test so that the magnetising effect of the current is opposed in each winding.

If a four-wire system is being used the resistance of each tapping of the winding can be measured without discharging the windings by connecting voltage leads across each tapping in turn.

Unless otherwise specified measure the resistance of all windings and on all taps.

Warning: Before removing the current leads from the transformer winding, discharge the winding under test. This may be achieved automatically by the test equipment (which may also have an indicator to say when discharge has been completed to a safe level) or by connecting a reverse biased diode across the winding

under test. As a rule of thumb, allow the discharge time to be at least as long as the charge up time.

Because of the large amount of energy stored in the transformer core, several thousand volts may be present across the winding terminals if not discharged correctly.

For oil filled transformers record the top and bottom radiator temperature at the time of test for each winding tested.

Calculate the average oil temperature from the top and bottom oil temperatures and use this as the winding temperature.

For dry type transformer measure the winding temperature by placing a probe, if possible, inside the winding.

Check that DC Resistance results against previous test results or typical data. The resistance can be calculated up to resistance at 75ºC for comparison to past results.

For copper:

$R_2 = R_1 (235 + t_2) / (235 + t_1)$

For aluminium:

$R_2 = R_1 (225 + t_2) / (225 + t_1)$

Winding resistance should step uniformly from one tap to the next and all phases should be similar (some cases there will be alternatively large and small steps).

5.11. Carry out Tap-changer Continuity Testing

Connect a DC current source to the transformer as required by the instrument manufacturer's manual.

Test each winding and phase at each tap to confirm continuity of transition between taps. Test to the full range of the OLTC.

Test transitions in both directions.

Measure ripple (%) and slope (A/s).

Compare between phases and like transformers. There should be <2% difference in ripple between phases and <1A/s for slope for a C3 defect level.

5.12. Measure Voltage Ratio

Auxiliary supply for operation of the tap-changer or heater circuits etc. does not have to be isolated for this test.

Short circuit CT secondary windings and connect to earth.

Short one side of all VT secondary windings to earth.

Connect ratio test equipment as required by the manufacturer's manual. Ensure the input volts are applied to the HV winding.

Set transformer to the required tap. If all taps are to be tested set the transformer tap changer to either the top or bottom tap and test each tap in sequence. If the transformer has an off line tap changer ensure the ratio test equipment is switched off when the tap is being changed.

Isolate test supply before removing test leads.

Check that test result are within the required limits (e.g. ±0.5% as per AS 2374.1 table 1) for the nominated taps. Use Commissioning Tool SP0504C12 (PTRatio) for calculation of limits.

A shorted turn is often indicated by a variation in the ratiometer reading, an increase in excitation current, or a change in phase angle between the input and output voltage of the transformer.

Remove all shorts.

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5.13. Carry out HV Testing

A transformer shall withstand a power-frequency RMS Test voltage applied for 1 minute between each respective winding to all others and earth.

a) Where no HV testing has been carried out at the manufacturer's works – 100%.

b) Where HV testing has been carried out at the manufacturer's works but subsequent assembly of the HV chamber / bushings is required on site – 80%.

c) Where HV testing has been carried out at the manufacturer's works and no on-site assembly of the insulating component is required – No HV withstand test.

d) If the transformer is aged or refurbished – 75%.

Short all CT secondary windings to earth.

Short one side of all VT secondary windings to earth.

Short the phases of the winding to be tested together.

Short all other windings together and to earth.

Measure capacitance between winding to be tested and other windings and earth. Calculate expected leakage current at test voltage:

$$I = 2\pi fCV.$$

Connect Power Frequency Withstand test equipment as required by the instrument instruction manual.

Place ammeter in the earth end of the transformer under test. The tank of the transformer under test must be isolated from earth if the leakage current is to be measured in this manner.

Alternatively an ammeter within the High Voltage Test Set may be used providing allowance is made for the set leakage.

Warning: Verify insulation resistance and oil quality is satisfactory before performing any high voltage tests.

