WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-60-05

BULK OIL POWER TRANSFORMER

I N D E X

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1. GENERAL

1.1 Scope

This specification covers the design, manufacture, inspection, testing and delivery of bulk-oil transformers.

This specification is applicable to all ratings of the bulk oil transformers.

1.2 Standards

The transformers supplied shall comply with the latest editions and amendments of the relevant International Electrotechnical Commission (IEC) standards and British Standards (BS), which shall include, but not be limited to, the following:

IEC 60076	Power transformers
IEC 60076-7	Power Transformers – Part 7: Loading guide for oil-immersed power transformers
IEC 60076-10	Power Transformers – Part 10: Determination of sound levels
IEC 60060	High-voltage test techniques
IEC 60034	Rotating electrical machines
IEC 61869-2	Instrument transformers – Part 2: Additional Requirements for current transformers
IEC 60127-2	Miniature fuses – Part 2: Cartridge fuse-links
IEC 60137	Insulated bushings for alternating voltages above 1000V
IEC 60404	Magnetic materials
IEC 60947	Low-voltage switchgear and controlgear
IEC 60296	Fluids for electrotechnical applications - Mineral insulating oils for electrical equipment
IEC 60836	Specifications for unused silicone insulating liquids for electrotechnical purposes

IEC 62770	Fluids for electrotechnical applications – Unused natural esters for transformers and similar electrical equipment
BS 2562	Specification for cable boxes for transformers and reactors
BS 6121	Machanical cable glands – Requirements and test methods

1.3 Type Tests

Type test certificates on transformers and cable boxes shall be submitted to certify that the equipment supplied has a proven design. Transformers and cable boxes without passing the required type tests will not be accepted.

The required type tests on transformers shall have been performed on a transformer of essentially similar design meeting the following criteria:

(a) The test current of short circuit withstand test is no less than that specified;

(b) The primary voltage is no lower than that specified; and

(c) The tank size is no smaller and the plate thickness is no larger than that to be used in this Contract.

Type test certificates of short circuit withstand tests shall be issued by the Association of Short Circuit Testing Authorities, (ASTA) UK or equivalent.

1.3.1 Type Tests on Transformers

The following type tests to IEC 60076 shall be required:

(a) Short Circuit Withstand Test

Calculations to demonstrate the thermal ability and test reports to demonstrate the dynamic ability of the transformer to withstand the specified short circuit current shall be provided.

(b) Lightning Impulse Test

Test records on observations made to detect any indications of insulation failure shall be submitted. Such indications shall include:

(i) Variation of wave shape

(ii) Occurrence of a chopped wave

(iii) Noise within transformer

(iv) Visual signs of sparkover under oil, e.g. presence of smoke

(v) All oscillograms shall be submitted with the test certificate

(c) Tank Deflection Test (for Transformers of 20MVA and above)

(i) Vacuum test - The transformer tank, conservator, cable-sealing chamber and disconnecting chamber of each size shall be subjected, when empty of oil, to a vacuum of 70 kPa below atmospheric pressure. The permanent deflection of flat plates after the vacuum has been released shall not exceed the value specified below.

Horizontal Length of Flat Plate (mm)	Permanent Deflection (mm)
Up to 1250	3
Over 1250 to 2000	6
Over 2000 to 2500	10
Over 2500	13

(ii) Pressure test - The tank shall be subjected to a positive pressure of 70 kPa or normal pressure plus 35 kPa whichever is the greater. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the figure specified in the Vacuum Test.

1.3.2 Type Tests on Cable Boxes

The following type tests to BS 2562 shall be required:

(a) Rated Lightning Impulse Withstand Voltage Type Test on the Complete Box

The test shall be made on the box complete with all its fittings except the cables.

The test shall be made with a 1.2/50μs full wave of negative polarity in accordance with IEC 60060.

Five consecutive waves with a peak value of 75kV for 12kV rated system voltage (11kV nominal system voltage) and 170kV for 36kV rated system voltage (33kV nominal system voltage) shall be applied without flashover or puncture of the bushing.

The test shall be made separately between each bushing stem and the earthed fixing flange, the bushing stems not under test being solidly earthed to the body of the box.

(b) Rated Lightning Impulse Withstand Voltage Type Test on the Bushings

The test voltages shall be the same as Clause 1.3.2(a).

(c) Rated Short Duration Power Frequency Withstand Voltage Type Test on the Bushings.
The tests shall be in accordance with IEC 60137.

2. PERFORMANCE PARAMETERS

2.1 Technical Particulars

The transformer shall comply with the following specific requirements:

(a)	Type	:	3-phase, two winding, oil-immersed, floor mounted, ONAN / ONAF for mineral; KNAN / KNAF for silicone and natural ester, indoor and outdoor application
(b)	Rating	:	Maximum continuous rating
(c)	Vector grouping	:	Dyn 11 with star point to be solidly earthed
(d)	Insulation	:	Class A or better
(e)	Tap changing equipment	:	Off-load, fitted on the primary side +5% to -5% in 2.5% steps
(f)	Site operating or storage conditions	:	Ambient air temperature: Average over 24 hours 40°C Peak for 4 hours continuous 45°C Minimum ambient temperature 0°C Average yearly temperature 30°C Relative humidity 0-98%
(g)	Altitude	:	not greater than 1000 metres above mean sea level
(h)	Electricity supply	:	3-phase, 50 Hz, solidly earthed neutral system of 11 kV or 800A resistance earthed at 33 kV
(i)	Normal limits of voltage fluctuation	:	+ 10%, - 2.5%
(j)	Normal limits of frequency variation	:	±2%
(k)	Flux density	:	Not exceeding 1.55 tesla with primary winding excited at rated voltage and frequency
(l)	Minimum efficiency	:	99% at full load rating and principal tap

2.2 General Design Parameters

2.2.1 Continuous Maximum Ratings (C.M.R.)

The transformer shall be rated for continuous operation under the specified site conditions. Due to local climate conditions, the maximum average winding temperature rise (measured by resistance) and top oil temperature rise (measured by thermometer) shall be limited to 55°C and 50°C respectively. These temperature rise limits shall be valid for all tappings.

