

## **SECTION VI**

### **4.1.3 PARTICULAR TECHNICAL SPECIFICATIONS FOR TRANSFORMERS**

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**TABLE OF CONTENTS**

<b>4.1.3 PARTICULAR TECHNICAL SPECIFICATIONS-TRANSFORMERS .....</b>	<b>1</b>
4.1.3.1 General.....	1
4.1.3.2 Power Transformers .....	1
4.1.3.2.1 Design Criteria .....	1
4.1.3.2.2 Construction.....	3
4.1.3.2.3 Painting and Galvanising .....	8
4.1.3.2.4 Fittings .....	8
4.1.3.2.5 Cooling.....	11
4.1.3.2.6 Off-load Tap Changer .....	12
4.1.3.2.7 Drain, Filter and Sampling Valves.....	12
4.1.3.2.8 Oil .....	13
4.1.3.2.9 On-Load Tap Changers .....	14
4.1.3.2.10 Local Control Cubicles and Wiring Cabinets.....	17
4.1.3.2.11 Wiring and Terminal Blocks .....	17
4.1.3.2.12 Manufacturing, Inspections and Tests .....	17
4.1.3.2.13 Erection.....	19
4.1.3.2.14 Delivery and Transport.....	19
4.1.3.2.15 Evaluation of Losses and capitalization .....	20
4.1.3.2.16 Transformer Drawings .....	21
4.1.3.3 Distribution and Auxiliary Transformers.....	23
4.1.3.3.1 General .....	23
4.1.3.3.2 General Design .....	23
4.1.3.3.3 Tanks and Conservators.....	25
4.1.3.3.4 Tests .....	29
4.1.3.3.5 Packing and Transport.....	29
4.1.3.3.6 Drawings and Diagrams.....	29
4.1.3.3.7 Evaluation of Losses.....	30

#### 4.1.3 PARTICULAR TECHNICAL SPECIFICATIONS-TRANSFORMERS

##### 4.1.3.1 General

This Specification provides for the manufacture, supply, testing before shipment, delivery, erection and commissioning of the transformers detailed in Scope of Works. Particular reference is also made to General Specification, General Technical Specification, Project Specific Data and IEC 60076.

The transformer shall be designed for a 40 years lifetime under full load operation and be supplied together with all ancillary equipment for a complete installation.

All connections and contacts shall be of ample section and surface for carrying continuously **120 %** of the specified current without undue heating. Fixed connection shall be secured by bolts or set screws of ample size, adequately locked. Lock nuts shall be used on stud connections carrying current.

On outdoor equipment, all bolts nuts and washers in contact with non-ferrous parts that carry current shall be of phosphor bronze.

Wherever possible, bolts shall be fitted in such a manner that in the event of the nut working loose and falling off, the bolts will remain in position.

##### 4.1.3.2 Power Transformers

###### 4.1.3.2.1 Design Criteria

###### 4.1.3.2.1.1 Service Conditions

The transformer shall be capable of operating continuously outdoors at any tapping during the ambient conditions specified in the section: "Project Specific Data"

Note that the average maximum ambient temperature in any one day is 30 °C. The maximum temperature rise shall therefore not exceed 55 °C of the top oil and 60 °C of the winding above the maximum ambient temperature of 40 °C.

For temperature correction due to attitude reference is made to IEC 60076 which limits the temperature rise further when tested at a normal altitude. The altitude used in the calculations shall be 2200m a.s.l.

###### 4.1.3.2.1.2 Rating

The transformers shall comply with the ratings specified in Scope of Works under the stated service conditions without exceeding the temperature rise limits specified above, over the complete tapping range. If the voltage on the secondary (LV) side is reduced or raised by up to 5 % from the rated voltage, the temperature rises of any part shall not rise by more than 5 °C (at rated power on any primary tapping).

###### 4.1.3.2.1.3 Tapping

All tappings shall be designed for constant kVA output, the rated voltage of each winding of the transformer on the principal tapping shall be as specified in Scope of Works and unless otherwise specified, shall correspond to the system nominal voltage. The tapping ranges shall be as specified in Scope of Works.

**4.1.3.2.1.4      *Noise***

The transformer, tap-changing equipment and supplementary cooling equipment shall operate without undue noise and every care shall be taken in the design and manufacture to reduce noise to the level of that obtained in good modern practice. The noise level of the transformer shall not exceed 78 dB(A) when tested in accordance with IEC 60076.

**4.1.3.2.1.5      *Radio Interference***

The design of the transformer shall be such that they will not cause any objectionable interference with radio reception in the vicinity of the transformer, either by direct radiation or by transmission through the power-lines and system to which the transformer may be connected, when energising at full rated voltage and when delivering any load up to the continuous maximum rating.

**4.1.3.2.1.6      *Interchangeability and Parallel Operation***

All transformer of any one type shall be identical and interchangeable with one another. No alteration to control circuits shall be permissible for this purpose except by means of built-in terminal boards fitted with links for effecting the alteration. All parts are to be made accurately to dimensions so that any corresponding parts will be interchangeable and any spare parts will fit into place without need of adjustments. Where similar equipment has previously been supplied, components shall interchange with those on previous contracts, unless otherwise approved.

The transformer shall be suitable for parallel master-follower operation with each other and with previously supplied transformer of similar rating which shall remain in service on the substations covered by this contract, both in respect of transformer characteristics and control circuits on all relevant taps. The new and old transformers shall share the load subject to the tolerances of impedance and voltage laid down in, IEC 60076.

