



Transformer Testing Guide



PARTNERS IN
POWER

About This Guide

Transformer testing is a set of electrical, dielectric and oil tests that together prove a power transformer is built as specified, arrived undamaged, is safe to energise and stays in good condition through its service life. This guide sets out how to test a transformer on site, what each test proves, the limits that apply and how to read the results.

What Transformer Testing Is

A defined set of tests on the windings, core, insulation, bushings, tap changer and oil. No single test proves a transformer is healthy; each one sees a different part of it.

When It Is Done

At the factory, again on site before energisation, routinely in service, and after any event such as a through fault, a protection trip or a relocation.

Why It Matters

A power transformer is usually the most expensive single item in a substation and has a long replacement lead time. Site tests compared with the factory record find transport damage before energisation, and trended results find deterioration while there is still time to plan the repair.

Guide at a Glance

Tests

Ratio, winding resistance, insulation, tan delta, bushings, excitation, SFRA, oil and DGA.

Compared With

The nameplate, the factory record, the other phases and previous results.

Key Limits

Ratio within $\pm 0.5\%$; winding resistance phases within 2%; new transformer power factor 0.5% or under at 20 °C.

Instruments

OMICRON CPC 100, CP TD1, TESTRANO 600, FRANEO 800 and DIRANA; Megger IR testers.

Standards

AS/NZS 60076.1, .3 and .18, IEEE C57.152, C57.12.00, C57.12.90, C57.104, AS 60422.

**Need a transformer tested, or the instruments to do it?
Megavar tests power transformers across Australia and
hires every instrument in this guide.**



Why Test a Power Transformer?

Transformer Testing in Four Numbers

±0.5%

Turns ratio tolerance against the nameplate, normally on every tap (IEEE C57.12.00)

2%

Winding resistance: phases expected to agree within this (IEEE C57.152, 7.2.7)

0.5%

Power factor limit, new mineral oil transformer at 20 °C (IEEE C57.152)

5%

Bushing capacitance increase that is cause to investigate (IEEE C57.19.100, 10.4.1)

Why It Matters

Each Test Sees One Part

Ratio and resistance check the windings and tap changer, tan delta and insulation resistance check the insulation, SFRA and impedance check the mechanical geometry, and oil tests check what is happening inside the tank.

Comparison Is the Test

A site result inside the limit but different from the factory record still means something has changed. The record is what makes a result meaningful.

What Goes Wrong

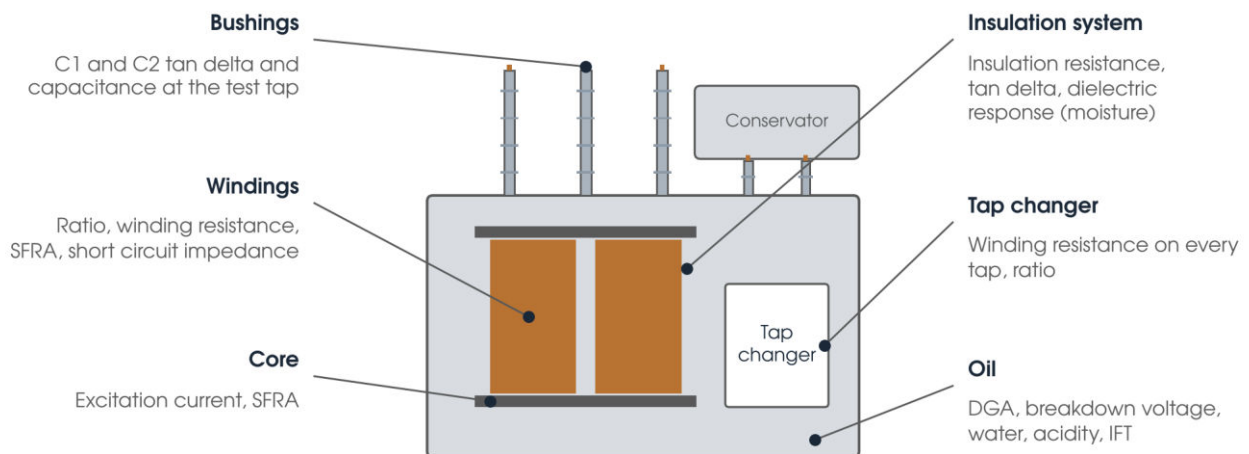
Transport and Assembly

Winding movement, core shift and damaged leads, found by SFRA, impedance and ratio.