The values of rated power shall be chosen from IEC 60076.

2.2.2 Service Life

The equipment shall be designed for a 25-year service life based on the conditions and loading detailed in this specification.

2.2.3 General Design Information

Power supply available for instruments, control and protection : 110V d.c. ±15%

Supply voltage available for auxiliary equipment : 380V 50 Hz TP&N +10% - 16%

2.2.4 Coordination of Equipment Insulation

Rated system voltage (kV)	36	12	7.2	3.6
Nominal system voltage (kV)	33	11	6.6	3.3
Minimum impulse withstand voltage (1.2/50 μs) (kV)	170	75	70	40
Minimum power frequency withstand voltage (1 min) (kV)	75	28	20	10

2.2.5 System Fault Level

Nominal system voltage	(kV)	33	11	6.6	3.3	0.38
Symmetrical 3-phase short current circuit	(kA)	31.5	20	20	25	43.1

2.2.6 Electrical Clearance

Air insulated outdoor and indoor busbars and connections shall have electrical clearances listed as follows in mm:

Nominal voltage between phases (kV)	33	11	6.6	3.3	0.38
Minimum clearance between live metal and earth	380	205	104	106	19
Minimum clearance between live metal of different phases	440	255	180	140	25
Minimum clearance between live metal and oil pipework, including conservator and pressure relief valve	480	255	180	140	25
Minimum clearance between any live metal of different voltage system	760	405	284	222	-

2.2.7 Harmonics Suppression

The transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third and the fifth, so as to eliminate wave-form distortion and any possibility of high frequency disturbances, inductive effects or circulating currents between the neutral points of transformer reaching to such a magnitude as to cause interference with communication circuits.

2.2.8 Winding Impedance

The positive-sequence impedance between the main windings at the principal tap position and the maximum plus and minus tap positions shall be within ±10% of the value specified by manufacturer. For transformers rated 2,000 kVA and above, the transformer winding impedance shall be not lower than figure specified in IEC 60076 by more than 0.5% and shall be not higher than the figure by more than 1.5% e.g. if the equivalent impedance shown on IEC 60076 is 7.15%, then the transformer winding impedance quoted shall be within 6.65 - 8.65%.

For transformers under 2,000 kVA, the transformer winding impedance shall be not lower than the figure specified in IEC 60076 and shall be not higher than the figure by more than 1.5%.

2.2.9 Noise Suppression

The sound power level of the transformer shall not exceed 68 dB(A). The measurement shall be to IEC 60076-10 with the transformer excited at rated voltage and frequency and the cooling fans, where provided, in operation.

2.3 Loading Design

2.3.1 Load Pattern

The transformer load will comprise induction motors, variable speed drives and other steady loads such as lighting and small power. The total load from 3-phase motors may vary between 10 - 100% of the transformer kVA rating and will employ vacuum switchgear as motor starters. The maximum unbalance current between phases on loads connected to the transformer will not normally exceed 10%. Transformers supplied shall be suitable for such variations and unbalance.

2.3.2 Overload Capacity

The windings shall be designed and constructed for operation under the following cyclic overload conditions:

Loading	Preloading	Duration	Frequency for 24 hours operation
120% rated kVA	100%	5 minutes	once every 4 hours period
200% rated kVA	100%	30 seconds	once every 5 minutes period
300% rated kVA	75%	10 seconds	once every 10 minutes period

Calculations shall be provided to show that the transformer insulation life is 25 years or more when the transformer is operating under the above overload conditions. The calculation shall be based on the results of the temperature rise tests and IEC 60076-7. In view of the local climate condition, the average annual ambient temperature used for the calculation shall be 30°C.

Details of thermal capability characteristics of the transformer shall be provided to facilitate setting and testing of the transformer protection.

2.4 Tolerance Limits

Tolerance limits on guaranteed values shall be as follows:

(a) Maximum load loss at full rated power (C.M.R.), principal tap and 75°C
: no positive tolerance permitted.

(b) Maximum no-load loss at rated voltage, principal tap, 50 Hz and 75°C
: no positive tolerance permitted.

(c) Impedance voltage at full rated power (C.M.R.), principal tap and 75°C
: per Clause 2.2.8 of this specification.

The above parameters shall be guaranteed by the manufacturer and verified in the routine tests.

Due allowance shall be made by the Contractor for the design and measurement tolerances of the transformer losses. The tolerances shall be deemed to have been included in the guaranteed maximum loss figures quoted in the tender.

Tolerance limits of other parameters shall comply with the IEC 60076. Where it is not specified in IEC 60076, the permissible tolerance limit of the parameter shall be ±5%.

3. DESIGN AND CONSTRUCTION

3.1 Transformer Windings

3.1.1 Insulation

The stacks of windings shall receive adequate shrinkage treatment before final assembly.

Transformers shall meet the impulse level as specified in Clause 2.2.4 of this specification.

3.1.2 Winding Construction and Treatment

Uniformly insulated copper windings shall be used.

The core shall be protected by an impregnated varnish which shall be resistant to moisture but elastic enough to withstand the expansion and contraction caused by the loading cycles.

All windings including the neutral point shall be fully insulated to the levels stated in this specification. The neutral point shall be accessible and brought out to a terminal chamber via bushing insulated to the same level as the winding.

The windings and connections shall be secured to withstand shocks which may occur during transport, or due to switching and other transient conditions during service.

Steel sheets and strips for magnetic circuits of the transformer shall comply with IEC 60404.

Internal electrical connections shall be brazed or soldered. Mechanically crimped joints will not be accepted.