Test each winding as required in the scope of works. In general, test:

- HV Winding to all other windings and earth
- LV Winding to all other windings and earth
- TV Winding to all other windings and earth

Warning: Refer to AS 2374.3.0 for test voltages applicable to windings with non-uniform insulation to avoid over stressing the neutral end of star connected windings.

The voltage to be applied for the 1 minute power frequency withstand test is listed in the following table.

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Nominal Voltage of system (Un) kVrms	Highest Voltage for equipment (Um) kVrms	Rated Short term Power-frequency withstand Voltage (PFWV) kVrms		
		100%	80%	75%
<1.1		3	2.4	2.25
3.3	3.6	16	12.8	12
6.6	7.2	20	16	15
11	12	28	22.4	21
22	24	50	40	37.5
33	36	70	56	52.5
66	72	140	112	105
110	123 (450 BIL) 123 (550 BIL)	185 230	148 184	138.75 172.5
132	123 (550 BIL) 123 (650 BIL)	230 275	184 220	172.5 206.25

Table 3: HV Withstand Levels:

If, due to test equipment current output limitations, the test voltage in the table above cannot be attained, then a reduced voltage for a longer duration may be applied (refer to J and P Transformer Book).

Duration of test in minutes	% of standard test voltage for manufacturers works testing	% of standard test voltage for on-site testing
1	100	75
2	83	70
3	75	66
4	70	62
5	66	60
10	60	54
15	57	50

Table 4: Reduced HV Withstand Levels:

Where U_n >132kV, refer to AS 2374.3.0 for applicable test values.

Record leakage current at test voltage.

The requirements of the test are satisfied if no disruptive discharge occurs.

Following the HV test, repeat insulation resistance measurements to confirm insulation integrity.

At completion of test isolate test circuit and earth winding under test.

5.14. Carry out Over-potential Test

Short all CT secondary windings to earth.

Short one side of all VT secondary windings to earth.

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Connect the voltmeter to the secondary of a VT available on the transformer under test. If no VT is available the test voltage must be measured from some other point such as Bushing DLA point or external voltage divider.

Bond the induced winding to earth.

Connect the Over-potential Withstand test generator to the transformer under test via a suitable interposing transformer, if required.

Test circuit will depend on the test method used. Refer to AS 2374.3.0 Clauses 12.2, 12.3 and 12.4.

Warning: Verify insulation resistance and oil quality are satisfactory before performing any high voltage tests.

Note: Test time will vary depending on the test frequency. Refer to the duration formula in AS 2374.3.0 Clause 12.1.

Check that the excitation current on each phase is roughly equal. If there is any major discrepancy notify the supervisor for further instruction.

At completion of test isolate test circuit and earth winding under test. Remove all test shorts.

5.15. Measure Power Transformer Load Losses

Short all CT secondary windings to earth.

Short one side of all VT secondary windings to earth.

Measure the Phase to Phase DC resistance of the HV and LV windings on the Top, Nominal and Bottom tap of the tapped winding.

Measure and record the Top and Bottom radiator oil temperature at time of DC Resistance test.

Short one winding of the transformer under test with shorting bars capable of carrying that winding's full load current. The winding to be shorted will depend on the available test supply (usually the LV winding).

Connect the Load Loss test supply to the input winding of the transformer under test with instrument transformer.

Connect the Load Loss test measuring equipment as required by the instrument instruction manual with correct polarities and ratios on instrument transformer connections.

Raise the input volts until full load current (FLC), or as close as practicable to FLC, is achieved (minimum current is 50% FLC).

Record the Current, RMS Volts and ± Watts on all three phases. The test must be performed in the minimum of time to prevent heating of the winding and changes to winding resistance (watts loss) on the top, nominal and bottom tap.

Lower test volts, isolate test supply and apply temporary earths.

Record top and bottom radiator temperatures immediately after the test is complete.

Record test results on form SP0504C05.