In Service

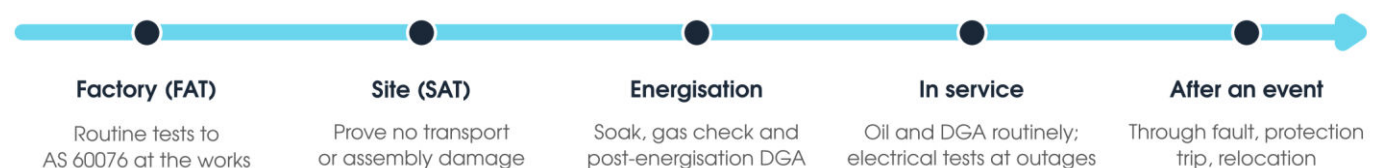
Moisture in the paper, ageing oil, loose joints, worn tap changer contacts and deteriorating bushings, found by trending.

Which Test Checks Which Part



The tests grouped by the part of the transformer they examine.

When to Test



Where Does Each Test Fit?

Tests by Stage

Test	What it proves	Factory	Commissioning	In service
Turns ratio and vector group	Correct turns, no shorted turns, tap changer on the right taps	Yes	Yes	At outages
Winding resistance	Sound conductors, joints, leads and tap changer contacts	Yes	Yes	At outages
Insulation resistance	No gross insulation fault before higher voltage tests	Yes	Yes	At outages
Tan delta and capacitance	Dry, clean insulation; unchanged winding geometry	Yes	Yes	At outages
Bushing C1 and C2	Condenser bushing insulation in good condition	Yes	Yes	At outages
Excitation current	Sound core and turn insulation	Yes	Yes	At outages
SFRA and impedance	No winding movement or core shift	Fingerprint	Yes	After an event
Oil quality and DGA	Dry oil; no active fault inside the tank	Yes	Yes	Routinely
Induced voltage with PD	Insulation free of damaging discharge at enhanced voltage	Yes	After repair	Rarely (after repair, cl 8)

Factory IR, tan delta and DGA are routine above 72.5 kV (AS/NZS 60076.1, 11.1.2.2), otherwise special tests.

Choosing the Tests

At Commissioning

Run the full site set and compare every result with the factory test certificate. SFRA is essential on any transformer that has travelled.

Induced Voltage With PD

A factory routine test above 72.5 kV. It is valid only with background 50 pC or less, and passes only if every clause 11.3.5 condition holds: no voltage collapse, no level above 250 pC or rise over 50 pC in the hour, no rising trend and no sudden sustained increase in the last 20 min, then 100 pC or less at $1.2 U_r/\sqrt{3}$ (AS/NZS 60076.3).

In Service

Oil and DGA on the routine cycle, and the electrical tests at planned outages, each compared with the previous record.

After an Event

After a through fault or protection trip: DGA first, then SFRA, impedance, ratio and winding resistance to look for winding damage.

Test Order Matters

AC Tests Before DC

Winding resistance passes DC through the windings and leaves the core magnetised, which distorts excitation current and SFRA. Run those first, or demagnetise the core before them (OMICRON).

Insulation Before Stress

Make a quick insulation resistance check before tan delta; the full timed test is step 5. Stop if the current rises without settling.

Good to Know

Demagnetise the core after winding resistance and before the transformer is energised.

Test at the same voltages and connections as last time, or the results cannot be compared.

How Does It Work?

The Insulation System

Three Insulation Gaps

A two-winding transformer is modelled as three capacitances: CH (HV winding to tank and core), CL (LV winding to tank and core) and CHL (between the windings).