Core bolts where used shall be detailed and shall be insulated from the respective magnetic circuits with material capable of withstanding a test voltage of 2,000V r.m.s. for one minute.

3.2 Oil Tank and Associated Accessories

3.2.1 Material

Oil tank shall be fabricated from weldable structural steel.

Unless otherwise approved, tanks shall be constructed of mild steel plate, the minimum thickness of which shall be 10 mm for the side plate and for the flat base plate as below:

Horizontal base length up to (mm)	2,000	4,000	6,000	8,000
Base thickness (mm)	13	19	25	32

3.2.2 Constructional Requirements and Features

The completely assembled transformer shall be designed to withstand any of the following vacuum treatment in absolute pressure:

(a) Vacuum of 50 kPa applied to tank and cooling equipment when empty of oil.

(b) Vacuum of 70 kPa applied above oil level to tank and cooling equipment when full of oil.

(c) Vacuum of 70 kPa applied to tank only when empty of oil.

Clear instructions shall be included in the maintenance instructions regarding any special precautionary measures (e.g. strutting of tap changer barrier, tank cover or closing tap changer shut off valve) which must be taken before the specified vacuum treatments can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment shall be provided with each transformer. The maximum vacuum which the complete transformer filled with oil can safely withstand without any special precautionary measures being taken shall also be stated in the maintenance instructions.

The base of each tank shall be provided with skid to facilitate movement of the complete transformer in any direction by the use of rollers, plates or rails and so designed to prevent the retention of water inside.

The tank shall be so designed as to allow the transformer, completely assembled and filled with oil to be lifted by crane or jacks, transported by road, rail or sea, skidded in any direction on plates or rails without undue strain on any part and without causing subsequent leakage of oil. It shall be fitted with lifting lugs, jacking lugs and draw plates. All lifting provisions shall be shown on the general arrangement drawings and detailed instructions for use of such lifting facilities in transport and erection shall be covered in the operation and maintenance manual. The mounting of all external fittings, lugs and stiffeners shall be such that the retention of water is avoided. It shall be provided with a removable cover which shall be of sufficient rigidity to be capable

of being lifted without distortion. Inspection openings to facilitate winding disconnection or testing of the earth connection at the link board shall be provided without the need to remove the tank cover. The tank cover shall also be fitted with pockets for the insertion of a thermometer and the bulbs of winding and oil temperature indicators. Pockets shall be provided with captive screwed caps to enable them to be sealed to prevent the ingress of water when the instruments are removed.

For internal tank lengths in excess of 1.8 m, tank covers shall be vented at both ends.

3.2.3 Pressure Relief Device

Each tank shall be fitted with approved pressure relief device(s) designed to protect the tank from damage and to control the expulsion of oil under internal fault conditions. The device(s) shall operate at a static pressure of less than the hydraulic test pressure for the transformer tank but not exceeding 70 kPa. Means shall be provided to prevent the ingress of rain and dust.

If diaphragm type device is used, it shall be of approved design and material and situated above the maximum oil level. A spare diaphragm shall be provided.

An equaliser pipe connecting the pressure relief device to the conservator tank shall be provided.

Where pressure relief valve is used, one pair of normally open volt-free contacts shall be provided for alarm/trip initiation when the valve operates. Detailed construction and recommended setting of the pressure relief valve shall be provided.

3.3 Conservator Tank

For bulk oil power transformer of primary voltage at 33kV, a conservator tank shall be provided, which shall be mounted above the highest point of the oil circulating system. Connections between the main tank and the conservator tank shall prevent air or gas from being entrapped to ensure that a Buchholz relay can be correctly installed.

Tank cover should not be the sole means of support for the oil conservator. An independent support shall be provided.

The capacity of the conservator tank shall be adequate to accommodate the expansion and contraction of oil in the whole system. The capacity between the highest and lowest visible levels shall be not less than 7.5% of the total cold oil volume in the transformer and cooling equipment.

Each conservator tank shall be fitted with:

(a) an oil level indicator of prismatic glass visible from ground level over the range specified. It shall be marked to indicate the correct oil level at oil temperatures of 15°C, 50°C and 90°C.

(b) a 50 mm diameter filling orifice with an air-tight captive screwed cap.

(c) a drain valve.

(d) an oil seal silica gel breather or other approved type (e.g. breather complete with dehydrating agent, indicator and sight glass). Breathers shall be at least one size larger than that required in a temperate climate and shall be mounted approximately 1,000 mm above ground level for mineral oil only.

3.4 Cooling Equipment

3.4.1 Cooling Equipment - General

A minimum of two banks of radiators shall be provided for a transformer which shall have natural oil circulation. Failure of one of the radiators shall not result in a loss of more than 50% of the transformer rated output. Transformers of 5MVA and below shall be designed for natural air cooling.

For forced draught cooled radiators, the failure of the air blower(s) shall not result in a loss of more than 30% of the transformer rated output.

3.4.2 Performance Requirement

The blowers for forced air cooling shall be suitable for continuous operation outdoors under all climatic conditions.

The forced air system shall be designed to minimum noise emission and vibration of the blowers shall be damped with an approved form of anti-vibration mounting.

The motor of air blower shall be of squirrel cage induction type complying with IEC 60034 with speed not exceeding 1,000 rpm.

3.4.3 Constructional Features

Radiators shall be designed to avoid formation of water trapping pockets and all painted surfaces shall be easily accessible.

Radiators shall be connected via flanged joints directly to the tank and shall be detachable. Plugs shall be provided at the top and bottom of each radiator for draining and filling.

3.4.4 Air Blower Control

Motor starters and control gear of an approved design shall be provided for the air blower control. The control mode shall be manual or automatic as selected by a selector switch. On automatic mode, the air blower operation shall depend on the winding temperature. Thermal overload relay with single phase protection shall be provided for the motor but no-volt release shall not be fitted.