Calculate transformer load loss on SP0504C06.

Compare results with past test results or results of similar units. If results vary greatly from compared results notify relevant authority for further instruction.

5.16. Measure Power Transformer No Load Losses

No load loss tests shall be performed on one of the windings at rated frequency and at the rated voltage of the winding tapping – usually nominal tap. Remaining windings shall be left open

circuited and any winding which can be connected in open delta shall have the delta closed.

Short one side of all VT secondary windings to earth.

Short all CT secondary windings to earth.

Connect the No Load Loss test supply to the transformer winding. Either winding can be used depending on available supply equipment (usually the LV winding).

Connect the No Load Loss test measuring equipment as required by the instrument manufacturer's manual with correct polarities and ratios on instrument transformer connections.

Raise the input volts until full rated voltage is achieved (average of all three phases on the average sensing voltmeter).

Record Current, RMS volts (U) mean volts (U') and ± Watts on all three phases. The difference between the mean and the RMS voltmeters should be no more than 3%.

Record test results on form SP0504C04.

Lower test volts, isolate test supply and apply temporary earths.

Calculate corrected transformer No load loss (P_0):

$P_0 = P_m (1 + d)$

Where

$d = (U' – U) / U'$

Note: The formula for No Load Loss correction is:

$P_0 = P_m / (P_1 + K * P_2)$

The core on transformers manufactured prior to 1960 was made from hot rolled steel, after then Cold Rolled Grain Oriented steel was used.

P_1 = Ratio of hysteresis to total iron loss

P_2 = Ratio of eddy current losses to total iron loss

P_1 = 0.7 (prior 1960); 0.5 (after 1960)

P_2 = 0.3 (prior 1960); 0.5 (after 1960)

$K = U^2$ (RMS volts)^2

U'^2 (mean volts)^2

Compare results with past test results or results of similar units. If results vary greatly from compared results notify relevant authority for further instruction.

5.17. Carry out OTI / WTI Calibration

Check calibration of the WTI heater by applying a current equivalent to the full load current of the transformer to the WTI heater. Confirm that the temperature difference between the WTI and OTI is as per the manufacturer's specification.

Note: Normally 30 minutes constant current and constant OTI temperature is required to obtain an equilibrium in the WTI value.

The OTI should be at the temperature specified by the manufacturer for this test. If a different temperature difference between the WTI and OTI is specified for different cooling conditions (ie ONAN and ODAF) then the calibration should be checked at each condition.

Check calibration of the Oil Temperature Indicator and Winding Temperature Indicator by immersing the temperature sensing bulb in oil and heating the oil to a temperature that causes the highest set auxiliary switch to operate – this will normally be the WTI trip.

Record temperature, output of the OTI and WTI transducers and compare to calculated values.

Stir the oil regularly while heating to ensure an even temperature distribution. As the oil is heated, compare the temperature readings on the OTI and WTI with a calibrated reference thermometer.

Typical accuracy of an OTI or WTI is ± 3ºC. Also check the operation of any auxiliary switches as the temperature increases.

5.18. Carry out Transducer Calibration

Carry out calibration of transducers as required.

For Tap Position Indication:

- Record the tapping range of the OLTC.
- Record the output range of the transducer.
- Calculate the transducer output for each tap position.
- With the transformer at bottom tap, set through each tap and measure the output of the transducer. Compare to calculated values.

5.19. Carry out DLA Testing

If required, carry out Dielectric Loss Angle measurements on the transformer windings and/or bushings as per MN000301R172 Doble DLA Testing.

DLA Testing is at Asset Manager's discretion but in general:

a) If the transformer is >=5MVA (ONAN Rating) – Perform Winding DLA tests.

b) If the transformer is <5MVA (ONAN Rating) – Winding DLA tests not required.

c) If transformer bushings are U_m of >=66kV – Perform Bushing DLA tests.

d) If transformer bushings have a U_m of <66kV – Bushing DLA tests not required.