Power Factor and Capacitance

A test set applies up to 10 kV, the cap in IEEE C57.12.90-2021 clause 10.10.3, and measures the loss (power factor or tan delta) and capacitance of each gap. Loss shows moisture and contamination; capacitance shows changed geometry.

Why CHL Matters

Most of the paper sits between the windings and moisture migrates into it, so CHL is the best single indicator of moisture in the main tank (OMICRON).

Connection Rules

Short Each Winding

Short all HV bushings together and all LV bushings together, neutral included, so the winding inductance takes no part in the measurement.

UST and GST

Ungrounded specimen test (UST) measures between two leads only; grounded specimen test (GST) measures to earth. A guard lead removes a gap from the reading.

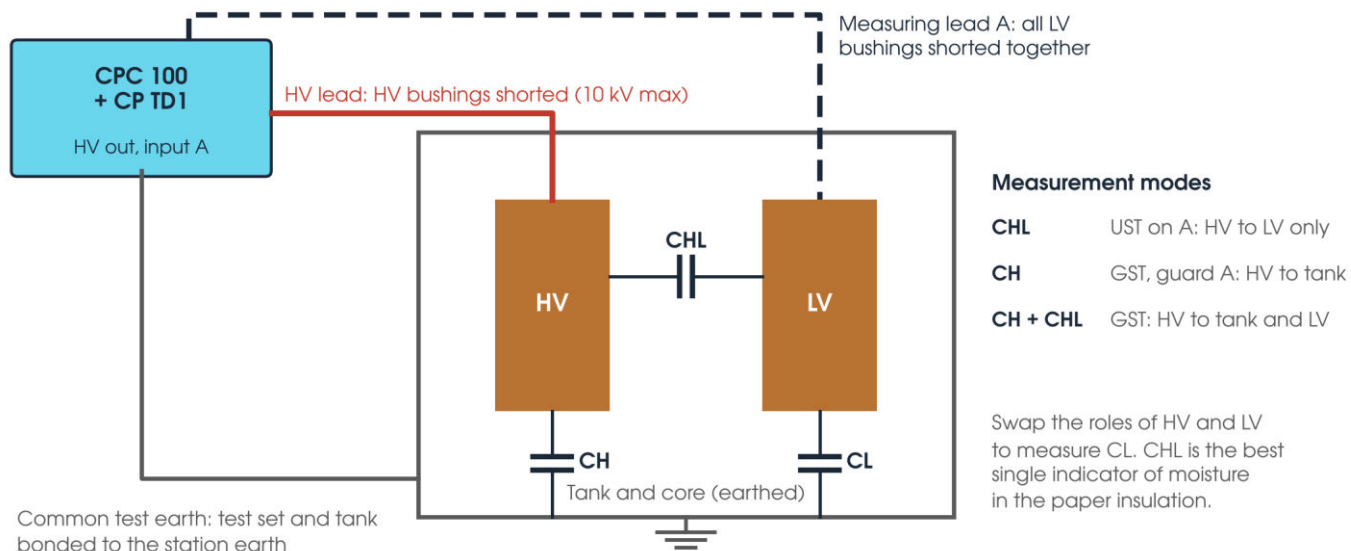
Bushings Separately

Condenser bushings are measured from the test tap: C1 is the main insulation, C2 the tap insulation. Test C2 at the manufacturer's lower tap voltage, never at the C1 voltage, and keep other taps earthed.

Good to Know

Clean and dry the bushing porcelain before tan delta. Surface leakage on a damp bushing can make the reading meaningless.

Insulation Model and Tan Delta Connections



Two-winding transformer insulation model with CPC 100 and CP TD1 connections for the CHL measurement.

How Do I Set Up Safely?

Permits, Isolation and Earthing

1 Access Permit

Confirm the permit covers the tests, including removal of line and neutral connections and any temporary removal of earths by the person the asset owner authorises.