The control gear shall be accommodated in a weather proof cubicle mounted on each transformer in a convenient location for access from ground level. The material and workmanship of the cubicle shall comply with the requirements specified in Clause 4.3 of this specification.

Where multiple fan cooling is employed using small single phase motors, the motors in each cooling bank shall be grouped so as to form approximately a balanced 3-phase load.

The following control equipment shall be provided for each group of motors:

Auto/Manual selector switch

Start push button (Green)

Stop push button (Red)

Blower failed indicating lamp (Red)

The blower failed alarm contacts shall be wired to a terminal block for external alarm initiation.

Auxiliary power supply for motors and control circuits shall be 220/380V 50 Hz with voltage variation +10% and -16%.

Motor starters shall comply with IEC 60947 for type “2” co-ordination and utilization category AC-3. Fuses shall comply with IEC 60127-2.

3.5 Power Connections, Earthing and Transformer Tapping

3.5.1 Transformer Connections

Disconnecting chamber shall be provided and bolted onto the side of the transformer tank and shall accommodate the through bushings to the transformer tank and the cable box bushings. These bushings shall be connected by a removable copper link which shall be accessible from a manhole on the top of the chamber. The chamber shall be fitted with a drain valve together with an air release plug. A vent pipe having a minimum inside diameter of 19 mm shall be connected between the disconnection chamber and the main expansion pipe to the conservator tank.

Power supply and output terminations shall be made on cable boxes.

3.5.2 Cable Boxes

Cable boxes shall be air-insulated, suitable for dry-type cable termination and designed and type tested in compliance with BS 2562.

Cable boxes shall be designed to withstand the 3-phase short circuit current and duration as the power transformer.

An approved desiccator shall be provided in the cable box to prevent moisture condensation due to temperature variation. The design of the cable box shall take into consideration of provision of pressure relief device.

The cable gland plates and tank wall supporting the cable bushings shall be designed to reduce the heat generated by induced eddy current. For single core cables carrying a current of 400A or more, the gland plate shall be of non-magnetic metal such as brass.

Cable boxes shall be designed to accommodate all cable joint fittings as required for terminating the cables, including stress cones and other approved means for grading the voltage stress on the terminal insulation of cables.

Provision for earthing the body of each cable box shall be made.

Cable boxes for 380V shall be designed for 3-phase 4-wire system, i.e. the neutral terminal shall also be brought into the main cable box. Cable boxes for 3.3 kV or above shall be designed for 3-phase 3-wire system.

Cable boxes shall be fitted with cable accessories as specified in Clause 4.5 of this specification.

3.5.3 Internal Earthing of Transformers

Metal parts of the transformer shall be maintained at earth potential. The main core clamping structure shall be connected to the tank body by a copper strap.

The main core shall be insulated and earthed to the clamping structure at one point only through a removable link placed in an accessible position beneath an inspection opening in the tank cover. The connection to the link shall be on the same side of the core as the main earth connection. The insulation of the main core shall withstand a test voltage of 2,000V r.m.s. for 1 minute.

Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure.

Drawings showing the details of internal earthing of the transformer shall be submitted for approval.

3.5.4 External Earthing and Frame Leakage Protection

Provision shall be made for protection against danger arising from the charging of the low voltage components by contact with or induction from high voltage components.

The neutral point of the secondary winding shall be brought out to a separate single-gland cable box for the termination of neutral earthing cable. The bushings to be used shall be insulated to the same level as the line terminals.

For transformer incorporated with restricted earth fault protection, suitable brackets and channels fixed to the tank shall be provided for mounting the neutral C.T.

Four external earthing terminal studs shall be provided near the bottom of transformer tank to enable the tank to be securely and efficiently earthed. Each earthing stud shall be designed for connection to a 51 mm x 6.25 mm thick copper earth bar.

Connections or links for earthing shall have a current carrying capacity of not less than the current carrying capacity of the connections for line conductors.

Metalwork other than current carrying conductors shall be effectively bonded to earth. Where an earth bar is provided on the transformer enclosure, metalwork shall be bonded to the earth bar.

3.5.5 Transformer Tapping

A set of links shall be provided for changing the transformer tapping. The current carrying capacity of the links shall conform with the full rating and overload capacity of the transformer. An inspection opening with cover plate shall be provided on the transformer tank to facilitate tap changing outside the transformer after draining of transformer oil to a level below the links. The tap positions shall be clearly labelled and visible. The Contractor shall submit detailed arrangement of the tap changing procedure for approval before manufacture.

The tapping range shall comply with Clause 2.1(e).

3.6 Vibration suppression

For transformer of 5 MVA and above, or where considered necessary, anti-vibration pads of oil and weather-resistant material, suitable for operation over the temperature range 0°C to +90°C, shall be provided between transformer base, ground-mounted fans, etc., and their respective foundations to minimise ground and structure-borne vibration. When loaded as in service, at 45°C, the mountings shall give a vibration attenuation of not less than 32 dB at 100 Hz, assuming an infinite ground impedance.

The instrument cubicle shall be fixed onto the transformer with anti-vibration mountings. All instruments, relays, contactors, etc., contained in the cubicle shall have a suitable anti-vibration design.

3.7 Small Wiring

3.7.1 General

Small wiring shall include wiring for control, alarm and indication for instruments and other devices, and power supply to auxiliaries up to 10A.

3.7.2 External Wiring

Wiring liable to come in contact with oil shall have suitable oil resisting insulation. The ends of stranded conductors shall be sweated together to prevent creepage of oil along the wire.

There shall be no possibility of oil entering connection boxes for cables or wiring. Wiring in conduits shall not be used.

Unless otherwise approved, high temperature insulation shall be provided on all wiring when this comes into contact with the transformer tank. The external cabling on transformers shall be armoured or alternatively protected from mechanical damage in an approved manner.