5.20. Carry out Dielectric Response Analysis Testing

If required, carry out Dielectric Response Analysis measurements (Dirana testing) on the transformer as per the DIRANA User Manual.

Dirana Testing is at Asset Manager's discretion but in general:

a) If the transformer is >=20MVA (ONAN Rating) – Perform Dirana tests.

b) If the transformer is <20MVA (ONAN Rating) – Dirana tests not required.

5.21. Carry out Swept Frequency Response Analysis Testing

If required, carry out Dielectric Response Analysis measurements, Dirana testing, on the transformer as per the Doble 5200 User Guide.

SFRA Testing is at Asset Manager's discretion but in general:

a) If the transformer is >=20MVA (ONAN Rating) – Perform SFRA tests.

b) If the transformer is <20MVA (ONAN Rating) – SFRA tests not required.

5.22. Carry out Partial Discharge Testing

If required, carry out offline Partial Discharge measurements as per the MPD 600 Test Procedure.

Partial Discharge Testing is at Asset Manager's discretion.

Refer to STNW1160 Standard for Maintenance Acceptance Criteria for minimum acceptance values.

Schedule of Tests

Test	New Power Transformer	Aged or refurbished Power Transformer
Aux. and Control Circuit Voltage Withstand.	As per 5.7 (a) and (b)	As per 5.7 (c) and (d)
Insulation Resistance.	On-site test required.	
Oil Sampling	As per 5.9 (a) and (b)	As per 5.9 (c) and (d)
Winding Resistance.	On-site test required.	
Tap-changer Continuity	On-site test required.	
Voltage Ratio	On-site test required.	
High Voltage Withstand.	As per 5.13 (a) to (c)	As per 5.13 (d)
Over-potential	At Asset Manager discretion.	At Client's discretion.
Load Losses	Review manufacturer's results only.	At Client's discretion.
No Load Losses	Review manufacturer's results only.	At Client's discretion.
OTI / WTI	On-site test required.	
DLA	At Asset Manager discretion.	
Partial Discharge	At Asset Manager discretion.	
Dirana	At Asset Manager discretion.	
SFRA	At Asset Manager discretion.	
Transducer Calibration	On-site test required.	

Table 5: Details the circumstances in which different tests are carried out

5.23. Complete Commissioning Checklist

A requirement for a power transformer being placed in service for the first time or after refurbishment is that all checklists nominated in the Construction and Commissioning Tools have been completed.

5.24. Complete and Clean Up

Disconnect test equipment and remove safety barriers and warning signs.

Remove all test shorts.

Return test equipment to designated storage.

APPENDIX 1 – ELECTRICAL CLEARANCES

Extracted from Ergon Energy Substation Standard “Clearances in Air” SS 1-3.1 and AS 2374.3.1

System nominal voltage - kV	11	22	33	66	110	132	132	275
System highest voltage - kV	12	24	36	72.5	123	145	245	300
Rated LIWV# - kV	95	150	200	325	550	650	1050	1050
Rated short duration PFWV# - kV	28	50	70	140	230	275	460	460
Electrical clearances								
Minimum Ph-E - mm	160	280	380	630	1100	1300	2100	2300
Minimum Ph-Ph - mm	185	325	440	725	1265	1495	2415	2650

Table 6. – External Air Clearances

Extracted from British Standard **BS 6435**

Rated voltage	Type of enclosure	Clearance between live metal of different phases	Clearance between live metal and earth	Creepage over insulator
kV		mm	mm	mm
12	Fully insulated	45	32	*
	Partially insulated	127	76	127
17.5	Fully insulated	75	60	*
	Partially insulated	165	102	153
24	Fully insulated	100	75	*
	Partially insulated	242	140	203
36	Fully insulated	125	100	*
	Partially insulated	356	222	305

*See 10.1.1.

Table 2 – Internal Cable Box Clearances

Unless **all** parts of the termination are fully shrouded with high voltage insulation, use the “partially insulated” values in this table.