2 Isolated, Proved Dead, Earthed

Confirm it at the plant with the permit issuer before connecting anything.

3 Disconnect the Transformer

Remove all line and neutral connections, surge arresters and VTs. Short and earth bushing CT secondaries.

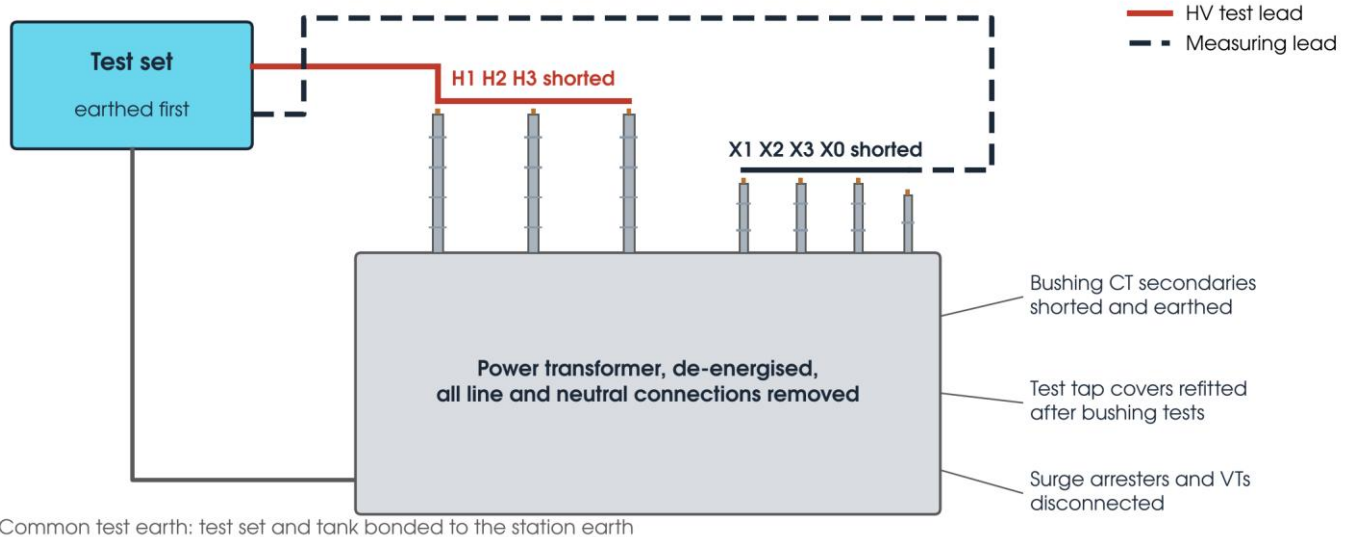
4 Earth the Test Set First

Bond the test set and tank to one common test earth before any other lead, and remove it last.

Who Should Test

Competent, authorised testing personnel under the asset owner's safety rules. At Megavar, assessed testers; less experienced staff work under direct supervision.

Lead Placement on the Transformer



Typical lead arrangement for an overall tan delta test. Winding resistance and ratio use per-phase connections at the same bushings.

Important

This guide describes general practice for competent HV testing personnel. It is not a work procedure. Work under the asset owner's safety rules, the access permit and a site-specific safe work method statement. Manufacturer and asset owner criteria take precedence over the general guidance here.

Hazards Specific to Transformers

Test Voltage

Tan delta applies up to 10 kV, and never more than half the withstand voltage of any connected part (IEEE C57.12.90-2021, 10.10.3). Barricade every energised terminal.

Stored Energy

After insulation resistance, keep each winding earthed until the trapped charge has decayed to a negligible value (IEEE C57.12.90-2021, 10.11.4). After winding resistance, let the instrument discharge the winding before touching a lead.