3.7.3 Wiring in Cubicle

Wires shall be coloured black for a.c. circuits, grey for d.c. and yellow/green for earth connection.

Wires shall be neatly bunched in plastic strapping or run in plastic slot channels.

Fuses and links shall be provided to enable all circuits in a cubicle to be isolated from the bus wires.

Terminal blocks shall be provided in an easily accessible location for termination of external cables. Different wires of the same wire number shall be terminated at adjacent terminals and shorted by tinned or nickel plated copper links at the terminal block. Stud terminals shall be used for wiring rated 30A or above.

3.7.4 Ferrule Number for External Wirings

The ferrule number for external wirings shall be as follows:

Neutral C.T. connection	A141, A142
380V 50 Hz auxiliary supply terminals	L1, L2, L3, N
110V d.c. control supply terminals	K121, K122
Oil temperature alarm contacts	K121, K127
Oil temperature trip contacts	K121, K133
Winding temperature alarm contacts	K121, K125
Winding temperature trip contacts	K121, K131
Buchholz gas alarm contacts	K121, K123

Buchholz surge trip contacts	K121, K129
Air blower failure alarm contacts	K121, K141
Pressure relief valve operated limit switches	K121, K143

3.8 Finishes

3.8.1 Surface Preparation

Before untreated steelwork is painted it shall be thoroughly cleaned by an approved method. Oil tanks, conservators, support fabrications and pipework but excluding radiators shall be grit blast. Radiators shall be chemically de-rusted and phosphate coated by immersion. Treated steel-work shall be suitably cleaned and degreased.

3.8.2 Painting - External Surface

Tanks, conservators and other accessories, excepting radiators shall be coated with air-drying paints by cold airless spray to a minimum total dry film thickness of 0.127mm.

Radiators shall be given stove enamel coatings to a minimum total dry film thickness of 0.076 mm.

Covering tanks, accessories and radiators shall be painted in gloss Admiralty Grey to BS 381C No. 632.

Components mounted on the transformer shall be of the same colour finish, texture and colour match as that of the transformer.

3.8.3 Painting - Internal Surface

Internal surface of the transformer enclosure shall be painted in an identical manner to the external surface.

3.9 Monitoring Facilities and Fittings

3.9.1 Trip and Alarm Facilities

Transformers shall be complete with initiating contacts for the following trip and alarm functions:

Buchholz surge trip (if conservator is fitted)

Buchholz gas alarm (if conservator is fitted)

Winding temperature trip

Winding temperature alarm

Oil temperature trip

Oil temperature alarm

Air blower failed alarm (if fitted)

Pressure relief valve operated alarm (if fitted)

The trip contacts shall remain open in case of failure of the auxiliary power supply to avoid inadvertent tripping of the transformer.

3.9.2 Fittings and Accessories

Transformers shall be supplied with accessories to IEC 60076 and additional accessories as called for in the specification.

3.10 Erection Requirements

Facilities shall be provided so that after the transformer has been erected and completely filled with oil at site, all air which may be trapped within the tank and pipework can be exhausted.

4. AUXILIARIES AND ACCESSORIES

4.1 Temperature Indicating Devices

4.1.1 General

Each transformer shall be provided with separate indicators for indicating winding temperature and oil temperature. The indicator shall have a pointer to register the maximum temperature reached. The winding temperature indicator shall be calibrated to show the temperature in the HV or LV winding whichever is hotter.

Capillary connected sensing bulbs, and the associated heating device where required, shall be positioned in separate oil tight pockets at top oil level. The heating device shall be capable of operating continuously at the full rating and cyclic loading capacity of the transformer.

4.1.2 Performance Requirements

The indicators shall have an accuracy better than 2%.

These devices shall incorporate three sets of normally open, electrically separate switch contacts for air blower control, and to initiate temperature high alarm and tripping of an associated circuit-breaker on high temperature.

The control settings shall be fully adjustable over the range of the instrument. The contacts for air blower control shall have an adjustable reset range between 5 - 20°C.

Alarm and trip contacts shall have making or breaking capacity of 2A at 250V 50 Hz and 0.5A at 110V d.c.

Dials of temperature indicators shall be scaled uniformly from 30°C to 150°C.

4.1.3 Constructional Features

Temperature indicators shall be housed in the instrument cubicle. An ammeter shall also be provided in the instrument cubicle with provisions for:

(a) Checking the output of the current transformer used for thermal image current detection for the winding temperature indicator.

(b) Short circuit the current transformers secondary.

(c) Current injection to check indicator calibration.

Interconnecting capillaries between the indicator and its sensing bulb shall have an armouring of stainless steel for mechanical protection.

4.1.4 Calibration of Equipment

A formula used for the relationship between winding hottest spot temperatures and other values recorded during temperature rise tests to determine calibration of temperature indicator, shall be provided to check that values indicated do not vary by more than ±3°C from the values determined by the formula.

4.2 Gas and Oil Actuated Relays (if conservator is fitted)

4.2.1 General

The transformer shall be fitted with a Buchholz type relay.

The relay shall have a contact to close on collection of gas to initiate alarm and another contact to close on oil surge or low oil level to initiate tripping.

Relay contacts shall be volt-free, rated to make and break 2A at 250V 50 Hz and 0.5A at 110V d.c. Alarm and trip contacts shall be wired to the instrument cubicle.

4.2.2 Constructional Features

The relay shall be provided with an oil drain plug and a test cock to which a flexible pipe can be connected for checking the operation of the relay.

Each relay shall be provided with a window and calibrated scale in c.c. to indicate the volume of gas collected. Test cock facilities shall be provided to enable the operation of the gas element and its contacts to be checked.

To allow gas to be collected at ground level, a tube of approximately 5 mm inside diameter shall be connected to the gas release cock of the relay and brought down to a point approximately 1,350 mm above ground level, where it shall be terminated by a pet cock.

The Contractor shall provide full details, including pipe sizes and settings of relay.