**4.1.3.2.1.7      *Insulation Levels***

When assembled complete with connections as in service, electrical clearances in air shall be adequate to withstand the required impulse withstand voltage given in Project Specific Data. The Bidder shall propose in his Bid details of bushings with drawings showing air clearances and creepage distances. The creepage distance shall not be less than 31 mm/kV line voltage in Coast and industrial area and 25 mm/kV for inland installations. Care shall be taken to ensure that no fittings are located so as to interfere with the external connections to the bushing terminals.

The insulation test levels are given in Project Specific Data. All transformers shall be designed for full insulation on all terminations also the neutral termination.

**4.1.3.2.1.8      *Short Circuit Performance***

The transformer shall be capable of withstanding, without damage, the effects of a symmetrical three-phase short circuit and a phase to earth short circuit under conditions specified in IEC 60076.

It can be assumed that during a short circuit, nominal voltage will be maintained on one side of the transformer with a short on the other, the external impedance being zero. It can also be assumed that up to four transformers may be connected in parallel between HV and LV busbars.

**4.1.3.2.1.9 Frequency**

The normal frequency will be 50 cycles per second. The transformer shall, however, be suitable for continuous operation with frequency variation of plus or minus 2.5 % from the normal, without exceeding the temperature rise limit specified.

**4.1.3.2.1.10 Flux Density**

The maximum flux density in any magnetic component under any condition of voltage and frequency specified under all the operating conditions given in these specifications shall not exceed 1.9 Tesla.

**4.1.3.2.2 Construction****4.1.3.2.2.1 General**

Transformers shall be of the oil immersed “core” type (i.e. not “shell” type) suitable for outdoor use, they shall be dried out at the manufacturers works and it should be possible to commission them without further dry out.

Designs shall be such that water does not collect on any of the equipment. Particular attention shall be paid in the design of all equipment to ensure that there is not damage to working parts or insulation through the ingress of dust, insects or vermin which are prevalent for long periods in the year.

**4.1.3.2.2.2 Cores**

The transformer core shall be built up of laminations of the best quality non-ageing cold-rolled grain-oriented silicon sheet steel of high permeability and low loss coefficient. All joints between laminations shall be of the interleaved type and the laminations shall be clamped securely. Bolting of the core should be avoided to reduce losses. On no account shall butt joints be offered. The cross-section of the core shall form an approximate circle.

The laminations shall be separated by hot-oil proof insulation, and the clamping of the frame shall be firm to ensure even pressure over the whole of the core laminations so as to prevent undue vibrations or noises.

The core sheets shall be insulated with high-grade oil-proof insulation, for example magnesium-silicate-phosphate. Paper will not be accepted.

The core clamping arrangement and framework shall be efficiently insulated from the cores and withstand a test voltage of 2 KV, 50 HZ during 1 minute. The core shall be designed and built up in such a manner as to avoid accidental or slow development of short circuit paths through the iron and framework.

The core, framework, clamping arrangements and general structure of the transformer shall be of robust design, capable of withstanding any shock to which they may be subjected during transport, installation or service.

Suitable axial cooling ducts shall be provided to ensure free circulation of oil and efficient cooling of the core. The ducts shall be proportioned so that the maximum temperature at any point will be within the prescribed limits of temperature rise.

Lifting lugs or other similar means shall be provided for conveniently lifting the complete assembly (with windings).

Provision shall be made for efficient arrangement of guides to prevent movement of the core and windings during transport, installation or service.

The framework of the core shall be so designed as to prevent the presence of oil pockets, which would prevent complete emptying of the oil from the tank through the drain valve.

#### 4.1.3.2.2.3 *Windings*

The windings shall be circular and consist of high quality rectangular section copper, wound with age resisting paper of high dielectric strength. The current densities in the windings shall be stated in the Bid.

The amount of insulation between turns shall be determined not merely by normal volts per turn, but also by due consideration of the line voltages and the service conditions, under heavy lightning storms.

Adequate insulation and clearances between the windings shall be provided and all insulation and clearance between live parts must be adequate for operation at 5 per cent over the highest tap voltages on all the windings.

Phase and neutral shall be insulated for full design Voltage. **Graded winding insulation** shall not be allowed for HV, LV, Neutral or Tertiary windings

The insulation of the end turns of each winding adjacent to the transformer terminals shall be reinforced between turns to protect the windings satisfactorily against surges and transients. Details of the reinforcements shall be given in the Bid.

None of the materials used shall shrink, disintegrate, carbonise or become brittle under the action of hot oil, to an extent lowering the lifetime below 40 years when the transformer is operated continuously at the maximum specified loading.

The windings shall be so placed that they remain electrostatically balanced with their magnetic centres coincident under all conditions of operation. To prevent excessive static voltage, static end rings shall be provided, wherever necessary, at the live end of the windings.

The windings, connections and trappings of the transformer shall be clamped in position and braced so as to withstand shocks or undue stresses during transport, short circuit conditions, and other transient causes. No mechanical movement of the coils should be possible with dead short circuit on the transformers.

All windings and all fibrous and hygroscopic materials used in the construction of the transformer, shall be dried under vacuum and impregnated with hot oil. Full details of the drying out and vacuum treatment shall be furnished by the Bidder.

Leads from windings to terminal board and bushings shall be rigidly supported to prevent damage from vibration and short circuit forces.

Adequate provision shall be made for the circulation of oil round and between the winding so that a low temperature gradient between the conductors and the oil is assured and any danger of excessive local heating is avoided.