Induced Voltage

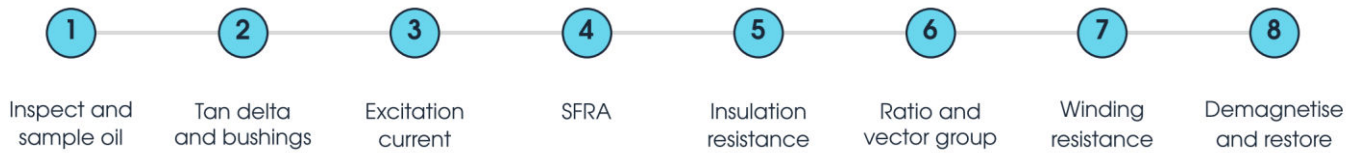
Disconnected bushings near live circuits can pick up induced voltage. Keep windings earthed until the moment of test.

Working at Height

Bushing connections are usually reached from an elevating work platform under the site's working at height rules.

How Do I Make the Measurement?

How to Test a Transformer: The Site Sequence



Steps 1 to 4

1 Inspect and Sample Oil

Nameplate against the drawings, oil level, breather, Buchholz, bushings and the transport impact recorder. Take the oil sample and baseline DGA, and make a quick insulation resistance check on each winding.

2 Tan Delta and Bushings

Power factor and capacitance of CH, CL and CHL, then C1 and C2 of each condenser bushing (C2 at its tap rating), with the top oil temperature.

3 Excitation Current

Single-phase, typically 10 kV, each HV phase in turn with the other windings open (OMICRON).

4 SFRA

From 20 Hz to at least 1 MHz above 72.5 kV, 2 MHz recommended, on each winding, against the factory fingerprint (AS/NZS IEC 60076.18, 4.5).

Steps 5 to 8

5 Insulation Resistance

One and ten minute values on each winding to earth and between windings, at a voltage suited to the winding. Never under vacuum (IEEE C57.12.90-2021, 10.11).

6 Ratio and Vector Group

Every tap, all three phases, with phase angle.

7 Winding Resistance

Every winding, every tap, all three phases, with the oil temperature recorded.

8 Demagnetise and Restore

Demagnetise the core, return the tap changer to its service position, then CT tests, tap changer, cooling and protection devices before energisation.

Good to Know

Record top and bottom oil temperature and the time since de-energisation with every result.

Common Mistakes

Winding Resistance Before SFRA

Residual magnetism distorts the SFRA core region and the excitation current pattern.

Bushings Not Shorted

Winding inductance enters the tan delta measurement and the result is wrong.

No Temperature Record

Resistance not corrected, or power factor reported without the oil temperature, cannot be compared.

More Common Mistakes

Different Test Voltage

Insulation resistance at a different voltage or connection from last time cannot be trended.

Damp or Dirty Porcelain

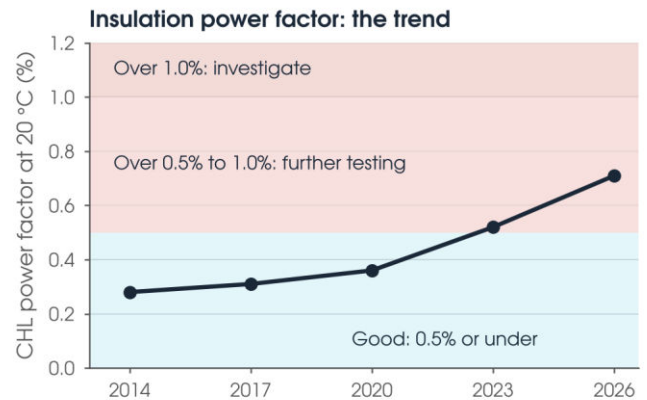
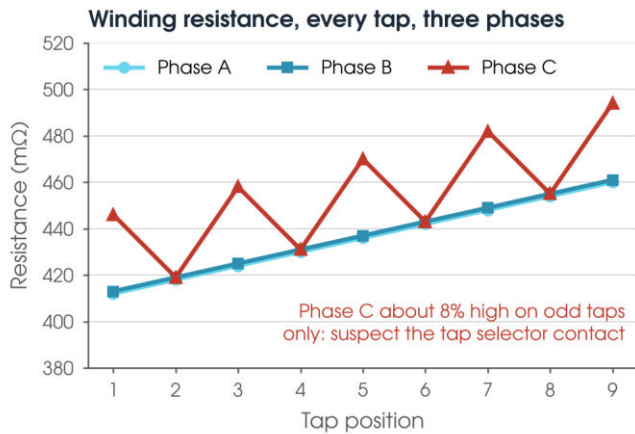
Surface leakage makes a healthy bushing look poor.