4.3 Instrument Cubicle

An IP65 weatherproof cubicle shall be provided and mounted at the side of each power transformer to accommodate the dial type temperature indicators, terminations for C.T. and other control/monitor devices.

The cubicle shall be fabricated from zinc coated sheet steel of minimum 3 mm thickness, suitably braced to form a rigid structure. Exterior corners and marks of welding shall be rounded to give a smooth appearance. Crevices which may collect water or dust shall be avoided. Steelwork shall be cleaned, degreased and treated with two stoved undercoats of epoxy based paints and two final coats in semi-matt shade 18B21 to BS 4800 finish. Cubicle interior shall be of white anti-condensation finish. The final coats of paints shall be 0.075 mm thick.

The door of the enclosure shall be equipped with viewing windows of adequate size glazed with clear wired glass. Mechanical protection shall be provided and sharp bends shall be avoided at points where capillary tubes enter the enclosure. The cubicle shall be mounted for easy access from ground level and for convenient reading of indicating devices. The door shall have return flanges fitted with sealing gasket. It shall also be fitted with fasteners and a lockable handle.

An anti-condensation heater complete with an isolating switch and thermostat shall be provided in the cubicle.

4.4 Current Transformers (C.T.)

C.T. mounted on power transformers shall comply with IEC 61869-2.

The short circuit capacity and short time current duration of C.T. shall be compatible with the transformer winding.

Routine test reports to IEC 61869-2 shall be supplied for each current transformer, with the actual measured test figures provided.

4.5 Cabling Accessories

The following accessories shall be provided for the termination of external cables.

(a) Terminal Bases and Studs

Terminal bases and insulators shall be epoxy resin or glass-fibre polyester high pressure mouldings. Porcelain insulators shall not be used.

Studs, bolts or screws shall be of steel or alloy material of suitable strength and temperature expansion coefficient.

Steel load bearing washers shall be used and shall be placed immediately on top of the palm of the termination. The size and finish shall be compatible with that of both the palm of the termination and the stud.

(b) Terminal Sockets for Power Cables

Cable terminal lugs shall be hard-drawn cadmium copper with single hole palm terminals. The socket portion shall be locally annealed for crimping.

Compression type cable sockets shall be used. Each socket shall be supplied with a piece of heat shrinkable tubing of sufficient length to cover, when shrunk, the socket portion and an adequate length of cable entering the socket.

Stud holes in the palm of cable lugs shall have nominal diameters corresponding to the appropriate sizes of standard studs to BS 91 Table 1 and Table 2.

(c) Mechanical Cable Glands

Cable glands for single core cables shall be provided with insulation between the gland and the gland plate with a removable bonding link to enable the cable sheath and armour to be earthed to the cable box. Gland insulation shall be capable of withstanding a high voltage test of 2,000V 50 Hz for one minute. The armour clamp shall be suitable for gripping aluminium wire armour.

Each cable gland shall be supplied with a brass gland backnut for plain hole fixing, slip-on copper earth tag with galvanized bolt and nut for earth strip and a polycholoroprene (PCP) outer gland shroud.

Cable glands for unarmoured cables with elastomer or plastics outer sheath shall be made of brass to BS 6121 Type A4. Cable glands for armoured cables with elastomer or plastics outer sheath shall be made of brass to BS 6121 Type ElW.

4.6 Transformer Oil

The insulating fluid used shall be comply with the relevant IEC standards and the requirements as stated below:

(a) Mineral insulating oil (applicable to power transformer of all ratings)

i.	Standard	:	IEC 60296
ii.	Density	:	max. 895kg/m^3 at 20˚C
iii.	Viscosity	:	max. 12mm^2/s at 40˚C
iv.	Flash point	:	min. 135˚C
v.	Pour point	:	max. -40˚C
vi.	Fire point	:	min. 160˚C
vii.	Water content	:	max. 30mg/kg
viii.	Dielectric dissipation factor	:	max. 0.05 at 90˚C
ix.	Breakdown voltage	:	min. 30kV
x.	Polychlorinated aromatics content	:	< 3%
xi.	Polychlorinated biphenyls content	:	Not detectable (<2mg/kg)

(b) Silicone insulating oil (applicable to power transformer of primary voltage less than or equal to 11kV only)

i.	Standard	:	IEC 60836
ii.	Density	:	0.955 to 0.97kg/m^3 at 20˚C
iii.	Viscosity	:	max. 40mm^2/s ±4 at 40˚C
iv.	Flash point	:	min. 240˚C
v.	Pour point	:	max. -50˚C
vi.	Fire point	:	min. 340˚C
vii.	Water content	:	max. 50mg/kg
viii.	Dielectric dissipation factor	:	max. 0.001 at 90˚C
ix.	Breakdown voltage	:	min. 40kV

(c) Natural Ester (applicable to power transformer of primary voltage less than or equal to 11kV only)

i.	Standard	:	IEC 62770
ii.	Density	:	max. 1kg/dm^3 at 20˚C
iii.	Viscosity	:	max. 50mm^2/s at 40˚C
iv.	Flash point	:	min. 250˚C
v.	Pour point	:	max. -10˚C
vi.	Fire point	:	min. 300˚C
vii.	Dielectric dissipation factor	:	max. 0.05 at 90˚C
viii.	Water content	:	max. 200mg/kg
ix.	Breakdown voltage	:	min. 35kV
x.	Biodegradation	:	readily biodegradable
xi.	Toxicity	:	non-toxic

The first filling of transformer oil shall be supplied with the contract.

4.7 Miscellaneous Fittings

4.7.1 Valves and Flanges

Valves shall be opened by turning counter-clockwise when facing the handwheel. Butterfly type valves shall only be used for isolation of radiator.

Means shall be provided for padlocking the valve in the open and closed positions. Every valve shall be provided with a mechanical indicator to show clearly the position of the valve. Valves of 25 mm diameter and larger shall be flanged type.

