WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-60-05

BULK OIL POWER TRANSFORMER

Revision Date : 08.09.2008

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1. GENERAL

1.1 Scope

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

The range includes transformers of primary voltages of 3.3 kV, 6.6 kV, 11 kV or 33 kV and secondary voltages of 380V, 3.3 kV and 6.6 kV.

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	Loading guide for oil-immersed power transformers
IEC 60034	Rotating electrical machines
IEC 60044-1	Current transformers
IEC 60085	Electrical insulation - Thermal evaluation and designation
IEC 60127-2	Cartridge fuse-links
IEC 60137	Insulated bushings for alternating voltages above 1000V
IEC 60404	Magnetic materials
IEC 60947	Low-voltage switchgear and controlgear
BS 148	Specification for unused and reclaimed mineral insulating oils for transformers and switchgear
BS 2562	Specification for cable boxes for transformers and reactors

2. PERFORMANCE PARAMETERS

2.1 Technical Particulars

The transformer supplied shall comply with the following specific requirements:

(a)	Type	:	3-phase, two winding, oil-immersed, floor mounted, ONAN / ONAF 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 changer	:	Off-load, fitted on HV winding +15% to -5% in 2.5% steps for transformers with 380V secondary +5% to -5% in 2.5% steps for other transformers
(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 to exceed 1.55 tesla with primary winding excited at rated tap voltage and 50 Hz
(l)	Noise level	:	Sound power level not to exceed 68 dB(A) to IEC 60076-10 pursuant to Clause 2.2.9 below

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 micro-second) (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	-	-	-

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 of the principal tap position and the maximum plus and minus tap position shall be within ±10% of the value specified by manufacturer. For transformers rated 2000 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 2000 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 transformer excited at rated voltage and cooling fans in operation.

2.3 Loading Design

2.3.1 Load Pattern

The transformer load will comprise 3-phase induction motors, single-phase motors 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

Contractor shall provide calculations to show that the transformer insulation life is 25 years or more when the transformers are operating under each of 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.

To facilitate settings and testing on the transformer protection, Contractors shall provide details of thermal capability characteristics of the transformer after the contract awarded.

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 vertified 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 supplied.

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

Steel sheet 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)	2000	4000	6000	8000
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 minimum absolute pressures:

(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 so as 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 a thermometer and for the bulbs of winding and oil temperature indicators. Pockets shall be provided with captive screwed caps to enable them to be closed to prevent the ingress of water when the instruments or bulbs 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 an approved pressure relief device designed to protect the tank from damage and control the expulsion of oil under internal fault conditions. The device 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, or dust.

If a 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 and included in the tender.

An equaliser pipe connecting the pressure relief device to the conservator pursuant to Clause 3.3 below 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

A conservator tank shall be provided, which shall be mounted above the highest point of the oil circulating system of the equipment. Connections between the main tank and the conservator shall be such that air or gas shall not be entrapped and that a Buchholz relay can be correctly installed.

The capacity of each 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 shall be fitted with:

(a) an oil level indicator of prismatic glass visible from ground level and indicating the oil levels over the range specified. The oil level indicator shall be marked to indicate the correct oil level with the oil at a temperature 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. Drycol device complete with dehydrating agent, indicator and sight glass). Breathers shall be at least one size larger than the size that would be fitted in a temperate climate and shall be mounted approximately 1000 mm above ground level.

3.4 Cooling Plant

3.4.1 Cooling Plant – General

A minimum of two banks of radiators shall be supplied for all transformers which shall have natural oil circulation. For transformers of 5 MVA and above, forced air cooling may be chosen but for smaller transformers, they shall be designed for natural air cooling.

Cooling arrangement shall be such that failure of one of the radiators will not result in a loss of more than 50% of the transformer rated output.

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 cooler banks shall be capable of dissipating the total losses at MCR of the transformer at any tapping position without the top oil temperature rise exceeding specified limits.

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. It shall be possible to remove the blower, complete with motor, without disturbing or dismantling the cooler structure framework.

The motor of air blower shall be of squirrel cage induction type complying with IEC 60034 with speed not exceeding 1000 rpm.

3.4.3 Constructional Features

Coolers shall be suitable for mounting on a flat concrete base and shall not require separate foundation fixings.

Radiators and coolers 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.

Oil circuit of coolers shall be provided with the following:

(a) A valve at each point of connection of the transformer tank.

(b) A valve in the main oil connection at the bottom of each cooler.

(c) Removable blanking plates to permit the blanking off of the main oil connection to the top of each cooler. The blanking plates, when not in use, shall be bolted to some suitable structure on the transformer.

(d) A drain valve at the lowest point of each cooler and associated piping.

(e) A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.

(f) Air release plugs fitted where necessary.

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 equipments 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 cooler 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 'C' co-ordination and utilization category AC3. Fuses shall comply with IEC 60127-2.

3.5 Power Connections, Earthing and Tap Changer

3.5.1 Transformer Connections

Disconnecting chamber shall be provided and bolted onto the side of the transformer tank and shall accommodate the through bushing between the chamber and the tank and the cable box bushing. 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. An vent pipe having a minimum inside diameter of 19 mm shall be connected between the disconnection chamber and the main expansion pipe.