The finished width of any duct and clamping arrangement shall be such as not to impede the free circulation of oil through the ducts.

It is essential that the windings shall be subjected to a thorough shrinking and seasoning process, so that no further shrinking of windings occur at site. However, clamping arrangement shall be provided for taking up any possible shrinking of coils when in service.

All similar coils shall be strictly interchangeable. Full detailed description of the windings shall be submitted with the Bid.

When specified in Scope of Works, stabilising windings shall be provided. The windings shall be capable of withstanding the forces to which they are subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth with full voltage maintained on all other windings intended for connection to external sources of supply. When stabilising windings are to be used for purposes other than decreasing zero sequence impedance, this will be declared in the scope of work and the windings must be designed accordingly.

Unless otherwise specified, only one terminal of the stabilising winding shall be brought outside the tank and a suitable bushing shall be provided for this purpose through the tank cover. When used additionally for an auxiliary supply each corner of the winding shall be brought out.

It shall be possible to earth the winding externally to the main tank by means of a flexible bolted link to be provided by the supplier between the terminal and a suitable pad on the tank cover.

The neutral points of star connected windings shall unless otherwise specified in Scope of Works be brought out to bushings located on the tank cover and connected to an earthing bus attached to the main transformer earth terminal.

Where the star point of a winding is not specified to be brought out through a neutral bushing, the connection shall, nevertheless, be available under the main tank cover plate to permit the subsequent fitting of a neutral bushing. The subsequent installation of this bushing shall not necessitate any alteration to, or repositioning of existing fittings.

#### 4.1.3.2.2.4 *Internal Earthing*

Each part of the core shall be electrically earthed to the transformer tank. The internal earth connection shall be of the detachable link type and shall be located in an accessible position.

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 and be taken from the extreme edge of the top yoke. The main core clamping structure shall be connected to the tank body

Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section and the arrangement of the connections shall be to approval.

Where oil ducts or insulation parallel to the plane of the laminations divide the magnetic circuit into two or more electrically separate parts, the ducts or barriers shall be bridged and the magnetic circuit shall not be regarded as being of sectional construction.

Where coil clamping rings are of metal, each ring shall be connected to the adjacent core clamping structure on the same side of the transformer as the main earth connection.

All earthing connections, with the exception of those from the individual coil clamping rings, shall have a cross-sectional area of not less than 90 mm<sup>2</sup>. Connections inserted between laminations may have the cross-sectional area reduced to 25 mm<sup>2</sup> where in close thermal contact with the core.

#### 4.1.3.2.2.5 *Transformer Tank*

Each transformer shall be enclosed in a steel tank of welded construction, suitably stiffened by means of channel or angle sections welded to the tank, for withstanding the stresses imposed during transit to site and subsequent operation with no signs of oil leakage. The transformer tank shall have a removable lid on top, i.e. "Bell" type transformer tanks are not permitted.

The tank shall be complete with all accessories and shall be designed to allow the complete transformer (tanked and filled with oil) to be lifted by crane or jacks, transported by road, rail and water without overstraining any joints and without causing subsequent leakage of oil. Corrugated tanks are not acceptable.

The tanks must be so constructed as to be capable of withstanding an internal positive pressure of not less than 70 kPa without any permanent deflection of any parts. The tank must also be capable of withstanding a vacuum of 50 mm of mercury absolute when emptied of oil.

Guides shall be provided inside the tank to facilitate the lowering into the tank of the core and coils and their raising and correct positioning. The guides shall extend from the bottom of the tank to within 150 mm of the top of the tank.

The tank covers shall be of adequate strength and shall not be distorted when lifted in the lifting eyes to be provided. Inspection openings/manholes suitably bolted shall be provided as necessary to give easy access to bushings, tap changer connections and earth connections. Each inspection opening shall be of ample size for the purpose for which it is provided. Covers for such openings shall not weight more than 25 kg and shall be provided with lifting eyes.

A rail for connection of safety belt shall be arranged on the tank cover.

All oil-pipe connections shall have flanged joints provided with gaskets, preferable set in grooves or held in position by stops to prevent over compression of the gaskets.

Four jacking lugs shall be fitted 500 mm above ground level and four holes with a diameter of not less than 50,8 mm shall be provided on the jacking lugs in order to permit the transformer to be slewed in any direction.

The base of the tank shall be reinforced and so designed that it shall be possible to move the complete transformer unit in any direction without injury when using

rollers, plates or rails. A design which necessitates rails being placed in a particular position shall not be used.

Wheels, where specified, shall be plain, flanged uni-directional or bi-directional, whichever is specified in Scope of Works. Bi-directional wheels shall be designed so that it is possible to change the direction of the wheels without removing them from the transformer, and provision shall be made for locking the wheels parallel or at right angles to the major axis. Grease nipples or cups shall be provided for lubricating the swivel bearings and the wheel bearings. The Employer will provide the wheel gauge.

Lifting lugs shall be fitted capable of lifting the transformer complete with windings and filled with oil.

The tank cover shall be fitted with pockets for a thermometer and for the bulbs of the winding temperature and oil temperature indicators specified. Protection shall be provided when necessary for each capillary tube. The thermometer pocket shall be fitted with a captive screwed cap to prevent ingress of water. The pockets shall be located in the position of maximum oil temperature and it shall be possible to remove the instrument bulbs without lowering the oil in the tank.