CT Secondaries Open

An open CT secondary on a bushing CT can develop a dangerous voltage during testing.

How Do I Read the Result?

Winding Resistance by Tap, and the Power Factor Trend



Illustrative values. Bands: IEEE C57.152, service-aged mineral oil

A phase that is high on alternate taps only points to one set of tap selector contacts. A power factor still under the 1.0% investigation line but rising through the bands is a reason to investigate now.

Comparing the Result

Turns Ratio

Normally within $\pm 0.5\%$ of the nameplate, with the standard's nearest-turn and bridging-tap exceptions (IEEE C57.12.00-2021, 9.1; C57.152-2025, 7.2.10). For a new unit, AS/NZS 60076.1 Table 1 sets the lower of $\pm 0.5\%$ and one tenth of the percentage impedance on the principal tap.

Winding Resistance

Phases within 2% of each other; within 5% in any comparison, such as the corrected factory value, is usually satisfactory (IEEE C57.152-2025, 7.2.7).

Power Factor

Mineral oil, at 20 °C: new, 0.5% or under (0.4% at 230 kV and above); service aged, over 0.5% to 1.0% calls for further testing and over 1.0% for investigation (IEEE C57.152-2025, Table 15).

Bushings

Power factor 1.5 to 2 times its initial value: test more often or remove; three times: remove (IEEE C57.152-2025, 7.3). Capacitance over $\pm 5\%$ of nameplate is questionable, over $\pm 10\%$ unacceptable (OMICRON); an increase of 5% or more is cause to investigate (IEEE C57.19.100-2025, 10.4.1).

What a Bad Result Looks Like

Ratio Out on One Phase

Shorted turns or a tap changer fault. Confirm with excitation current.

Resistance High on Some Taps

A worn or burnt tap changer contact.

Excitation Pattern Broken

A three-limb core gives high, low, high; a four-limb core low, high, low. Otherwise suspect shorted turns, a core fault or residual magnetism (IEEE C57.152-2025, 7.2.11).

SFRA Trace Moved

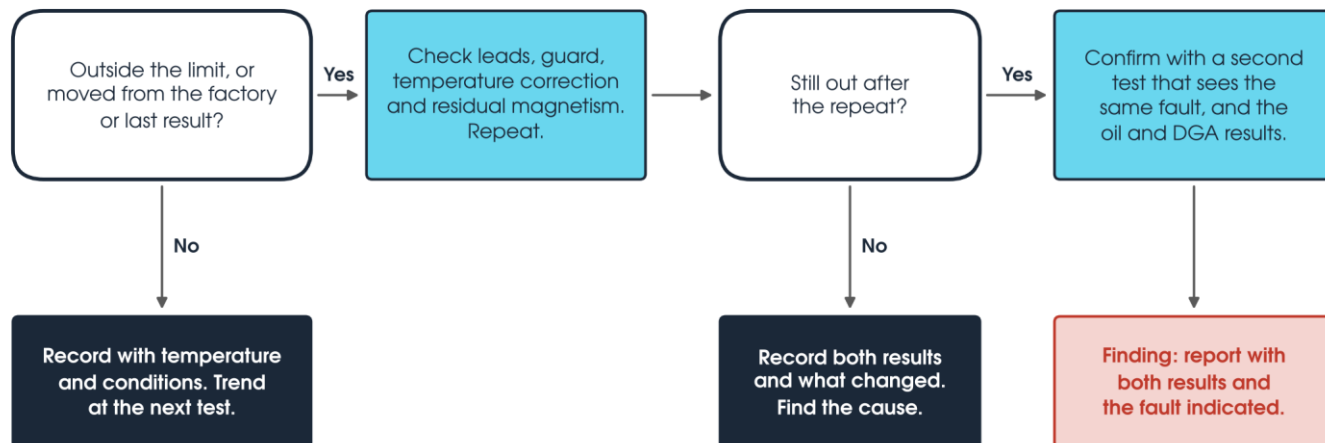
Winding movement or core shift. Compare with the fingerprint or a sister unit.