Each transformer shall be fitted with the following:-

(a) One 50 mm filter valve at the top and one 50 mm combined filter and drain at the bottom of the tank mounted diagonally opposite to each other for connection to oil circulating equipment.

(b) A drain valve for oil tank.

(c) A robust sampling device at top and bottom of the main tank. The sampling devices shall not be fitted on the filter valves specified under (a) above.

(d) Air release plugs as necessary.

All valves opening to atmosphere shall be fitted with blank flanges.

4.7.2 Joints and Gaskets

Unless otherwise approved, oil resisting synthetic rubber gaskets shall not be used, except where the synthetic rubber is used as a bonding medium for cork or similar material.

4.7.3 Rating Plates and Diagrams

The following plates shall be fixed to the transformer tank at 1,700 mm average height above ground level:

(a) A rating plate bearing the data specified in IEC 60076 and the additional data specified below:

(i) temperature rise by resistance

(ii) weight of core and winding

(iii) total quantity of oil in litres

(iv) quantity of oil in main tank

(b) A diagram plate showing the internal connections and also the voltage vector relationship of the several windings and in addition a plan view of the transformer giving the correct physical relationship of the terminals. When links are provided for changing the transformer group symbol and/or ratio, means shall be provided for clearly indicating the group symbol and/or ratio

for which the transformer is connected. The transformer ratio shall be indicated for each tap.

(c) A property plate worded "Water Supplies Department" unless specified otherwise.

(d) A plate showing the location and function of all valves and air release cocks or plugs.

(e) Terminal plates, not less than 95 mm in diameter and with main characters not less than 30 mm high shall be provided for all terminals.

(f) Label plates for identifying each removable inspection cover e.g. core earth link access, current transformer access etc.

The above plates shall be of stainless steel and capable of withstanding continuous outdoor service.

5. INSPECTION AND TESTING

5.1 Inspection and Testing in Manufacturer's Works - General

The transformer supplied shall be inspected and tested at the manufacturer’s works by an Independent Inspection Body (IIB) in compliance with WSD Standard Specification EM-00-01 in manufacturer’s works. The qualification and experience of IIB shall comply with the requirements stipulated in WSD Standard Specification EM-00-01.

Tolerance limits shall be in accordance with Clause 2.4 of this specification.

5.2 Routine Tests

5.2.1 General

The following tests shall be carried out in compliance with IEC 60076 on each transformer supplied except the noise level test, temperature rise test and pressure relief device test which are only required to be carried out on one transformer of each rating. Tests (a) to (p) shall be witnessed by the IIB and test reports for tests (q) to (t) shall be inspected by the IIB.

(a) tests on magnetic circuit

(b) oil leakage tests

(c) voltage ratio, polarity and vector grouping tests

(d) measurement of no-load loss and current

(e) measurement of load loss

(f) noise level tests

(g) temperature rise tests

(h) impedance voltage tests

(i) measurement of winding resistance

(j) insulation resistance tests

(k) oil tests

(l) gas and oil actuated relays tests

(m) radiator leakage tests

(n) instrument tests

(o) pressure relief device tests

(p) air blower motor tests

(q) cable box and disconnecting chamber tests

(r) current transformer tests

(s) bushing tests

(t) voltage regulation tests

5.2.2 Routine Test Requirements

(a) Tests on Magnetic Circuit

After assembly each core shall be pressure tested for one minute at 2,000 volts A.C. between all bolts, side plates and structural steelwork.

Immediately prior to the despatch of the transformer from the manufacturer's works, the magnetic circuit shall be pressure tested for one minute at 2 kV 50 Hz between the core and earth. Alternatively a 2,500 volt megger test will be accepted providing that a reading greater than 5 MΩ is obtained.

(b) Oil Leakage Tests

Tanks and oil filled compartments of each transformer shall be tested for oil tightness after assembly and oil filling to a pressure equal to the normal pressure plus 35 kPa or 70 kPa whichever is greater. This pressure shall be

maintained for a period of not less than 24 hours, during which time no leakage of oil shall occur.

(c) Voltage Ratio, Polarity and Vector Grouping Tests

Tests shall be made to check the connections and also the voltage ratio of all tappings.

(d) Measurement of No-load Loss and Current

Each transformer shall be tested at 100% of rated voltage on principal tap to give the following data to prove compliance with the guarantee of no-load losses:

Core loss

Dielectric loss

For transformers of 5 MVA and above, additional tests at 90% or 110% rated voltage shall be conducted.

The losses shall be measured at rated frequency and with rated voltage applied to one winding, the other winding being open circuited.

(e) Measurement of Load Loss

Each transformer shall be tested to prove compliance with the guarantee of load losses at rated output. The load losses shall be measured at not less than 50% full load current of transformer.

(f) Noise Level Tests

Noise level tests shall be carried out on one transformer of each rating.

Noise levels shall be measured with the transformer on no load at normal voltage and frequency. For ONAF transformers, noise levels shall be measured separately with and without the cooling fans running.

Readings on sound power level shall be made using a precision sound level meter.

(g) Temperature Rise Tests

One transformer of each rating and voltage ratio with its cooling apparatus, if any, shall be tested.

Transformers with combined natural and forced cooling shall be tested with and without the forced cooling at the respective specified rating.

The temperature rise test shall be carried out with the transformer on the highest tap position number on the primary side.

Oil and winding temperature indicators shall be checked during temperature rise tests.

The cooling plant of each transformer when subjected to the transformer temperature rise tests shall, during these tests, performed as designed with no excessive temperature, noise or vibration.

(h) Impedance Voltage Tests

The impedance voltages shall be measured on maximum, principal and minimum tap positions at not less than 50% of the corresponding full-load current, and the derived impedance values shall comply with the requirements specified.