The tank and cooling equipment shall be designed to permit vacuum treatment on site. The maximum safe permissible vacuum (millimetres of mercury) which may be applied above oil level, to the tank, cooling equipment and to the conservator, without causing permanent distortion, shall be stated in the Bid.

Two earthing terminals located at opposite side of the tank, capable of carrying for 30 seconds the full lower voltage current of the transformer, shall be provided. Provision shall be made at positions close to each of the four bottom corners of the tank for bolting the earth terminals to the tank structure to suit local conditions.

#### 4.1.3.2.2.6 *Gaskets*

Oil-resisting synthetic rubber gaskets will be preferred. If cork or similar material is used oil-resisting synthetic rubber be applied as a bonding medium. The Contractor shall submit details of gasket material for approval.

Spare unused sets of gaskets shall be supplied for use on site for all positions where joints have to be made after transportation of the transformer.

#### 4.1.3.2.2.7 *Current Transformer*

Current transformer for winding temperature measurements shall be mounted inside the transformer on a bushing turret, and in the connection between winding and neutral point for auto-transformers.

Accuracy class 3 shall be used for temperature indication.

#### 4.1.3.2.2.8 *Current Transformers*

Current transformers as indicated in scope of works shall be mounted in the bushing turrets.

#### 4.1.3.2.2.9 *Bushings*

Bushings shall be fitted to the equipment as specified in Scope of Works. Bushings for 66 kV and above shall be of the condenser type. Other bushings may be of solid porcelain.

All terminals shall be marked to correspond with the markings on the diagram plate.

The transformer bushings shall withstand accidental arcing or flashover without seals or other vital parts becoming damaged. Stresses due to expansion and contraction in any part of the bushing shall not lead to development of bulges, hair-line cracks or other defects. Suitable connecting clamps shall be able to absorb shocks due to vibration of the connecting jumpers. The bushings shall withstand internal vacuum in the transformer tank.

All the bushings of any transformer shall have a rated current of at least 120% of the rated currents of the windings to which they are connected (in order not to limit over-loads).

#### **4.1.3.2.3 Painting and Galvanising**

Oil-filled transformer shall have their interior surfaces sandblasted and finished with two coats of anti-corrosive and oil-resistant priming paint. Exterior surfaces shall be sand-blasted and have two rust inhibiting priming coats and one intermediate coat with paint on zinc chromate or urethane alkyd basis or equivalent; one final coat of weather and oil resistant paint. Minimum total thickness shall be 0.16 mm.

The radiator external surfaces shall be hot-dip galvanized with a zinc deposit on average not less than 400g/m<sup>2</sup>.

Outdoor control and marshalling boxes/cabinets shall have at least one prime coat and two layers of paint on zinc powder basis to be applied after perfect cleaning.

The particulars of priming and finishing paintings shall be stated in the Bid, with specifications of paint, together with a listing of colours available, for each of the plant and equipment.

The Employer is not bound to accept the finishing colour proposed by the Bidder. Determination of colour shall be at the option of the Employer and shall be finalised at the time of approval of drawings.

The exterior finish of outdoor control cabinets shall be in the same colour as that for the transformer.

Should any paint work be damaged during transit or erection, this shall be made good on site.

All interior and exterior surfaces, subject to corrosion, that cannot readily be painted, or where galvanising is explicitly specified, shall be hot-dip galvanised with an average thickness not less than 0.1 mm. Bolts and nuts associated with galvanised parts shall be hot-dip galvanised.

#### **4.1.3.2.4 Fittings**

The transformer shall be supplied with the fittings specified in Scope of Works. These fittings shall comply with the following clauses.

##### **4.1.3.2.4.1 Conservator**

The conservator shall be mounted on the main tank but not obstruct connection to overhead connection.

The conservator shall be fitted with a removable end on which shall be mounted the oil gauge. The conservator tank shall be mounted to slope lightly downwards towards the drain valve, which shall be adjacent to the removable end.

The pipe connecting the conservator to the tank shall extend at least 50 mm into the conservator and shall be brought out from the highest point of the main tank cover. A valve shall be provided immediately adjacent to the conservator. All pockets and bushing turrets of the main tank shall be connected into this pipe between the transformer and the Buchholz relay.

The conservator shall be so dimensioned that it will permit all expansion over the working range of temperatures from no load with the transformer cold and at -5 °C ambient air temperature to full load at 45 °C ambient air temperature while the sump pipe remains covered with oil and the oil level is visible or indicated. In any case, the volume of the conservator shall be at least 10% of the transformer oil volume.

The oil connections from the transformer tank to the conservator vessel shall be arranged at rising angle to the horizontal. The Buchholz relay (see Clause 4.6) shall be fitted in this pipe in such a position that inspection, testing and dismantling is possible with the transformer in operation. A step valve shall be provided between the conservator and the relay.

The conservator shall be equipped with the following fittings:

- a) A sump formed by extending the inlet pipe inside the conservator.
- b) A manhole formed by bolting one end-plate of the conservator.
- c) A drain valve with flanged plug.
- d) A flanged filling plug.
- e) An oil level gauge.
- f) A filter valve.

#### *4.1.3.2.4.2 Dial-type Oil Gauges*

Dial-type oil gauges, where specified, shall be of the magnetically operated type, in which breaking of the gauge glass will not release any oil. The gauge shall be fitted with at least two circuit-closing, potential free, low-oil-level alarm contacts wired to the marshalling box.