Impedance Changed

Outside 3% of nameplate, or one phase outside 3% of the three-phase average: investigate (IEEE C57.152-2025, 7.2.12).

Is My Result OK?

Decision Path



Temperature Correction

Winding resistance is corrected to a common temperature before it is compared (IEEE Std C57.12.90-2021, clause 5.2):

$$R_2 = R_1 \times (T_k + T_2) / (T_k + T_1)$$

T_k is 234.5 °C for copper and 225 °C for aluminium. Winding temperature equals the average oil temperature after 3 hours without excitation (1 hour with pumps running) and with top and bottom oil within 5 °C (clause 5.1.2).

Worked Example

A copper winding reads 412.0 mΩ at 18 °C. At the 75 °C reference of AS/NZS 60076.1 clause 11.1.1 it is $412.0 \times 309.5 / 252.5 = 505.0$ mΩ.

Power Factor

Report the measured value with the top oil temperature (IEEE C57.12.90-2021, 10.10.4). For the C57.152 limits at 20 °C, state the correction method and basis and report that value separately.

What to Report

Nameplate and Conditions

Ratings, vector group, tap range, oil and ambient temperature, weather and time since de-energisation.

Every Result

Each test on each phase and tap, the test voltage or current, and the corrected value.

The Comparison

Against the nameplate, the factory record, the other phases and the previous test.

Traceability

Instrument models, serial numbers and calibration dates, and the connections used.

What About Oil and DGA?

Oil Quality

What Is Tested

Breakdown voltage, water content, acidity, interfacial tension, dissipation factor, colour and furans.

Limits

AS 60422 Table 5 grades good, fair and poor by equipment category: for categories O and A, over 60 kV breakdown and under 15 mg/kg water are good. Before energisation above 72.5 kV, Table 3 sets over 60 kV and under 10 mg/kg.

Sampling

Sample correctly and to the laboratory's instructions; a contaminated sample produces a false result.

Dissolved Gas Analysis

What It Shows

Faults inside the tank produce characteristic gases that dissolve in the oil, so DGA finds a developing fault while the transformer is in service.

Interpretation

The laboratory reports IEEE C57.104-2019 status: 1 probably normal, 2 possibly suspicious, 3 probably suspicious. A transformer with no internal arcing device should make no acetylene (6.2.1).

Good to Know

Any increase in acetylene between samples is significant (IEEE C57.104-2019, Table 3).

Take a baseline before energisation and a follow-up sample after energisation (IEEE C57.152-2025, Table 1).

Key Gases and What They Indicate

H ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	CO, CO ₂
Hydrogen	Methane	Ethane	Ethylene	Acetylene	Carbon oxides
Partial discharge and stray gassing of oil	Heating of oil or paper	Heating of oil or paper	Heating of oil or paper, at high temperature	Arcing above 1000 °C	Heating of paper (cellulose) or oil

Source: IEEE C57.104-2019, 6.2.1

Key gases and the fault types they are most associated with. The laboratory interpretation, not a single gas, decides the finding.