(i) Measurement of Winding Resistance

The D.C. resistance of each transformer winding shall be measured and recorded. The resistance of tapped winding shall be measured for each tap position.

(j) Insulation Resistance Tests

Separate source power frequency voltage withstand test and induced overvoltage withstand test shall be carried out on each transformer.

The winding connections of each transformer including bushings and cable boxes shall be subjected to these tests. Where single phase induced voltage tests are used, tests shall be applied to each phase in succession.

(k) Oil Tests

Sample of oil from each transformer shall be tested before despatch. The test shall comply with the testing requirements as follows:

Mineral Oil – IEC 60296
Silicone Oil – IEC 60836
Natural Ester – IEC 62770

(l) Gas and Oil Actuated Relays Tests

Test reports of the relay manufacturer and test methods to form part of the instruction manual including the oil leakage test and dielectric test shall be inspected.

Operation of the gas actuated relay shall be conducted by the transformer manufacturer by the gas injection method.

(m) Radiator Leakage Tests

(i) Flat-plate radiators shall be filled with dry air to a pressure of 140 kPa, or maximum working pressure plus 35 kPa, whichever is the greater, and immersed in water for 15 minutes during which no leaks shall occur.

(ii) The oil pipework and valve shall withstand a hydraulic pressure of 140 kPa or maximum working pressure plus 35 kPa, whichever is the greater, for 15 minutes. The testing medium shall be oil of viscosity not greater than that of corresponding insulating oil used.

(n) Instrument Tests

Test reports of the instrument in accordance with relevant IEC Standards, or other approved standard prior to assembly shall be inspected.

Tests shall be carried out to prove the correct functioning and wiring of the complete equipment including the air blower control circuits.

(o) Pressure Relief Device Tests

One pressure relief device of each size shall be subjected to increasing pressure and shall operate before reaching a positive pressure of 70 kPa or normal pressure plus 35 kPa whichever is greater. The operating pressure shall be recorded on the test certificate.

(p) Air Blower Motor Tests

The air blower motors, where fitted, shall be tested to IEC 60034.

(q) Cable Box and Disconnecting Chamber Tests

(i) Oil Leakage - Each cable box and disconnecting chamber shall be tested with oil with a viscosity not greater than that of corresponding insulating oil used at temperature 15°C and 0.7 Bar for 12 hours, during which time no leakage shall occur, nor shall there be any permanent set when pressure is released.

(ii) High Voltage - Each cable box and disconnecting or sealing end chambers shall withstand the following voltages for 15 minutes:

2E kV d.c.

or $\frac{4E}{3}$ kV 50 Hz sinusoidal

where E is the rated nominal service voltage between phases.

(r) Current Transformer Tests

Inbuilt current transformers shall be tested to IEC 61869-2 and their performance shall be in accordance with their rating plate details.

(s) Bushing Tests

Bushings shall be routine tested to IEC 60137.

(t) Voltage Regulation Tests

Each transformer shall be tested at the rated voltage on the principal tap.

6. DRYING OUT, TRANSPORT AND PACKING

6.1 Drying Out

Transformers shall be dried out at the manufacturer's works and the transport and method of erection so arranged that they can be put into service without further drying out on site. The method of drying out shall be subject to approval.

6.2 Transport and Delivery

Transformers shall be delivered in the fully assembled state. Where necessary and approved, the conservator vessels and breathers, radiators, wheels or other external parts of large transformers may be removed for transport provided that they can be reinstated on site without necessitating drying out the transformer.

The Contractor shall be responsible for ascertaining the methods of transport to site and the limiting factors shall be taken into account in the design.

Datum centre lines shall be clearly and indelibly marked on the tank, including the position of the centre of gravity on each side and end.

The transport limitations are normally a maximum unit weight of 20 tonnes and the height of the transformer packing including the transportation trolley shall not exceed 4.5 metres for crossing under flyovers.

When transformers are shipped under oil, the expansion space above oil level shall be filled by a dry and insoluble inert gas at positive pressure. When the manufacturer recommends the shipment of transformers without oil or partially oil filled only, a dry inert gas filling arrangement shall be used to maintain a positive pressure up to arrival at site. Pressure gauges shall be provided to monitor the gas pressure in the transformer tank and gas cylinder. Oil for first filling or topping up of the transformers shall be supplied with the transformers.

6.3 Packing

Each item shall be packed properly and protected for shipment and transport from the place of manufacture to the Site.

Tube ends and other similar open ends shall be protected from both external damage and ingress of dirt and moisture during transit and while awaiting erection at Site. Flanged pipes shall have their open ends protected by adhesive tape or jointing and covered with a wooden blank flange secured by service bolts.

Contents of cases shall be bolted securely or fastened in position with struts or cross battens and not with wood chocks wedged in place only. All struts or cross battens shall be supported by straps fixed to the case above and below to form ledges on which the batten may rest.

Particular attention shall be given to the impact strength of projecting external fittings such as the oil conservator tank and radiators, and to the strength and rigidity of the internal core-to-tank location in view of the severe ship-board conditions that may occur.

Where parts are required to be bolted to the sides of the case, large washers shall be used to distribute the pressure and the timber shall be strengthened by means of a pad.

Stencil marks on the outside of casing shall be either of a waterproof material or protected by shellac or varnish to prevent obliteration in transit.

Woodwool shall not be used.

Waterproof paper and felt linings shall overlap at seams at least 15 mm and the seams secured together in an approved manner.

Each crate or package shall contain a packing list in a waterproof envelope and copies in triplicate shall be submitted in advance. Items of material shall be clearly marked for easy identification against the packing list.

Each case, package, etc., shall be clearly marked on the outside to indicate the total weight, to show where the weight is bearing and the correct position of the slings and shall bear an identification mark relating them to the appropriate shipping documents.

All packing crates that contain components not suitable for outdoor storage shall be clearly marked to this effect.

- End of this Specification -