#### *4.1.3.2.4.3 Silica-Gel Breathers*

Each conservator shall be fitted with a silica-gel type dehydrating breather to approval. The breather shall be provided with an oil cup or other device which prevents contact between the dehydrating agent and the air outside the transformer. If an oil cup is provided, the oil should be visible from the outside and the lowest oil level should be marked.

The weight of the dehydrating agent shall be not less than 0,5 kg per 1500 litres of oil in the transformer and cooler.

Unless the silica-gel container is transparent the breathers shall have a window for inspection of the colour and condition of the silica-gel.

**4.1.3.2.4.4      *Explosion-Vents***

An over-pressure device of the spring release type or similar shall be used for pressure relief in case of explosion or sudden overpressure. The type shall be approved by the Project Manager. Separate oil compartments as OLTC compartment shall have separate explosion vents.

The explosion-vent shall be provided of sufficient size for the rapid release of any pressure which may be generated within the tank and which might result in damage to the equipment. The device if used shall be so placed that any discharge from it will not be deposited on any part of the transformer or its associated equipment.

**4.1.3.2.4.5      *Buchholz Relays***

Buchholz relays shall be of the double-float type with separate floats for alarm and shut-down at low and high-speed gas development and shall be of approved manufacture suitable for operation in transformer oil as specified over the temperature range -10 °C to 115 °C. The two contact sets shall not be exposed to oil and shall be wired to the marshalling box.

The relays must be interposed in the connecting pipe between the oil conservator and the transformer tank in such a manner that all gas from the tank must pass through the relay as it rises to the oil conservator.

Two copper pipes shall be connected to the two pet cocks on the relay and extended to position 1 m above ground level and fitted with stop cocks for sampling and testing purposes. The stop cocks are to be labelled and easily accessible and be clear of surrounding steelwork. The sight window of the relay shall be readily visible from ground level. Separate oil compartments compartment shall have separate Buchholz relays. However, the OLTC chamber shall be equipped with pressure rise relay instead.

**4.1.3.2.4.6      *Temperature Indicators***

The local temperature indicators shall be of the dial-type graded in °C with a manually resettable pointer to register the highest temperature reached. The local indicators shall be mounted on the transformer tank in a suitable weatherproof steel cabinet with a lockable door. The cabinet shall be so positioned as to allow easy access to and readability of the gauges.

Each transformer shall be provided with winding temperature indicators of the "thermal image" type compensated for changes in ambient temperature (one for each winding type: common, series, HV, LV and tertiary as appropriate). The indicator shall have a load - temperature characteristic approximately the same as the hottest part of the windings. The primary current transformer for operating the indicator shall be built into the main transformer tank on the bushings. Information shall be included in the maintenance instructions in the form of either a graph or table showing the relationship between current injected into the heater coil and the corresponding temperature reading.

The indicators shall be provided with two sets of alarm/trip contacts, adjustable to close at any temperature between 45 °C and 150 °C such adjustment being possible without dismantling the instrument. Where supplementary forced cooling is specified, two additional set of contacts shall be provided on the winding temperature indicators, for automatic start of the cooling fans in two stages. The differential between "switch on" and "switch off" temperatures must also be variable in the range 15 °C to 30 °C.

The instrument and set points shall have an accuracy of  $\pm 1\%$  of full scale deflection and the indicated temperature must reflect the hot spot temperature to within  $\pm 3^{\circ}\text{C}$  under all operating conditions. Test links are to be provided for calibration purpose.

One temperature indicator of the capillary type for measurement of the top oil temperature shall be provided for each transformer.

#### 4.1.3.2.5 Cooling

##### 4.1.3.2.5.1 *Definition*

The types of cooling shall be designated by the IEC lettering symbols:

- a. Natural Air Circulation (ONAN)  
By radiators directly attached to the tank.
- b. Forced Air Circulation (ONAF)  
By fans cooling the radiators.

##### 4.1.3.2.5.2 *Declaration of Ratings*

The Bidder shall declare in the Schedule of Technical Guarantees the rated power available under the operating conditions ONAN or ONAF (as required in Scope of Works) and the ratings shall be indicated on the rating plate.

##### 4.1.3.2.5.3 *Radiators*

The transformers shall be fitted with detachable radiators (tube coolers are not accepted). Suitable valves, with blanking plates shall be provided at the inlet and outlet of each radiator so that it may be removed without draining oil from the tank. Inlet and outlet valve "OPEN" and "CLOSED" positions shall be clearly marked. The valves shall be readily accessible and easy to operate. Lifting facilities, a drain cock and an air release vent shall be provided on each radiator.

Radiators shall be hot dip galvanised and designed so that it is possible for the whole of the cooling surface to be cleaned. They shall also be designed so that they shall withstand dry-out vacuum without distortion or causing leakage of hot oil.

##### 4.1.3.2.5.4 *Forced-Air Cooling ONAN/ONAF*

The forced-cooling equipment shall be designed to start automatically from winding-temperature relay control at predetermined temperatures recommended by the Contractor. The equipment shall be designed to start in 2 stages at preset temperatures.

Indicate setting values are as follows:

<b>Stages</b>	<b>On</b>	<b>Off</b>
Stage 1	65°C	50°C
Stage 2	75°C	60°C

The cooler arrangement must allow for the maintenance or failure of any one fan or radiator without losing more than 20 % of the total cooling capacity.

All fans shall operate as a unit. Fan blades and fan ducting shall be of aluminium alloy, stainless steel, galvanised steel, or other corrosion-resistant metal and shall be designed to keep noise and vibration to a minimum. All fans shall be provided with galvanised wire-mesh guards. It shall be possible to remove fan assemblies complete without dismantling other equipment.