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 in compliance with BS 2562.

Cable boxes shall preferably be type tested with the power transformer and be designed to withstand the 3-phase short circuit current and duration as the power transformer. Type test certificates issued by an approved Testing Authority such as ASTA shall be submitted for evaluation. The type of insulation for cable box used in type tests shall be stated by the Contractor.

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 eddy current due to current carrying conductors. 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 required by the manufacturers of the cables, including stress cones or 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 with the exception of individual core laminations, core bolts and associated individual clamping plates shall be maintained at earth potential. Where metal parts of the core are connected to earth this shall be done by way of links accessible from the tank top to allow the insulation between core and earth to be tested. This insulation shall withstand a test voltage of 2000V r.m.s. for 1 minute.

The top main core clamping structure shall be connected to the tank body by a copper strap. The bottom main core clamping structure shall be earthed by an approved method.

The magnetic circuit shall be 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 magnetic circuit shall withstand a test voltage of 2000V 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 transformers 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 leakage 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, the neutral C.T. associated with this protection will be supplied by others. Suitable brackets and channels fixed to the tank shall be designed and supplied by the Contractor for mounting this C.T. The C.T. dimensional details will be provided to the Contractor within 4 weeks of placing the order.

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 e.g. on the transformer enclosure, metalwork shall be bonded to the earth bar.

3.5.5 Tap Changers

Each transformer shall be provided with means for varying the voltage ratio by selecting the appropriate taps using an off-circuit tapping selector of rigid construction and robust design.

All active moving parts of the equipment shall be positively located when at any on-tap position. Mechanical end stops shall be provided to prevent movement of the selector beyond the end position.

The tap selector shall have direct mechanical operation from a suitable position from ground level. The selector device shall be positive in action, with an arrangement for locking in any on-tap position by padlock. A device for indicating the number of the tap position in use shall be incorporated and shall be clearly visible when the tap selector is being operated.

The current carrying capacity of the tap changing equipment shall conform with the full rating and overload capacity of the transformer.

The tap changer shall be designed to avoid building up of oil films between the fixed and moving parts of the tapping switch resulting in a breakdown between the contact points and the transformer windings. The Contractor shall submit detailed arrangement of the tap changer for approval before manufacturing.

If operation of the tap changer is required after the transformer is in service for a period of time, this shall be clearly stated in the operation and maintenance instruction.

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, cooler feet, 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.

When control cubicles or marshalling kiosks are mounted on the transformer, anti-vibration mountings shall be provided for all instruments, relays, contactors, etc.,

contained in the cubicle. In addition, there shall be anti-vibration mountings between the cubicle and the supports on which it is mounted.

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 on transformer

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 e.g. MICV wiring.

3.7.3 Wiring in cubicles/devices

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 strappings 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.

Klippon type 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 pipeworks 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 0.127 mm.

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.

Manufacturers shall ensure that 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 transformer enclosures shall be painted in an identical manner to the external surface with air-drying oil paint.

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

Buchholz gas alarm

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 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 with their associated heating device 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 contacts settings shall be fully adjustable over the range of the instrument. The contact 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 marshalling cubicle. An ammeter shall also be provided in the marshalling cubicle for the winding temperature indicator for:

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

(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

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 the other contact to close on oil surge or low oil level to initiate trip.

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 a marshalling cubicle or panel.

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 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 1350 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 Marshalling Cubicle/Panel

An IP65 weatherproof cubicle/panel 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. Panel 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 60044-1.

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

Routine test reports to IEC 60044-1 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 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 with-standing a high voltage test of 2000V 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 transformer oil shall be mineral insulating oil complying with BS 148 and of an approved brand. Copper sulphide deposit shall not be formed on the copper conductor or insulation material of the transformer winding due to the reaction of corrosive sulphur in the transformer oil with copper. The Contractor shall submit documentary evidence to substantiate that the transformer oil supplied meets with this requirement.

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 1700 mm average height above ground level:

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

temperature rise by resistance

weight of core and winding

total quantity of oil in litres

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. This plate shall also warn operators to refer to the Maintenance instructions before applying vacuum treatment.

(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) Identification plates for the purpose of 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 Test Requirements

All tests listed in Clauses 5.3 – 5.4 of this specification shall be performed on the transformers in accordance with IEC 60076.

5.3 Type Tests

The following type tests to IEC 60076 shall be carried out:

(a) Short Circuit Withstand Test

Calculations to demonstrate the thermal ability of the transformer to withstand short circuit and tests to demonstrate the dynamic ability of the transformer to withstand short circuit 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:

Variation of wave shape

Occurrence of a chopped wave

Noise within transformer

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

All oscillograms shall be submitted with the test certificate.

(c) Tank Deflection Test

(i) Vacuum Test - One 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.

Type test certificates of the transformer, if available, shall be provided with the tender to prove that the relevant type tests have been performed on a representative transformer. Any outstanding test requirement on the type test certificate including no type test certificate submitted shall be conducted on one of the transformers supplied for the contract. The tests shall be witnessed by an IIB unless prior agreement has been obtained from the Purchaser for not doing so. However, short circuit type tests must not be carried out on the transformer supplied for the contract.