Recommended Solutions

Instrument	Main tests	Best used for
OMICRON CPC 100	Ratio, resistance, excitation, CT tests	Multi-function site testing of transformers and their CTs
OMICRON CP TD1	Tan delta and capacitance to 12 kV	Winding and bushing insulation, with the CPC 100
OMICRON TESTRANO 600	Three-phase ratio and resistance	Fast three-phase ratio, resistance, impedance and excitation from one connection
OMICRON CPX 200	Ratio, resistance and more	Compact multi-function primary testing
OMICRON FRANEO 800	SFRA	Mechanical integrity, compared with the factory fingerprint
OMICRON DIRANA	Dielectric response	Moisture in the paper insulation
Megger MIT1020 10 kV	Insulation resistance and PI	Large transformers at up to 10 kV
Megger MIT520 5 kV	Insulation resistance and PI	Distribution and power transformers at up to 5 kV

Every instrument is available calibrated, with leads, from Hobart, Launceston, Adelaide and Newcastle: [transformer test equipment hire](#).

Frequently Asked Questions

Common Questions

How do you test a transformer?

On site: inspect and sample the oil, then tan delta and bushings, excitation current, SFRA, insulation resistance, ratio and winding resistance, demagnetise, and prove the accessories and protection before energising.

How do you check if a transformer is bad?

Compare each result with its limit and with the transformer's own record. DGA, bushing power factor and capacitance, winding power factor, ratio, winding resistance and SFRA are the usual indicators.

How often should a transformer be tested?

Routine oil tests every 1 to 6 years by equipment category, sooner if results are fair or poor (AS 60422, Table 4). Electrical tests at planned outages and after any through fault, trip or relocation.

Is polarisation index useful on an oil-filled transformer?

On a service-aged unit IEEE C57.152-2025 (7.2.13.5) grades it from under 1.0, dangerous, to over 2.0, good. It should not be used to assess a new power transformer.

Standards and References

AS/NZS 60076.1:2014, Power transformers, Part 1: General; AS/NZS 60076.3:2017 Amd 1:2020, Part 3: Insulation levels and dielectric tests; AS/NZS IEC 60076.18:2025, Part 18: Frequency response.

IEEE Std C57.152-2025, Guide for Diagnostic Field Testing of Liquid-Filled Power Transformers, Regulators, and Reactors.

IEEE Std C57.19.100-2025, Guide for Application of Power Apparatus Bushings.

IEEE Std C57.149-2024, Guide for the Application and Interpretation of Frequency Response Analysis for Oil-Immersed Transformers.

IEEE Std C57.12.00-2021, General Requirements, clause 9.1; IEEE Std C57.12.90-2021, Test Code, clauses 5, 10.10 and 10.11.

IEEE Std C57.104-2019, Interpretation of Gases Generated in Mineral Oil-Immersed Transformers.

AS 60422:2017, Mineral insulating oils in electrical equipment: supervision and maintenance guidance.

OMICRON, Diagnostic Testing of Power Transformers, 2025; Bushing Power Factor Testing, 2019; Exciting Current Test, 2019; SFRA Testing, 2019; DC Winding Resistance Test, 2019.

Megger, Guide to Transformer Winding Resistance Measurements, 2010; Guide to Diagnostic Insulation Testing Above 1 kV, 2021.

More Questions

What is transformer oil testing?

Laboratory tests of breakdown voltage, water, acidity, interfacial tension, dissipation factor and furans, judged against AS 60422, plus dissolved gas analysis.

Can a multimeter test a transformer?

Only for continuity on a small transformer. It cannot measure ratio, insulation at test voltage or the condition of the insulation and oil.

What is SFRA?

Sweep frequency response analysis: a fingerprint of the winding and core geometry used to find movement after transport or a through fault.

Does Megavar test as well as hire?

Yes. Megavar tests power transformers from 11 kV distribution class to 500 kV transmission class, and witnesses factory acceptance tests. Call 1300 730 499.

Hire or Have It Tested

Have It Tested

Megavar's engineers carry out [transformer testing](#), [factory acceptance testing](#) and [substation commissioning](#) across Australia.

Next Step

[Hire transformer test equipment](#)

[Book transformer testing](#)

[1300 730 499](#)

Hire: rentals@megavar.com.au

Testing: service@megavar.com.au



Speak to our team today

megavar.com.au



service@megavar.com.au

1300 730 499