#### 4.1.3.2.5.5 *Cooler Capacity*

The coolers and fans shall be so dimensioned that at least 80 % of the transformer capacity remains (in both ONAN and ONAF) if one cooler or one fan is removed.

#### 4.1.3.2.5.6 *Cooler Control Equipment*

All the necessary automatic control, motor contactors, protective devices and switches for the forced-cooling equipment shall be assembled in cabinet or marshalling box mounted on the transformer.

The cooler control equipment shall include:

- An isolating switch rated to carry and break full-load current for each group of fan and pump motors.
- A "Cooler Auto" - "Cooler-Manual" changeover switch.
- Magnetic contactor for each group of fan motors. Contactor coil leads shall be wired to the terminal board. A set of normally closed contacts shall be provided on each motor contactor for alarm purposes.
- Overload and single-phasing relays.
- Fuses, links and terminal boards to approval to make a complete assembly.

All equipment must be in accordance with the requirement given in general technical specifications.

#### 4.1.3.2.6 **Off-load Tap Changer**

Transformer with an Off-load tap changer, if specified in Scope of Works, shall be provided with a ganged mechanism operated by means of an external handle which can be pad-locked in each tap position. This ganged Off-load tap changer shall have a rotary motion of operation. The tap positions shall be indelibly marked to indicate tapping position corresponding to the diagram plate.

The tapping ranges shall be  $\pm 2 \times 2.5\%$ , with a maximum of 5 tap positions as specified in the particular specifications and scope of works.

Tap changers with Mercury sealing glands are not acceptable in this project.

#### 4.1.3.2.7 **Drain, Filter and Sampling Valves**

##### 4.1.3.2.7.1 *General*

All valves shall be attached by bolted-on flanges and shall not be screwed or welded to the tank. Drain valves or isolating valves larger than 101,6 mm (4"B.S.P.) and of the double-flanged gate-type construction may have bodies of cast iron or cast steel. All valves shall be opened by turning counterclockwise when facing the hand wheel.

Every valve shall be provided with an indicator to show clearly the position of the valve.

Means shall be provided for padlocking the valves in their open and closed position.

All valves shall be suitable for operation in conjunction with transformer oil as specified in IEC Publication 60296 at temperatures up to 115 °C.

#### 4.1.3.2.7.2 *Drain Valves*

Drain valves shall be of suitable dimensions in relation to the volume of oil in the transformer tank and coolers.

#### 4.1.3.2.7.3 *Oil Sampling Valves*

Oil sampling valves shall be of the screwed globe type; handle or gate valves located so as to permit sampling of oil from the extreme bottom of the transformer tank and the bottom of the tap changer compartment.

#### 4.1.3.2.7.4 *Filtration Connections*

Filtration connections, which shall have flanges drilled to BS 4504 Table 6, for 50,8 mm (2") valves, or screwed 50,8 mm (2"B.S.P.) female, shall be as follows:

A valve at the top and bottom of the main tank. The drain valve of the main tank may be used for this purpose if of the size described above.

The oil conservator drain valve located within easy reach of the ground, by means of a pipe extension if necessary, shall be suitable for a filter connection.

#### 4.1.3.2.7.5 *Valve Entries*

All valve entries shall be blanked off with gasketed bolted-on plates or plugs.

#### 4.1.3.2.7.6 *Rating and Diagram Plates*

Rating diagram and valve plates shall be to IEC 60076, stamped or embossed on brass or stainless steel. They shall show the employer's Order Number and shall have a blank space for the Employer's serial number. The diagram plate shall show the internal connections and the voltage vector relationship of the terminals.

Where applicable, rating or diagram plates shall show locations, ratio, rating and accuracy class of current transformers. Rating diagram and valve plates shall be approved by the Project Manager.

#### 4.1.3.2.8 **Oil**

The oil shall be of the uninhibited mineral type and comply with BS 148, IEC 60296 or equivalent standard.

Oil shall preferably be supplied in bulk from within Kenya and dried and cleaned on site. If oil is provided in drums, these shall have a volume of approximately 200 liters and be full. A separate price shall be quoted for transformer oil.

#### 4.1.3.2.9 On-Load Tap Changers

##### 4.1.3.2.9.1 General

The transformer's voltage control equipment shall, if specified in Scope of Work, be of the tap changing type for varying its effective transformation ratio whilst the transformer is on load and without producing phase displacement. The on-load tap changing equipment shall comply with IEC 60214. The tappings shall be arranged in the electrical centre of the higher winding.

The tap changing equipment shall be of 3-phase type, preferably with combined diverter and selector switches and shall be designed so that it will not be possible for the main transformer winding to be open circuited or for a portion thereof to be short circuited, except through a transition impedance. The tap changers for transformer with higher capacity than 2.5MVA shall be of the vacuum type mounted inside the transformer, whilst lower capacity transformers may have conventional oil type.

Operation from any type of control shall cause one tap movement only.

The equipment shall be so arranged as to ensure that when a tap change has commenced, it shall be completed independently of the operations of the control relays or switches. Failure of the auxiliary supply during a tap change operation must not inhibit the independent completion of the tap change operation.

An auxiliary supply of 415/240 volts, 50 Hz, 3-phase 4-wire AC. will be available for operating the tap changing equipment and all its accessories. All equipment shall operate correctly at any voltage between the limits of 85 % and 115 % of nominal value.

The tapping ranges shall be  $\pm 8 \times 1.67\%$ , with a maximum of 17 tap positions.