A transformer is considered to be representative of others if it is identical in rating and construction. Type tests on a transformer which has minor deviations in rating or other characteristics may be acceptable subject to agreement by the Purchaser.

Furthermore, if the secondary voltages of the transformer which undergoes the type tests are different from those supplied for the contract, detailed calculations shall be provided to prove that the flux densities of the respective transformers are identical.

Submission of the above type test certificates will not exempt the manufacturer from carrying out the transformer routine tests as specified in Clause 5.4 of this specification.

5.4 Routine Tests

5.4.1 General

The following tests shall be carried out on each transformer supplied except the temperature rise test and noise level test which are only required to be carried out on one transformer of each rating. These tests shall be carried out in compliance with IEC 60076 and the requirements as specified in Clause 5.4.2 of this specification. These tests, except tests (r) – (u), shall be witnessed 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) radiators/coolers leakage tests

(n) marshalling panel equipment tests

(o) operation tests on off-load voltage tap changers

(p) pressure relief device tests

(q) air blower motor tests

(r) cable boxes and disconnecting chambers tests

(s) current transformer tests

(t) bushing tests

(u) voltage regulation tests

5.4.2 Routine Test Requirements

(a) Tests on Magnetic Circuit

After assembly each core shall be pressure tested for one minute at 2000 volts A.C. between all bolts, side plates and structural steelwork.

Immediately prior to the despatch of the transformer from the Contractor's works, the magnetic circuit shall be pressure tested for one minute at 2 kV 50 Hz between the core and earth. Alternatively a 2500 volt megger test would be accepted providing that a reading greater than 5.0 megohms 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:

Core loss

Dielectric 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 own tank, voltage control apparatus and 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.

Unless otherwise approved by the Purchaser, the temperature rise test shall be carried out with the transformer on the highest tap position number on the HV 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 each 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 and shall comply with the requirements of BS 148 as appropriate.

(l) Gas and Oil Actuated Relays Tests

(i) Tests by relay manufacturer

Operation of the gas and oil actuated relays shall be tested by the relay manufacturer. Test methods and results shall form part of the instruction manual. Oil leakage test and dielectric test shall also be conducted.

(ii) Operation tests on assembly

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

(m) Radiators/Coolers Leakage Tests

(i) Coolers - Unless otherwise approved, each cooler shall be filled with transformer oil and shall withstand for a period of 30 minutes a pressure equal to twice the maximum working pressure at the inlet to the cooler under service conditions during which time no leakage shall occur.

As an alternative, flat-plate radiators may 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) Valves - Bodies of each 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 BS 148 insulating oil.

(n) Marshalling Panel Equipment Tests

Components shall have been tested in accordance with relevant IEC Standards, or other approved standard prior to assembly in the complete equipment.

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

(o) Operation Tests on Off-Load Voltage Tap Changers

The assembled equipment shall be operated ten times in the normal manner through the complete cycle.

(p) 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.

(q) Air Blower Motor Tests

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

(r) Cable Boxes and Disconnecting Chambers Tests

(i) Oil Leakage - Each cable box and disconnecting chamber shall be tested with oil with a viscosity not greater than that of BS 148 insulating oil 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.

(s) Current Transformers Tests

Inbuilt current transformers shall be tested to IEC 60044-1 and their performance shall be in accordance with their rating plate details.

(t) Bushings Tests

Bushings shall be routine tested to IEC 60137.

(u) 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

Each transformer shall be dried out at the manufacturer's works and the transport and method of erection so arranged that unless otherwise approved they must be put into service without further drying out on site. The method of drying out shall be subject to approval. If subsequent drying out is necessary after delivery to site, the Contractor shall submit details of the drying method and procedures. These details should be incorporated into the Maintenance Instruction Manual.

6.2 Transport and Delivery

Irrespective of the actual method approved for transport to the individual sites, all transformers shall be suitable for transport in oil.

Transformers shall be delivered in the fully assembled state unless specified otherwise in the Particular Specification. Where necessary and approved by the Purchaser, the bushings, insulators, 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 and limitations of transport to site and designs affected by these factors shall be subject to agreement.

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 due to crossing under flyovers.

Transformers may be shipped under oil within the weight limit, the expansion space above oil level being filled by a dry, insoluble, inert gas at positive pressure. When the manufacturer recommends the shipment of transformer without oil or partially oil filled only, a dry inert gas filling shall be used at a positive pressure which must be maintained up to arrival at site. Pressure gauges shall be provided to monitor the gas pressure in the transformer tank and gas cylinder. Means shall be provided on the transformer tank and gas cylinder for connection of additional pressure gauges when required. Oil for first filling of the transformer shall be supplied by the Contractor and included in the tender price.

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 then be 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, unless they be fastened firmly in place. 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 forwarded to the Water Supplies Department prior to despatch. 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.

The Inspector may be required to inspect and approve the packing before the items are despatched but the Contractor shall be entirely responsible for ensuring that the packing is suitable for transit and such inspection will not exonerate the Contractor from any loss or damage due to faulty packing.

- End of this Specification -