Tap changing equipment shall be capable of carrying the same currents due to external short-circuit as the transformer windings and shall withstand the impulse and dielectric tests of the associated winding. The tap changer connection and switches shall be capable of handling continuously currents at least 20 % above the highest operating current in order to limit overloading.

Where oil type used, it shall not be possible for the insulating oil in those compartments which contain contacts for making or breaking current to mix with the oil in the main transformer tank or with the oil in compartments containing contacts not used for making or breaking current

Drop-down tanks which necessitate the provision of pits in the foundations are not acceptable.

Where it is necessary to remove parts, or the whole of the on-load tap-changer for transport purposes, it shall be possible to complete erection on site with the transformer windings covered with oil.

##### 4.1.3.2.9.2 Construction

The number of the tappings in use shall be indicated mechanically at the transformer, electrically at the local control room panel and digitally at the Control Centre.

The tap-changing switches and mechanism shall be mounted in an easily accessible cabinet on the transformer tank and shall be supported from the main tank or its base.

The oil compartment for the tap changing switch shall be fitted with its own over-pressure device and Conservator; together with suitable oil level indication and drain valves. The conservator shall be dimensioned such that applicable expansion rates can be met.

All switches forming part of the main tap-changing apparatus shall be readily accessible and it shall be possible to examine or repair such apparatus without lowering the oil level in the main transformer tank.

Each compartment in which the oil level is not maintained from the conservator shall be provided with an oil gauge of approved design.

Limit switches shall be provided to prevent the over-running of the mechanism and shall be connected directly in the circuit of the operating motor. In addition, mechanical stops or other approved devices shall be provided to prevent the overrunning of the mechanism under any condition.

Approved means shall be provided to protect the motor and control circuits.

The whole tap-changing equipment shall be of robust design and capable of giving satisfactory service without undue maintenance under the conditions to be met in service, including frequent operation.

An externally visible mechanical recorder shall be fitted to the mechanism to indicate the number of tap-change operations completed by the equipment. At least five digits must be provided. No provision for resetting the counter is to be made.

#### **4.1.3.2.9.3      *Operation***

The tap changer shall be operated in the following modes:

- From an automatic voltage regulator (AVR) in the substation (normal control).  
The AVR control panel is part of the transformer supply contract.
- Directly on the motor control cabinet in the switchyard (direct control).  
From the control room in the substation (local control).  
From the Control Centre (remote control).

A blocking switch shall be provided on the motor control cabinet/marshalling box with two positions: local/remote (supervisory).

When the switch is in local position, control can only take place from the control cabinet on the transformer and vice versa for the other position.

All the necessary equipment like relays, contactors, etc. shall be provided, wired up to terminal blocks to facilitate the functions outlined above. A potentiometer switch of the make before break type shall be provided for local and remote reading of tap position. The numbers shall range from 1 upwards, the lowest number representing a tapping position corresponding to the maximum number of high voltage winding turns i.e. the highest plus-percent positions. The lowest minus-percent position shall be represented by the highest number.

Grey or BCD codes shall be provided as an alternative for remote supervisory reading of tap position.

Unless specifically asked for in this document, all equipment for control and indication required in the control room shall be provided by the supplier of the control room equipment. Operating voltage for direct and local control shall be Single Phase 230V AC/50Hz.

Facilities shall also be provided to prepare the transformer for parallel operation with one or more transformers on the master - follower principle. An out-of-step device shall be provided and arranged to prevent further tap changing after a definite time interval when the transformer in parallel control is one tap out of step.

#### **4.1.3.2.9.4      *Tapping Switches***

The switch shall be mechanically robust and provided with a device between the handle and the switch to permit operation without strain in the event of imperfect alignment between switch and handle; the switch operating shaft shall be fully insulated as between tank and switch and shall be provided with a suitable oil and vacuum tight gland where it passes through the tank.

The use of wood shall be avoided wherever possible, and all the supports and terminal boards shall be completely unaffected by hot oil and non-moisture absorbent. High-grade insulating materials shall be used in the construction of tapping switches which shall be designed with special attention to the elimination of points where tracking is likely to occur.

#### **4.1.3.2.9.5      *Alarm and Trip Signals***

All alarm contacts shall have ample inductive making and breaking at the specified alarm and tripping voltage. Any auxiliary relays associated with the trip circuits shall be DC operated and suitable for the specified alarm and tripping voltage. Alarm and trip relays shall be provided with independent potential free contact.

The following alarms shall be provided and wired up to terminal blocks in the transformer cabinet:

- Tap changer not operating.
- Transformers on parallel control are out of step.
- Partial or complete failure of the voltage transformer supply to the voltage regulating relay. This alarm shall be inoperative when the transformer is on non-automatic control.
- Fan failure alarm.
- Bucholz relay transformer alarm.
- Bucholz relay transformer trip.
- Oil surge relay (OLTC) trip.
- Oil gauge low level transformer alarm.
- Oil gauge low level transformer, trip
- Oil gauge low level OLTC, alarm.
- Oil gauge low level OLTC, trip.
- Pressure relief device transformer trip.
- Pressure relief device OLTC trip.
- Top oil temperature high alarm.
- Top oil temperature high trip.
- Winding temperature high alarm.
- Winding temperature high trip.

#### **4.1.3.2.10 Local Control Cubicles and Wiring Cabinets**

Each power transformer shall be provided with a weatherproof (IP 54) local mechanism/control cubicle for control of the tap changer and the same for instrumentation and control of cooling fans. The cubicle shall be mounted on the side of the transformer tank. The cabinets and equipment installed there shall strictly follow the requirements found in general technical specifications.

All cubicles and cabinets shall be complete with the requisite front panels. Bidder shall provide in their Bid a complete list of all control, alarm, protection and indication facilities and equipment included in the Bid price each item to be identified with its function.

All indicating analogue instruments shall be flush mounting and the dials shall preferably be not less than 95 mm diameter if circular or, if rectangular have no side less than 95 mm.

An indelible chart showing lubrication points and specifying recommended lubricants and frequency of application shall be provided in all mechanism cubicles.

Provision for outgoing connections from the transformer control cubicles and cabinets shall be made for multicore cables. An undrilled removable glad plate to accommodate compression-type glands provided by the Employer shall be supplied. Each terminal box shall have an earthing stud for earthing of the incoming cable screens.

#### **4.1.3.2.11 Wiring and Terminal Blocks**

The switchgear contractor shall lay and connect control and power cables from the indoor control and switchgear to the local cabinets described above. All internal cabling between the transformer primary points and local cubicles and cabinets shall be provided by the Contractor. The cable laying and fastening shall be as described in general technical specifications.

#### **4.1.3.2.12 Manufacturing, Inspections and Tests**

The Contractor shall document the progress in factory with photographic records of the progress included in the progress reports. These colour photographs shall upon completion of the works be submitted in bound form together with explanatory description to the Employer.

##### **4.1.3.2.12.1 *Inspection/Witnessing of Tests***

The Employer and the Project Manager, reserves the right to inspect the transformer at any stage of manufacture or to be present at any of the tests specified. Such inspection shall not relieve the Contractor of his responsibility for meeting all the requirements of the specification, and it shall not prevent subsequent rejection if such material or equipment is later found to be defective.

The contract shall include financial provision for participation by the Employer in Factory Acceptance Tests as described in scope of works. The Contractor shall in good time inform when testing will take place and shall give the Employer/Project Manager not less than twenty-eight days' notice in advance. No transformer shall be tanked or dispatched from the Contractor's works without approval of Project Manager. Based on the Contractor's manufacturing Programme, factory inspection will take place as required by the Project Manager.

#### 4.1.3.2.12.2 *Factory Tests*

##### **Transformer Tests**

###### **Bushing Tests**

The Contractor shall submit for approval test records and data for all bushings. These records shall show the test performed on the bushings including but not necessarily restricted to the following tests:

- Standard one minute, 50 Hz dry withstand tests for all bushings.
- Type test of impulse withstand voltage.

All recorded test figures shall be given with the bushings serial number.

###### **a) Routine Tests**

Routine tests as far as applicable shall be carried out according the IEC Publication 60076.

The following routine tests shall be applied to all power transformer:

- Resistance measurements of all windings at all tappings.
- Ratio tests for all tappings and vector relationship tests.
- Measurement of no-load losses and currents.
- Measurements of impedance voltages (at maximum, principal and minimum tappings), short circuit impedances and load losses. Load losses shall be measured at both rated currents when ONAN and ONAF cooling are specified.
- Determination of efficiencies at 50%, 75%, 100% and 120% load at maximum temperature of the winding and 0.8 power factor lagging and unity power factor for all ratings (ONAN, ONAF ratings).
- Zero sequence impedance measurement.
- Induced voltage and separate source voltage withstand power frequency, dielectric tests on all windings on all phases including neutral points.
- Full wave impulse withstand tests. The transformer shall be subjected to a complete series of tests. Such tests shall be applied to the HV winding line terminal of each phase as well as to the neutral points.
- Tests on on-load tap changers.
- Routine tests on all transformer accessories such as motors, contactors wiring, etc.
- Partial discharge measurements.
- Measurements of capacity between the windings and each winding and ground.
- Oil leakage test. The complete oil filled transformer with bushings and radiators fitted and any other attachment normally in contact with oil shall be tested at a positive pressure measured at the tank bottom of twice the column of oil in the transformer when the transformer is cold, but in any case not less than 70kPa. Alternatively the radiators may be tested separately with the same pressure. The test period shall be not less than 12 hours.
- Core insulation test, 2 kV, 50 Hz for one minute.

**Special tests**

- Chopped wave impulse test on each transformer. The test shall be carried out in conjunction with the full wave test as described in IEC 60076-3.

**Type Tests**

The following type tests shall be carried out on one transformer of each type:

- Temperature rise test. Details of the test procedure shall be agreed between Contractor and Project Manager before testing commences.
- Noise measurements.
- Vacuum test. The transformer tank and radiators filled with oil shall be subjected to a vacuum test. Bushings need not be fitted and the radiators and conservator may be tested as separate units.

**4.1.3.2.12.3    *Site Tests***

Testing at site by the Contractor shall be carried out to prove that the transformer in all respects complies with provisions and guarantees set forth in the Contract.

Tests shall include but not be limited to the following:

- Dielectric oil tests.
- Insulation dryness by an agreed method.
- Electrical and functional control of voltage control equipment and cooling system.
- Core to tank insulation.

**4.1.3.2.13    *Erection***

Erection shall be carried out on foundations made by the switchgear contractor or by the Contractor under supervision by the Project Manager. The Contractor shall ascertain that the transformer have been erected according to the Terms of Contract before commissioning takes place.

All heavy erection equipment like lifting cranes and other equipment to be used for erection purpose shall be provided by the Contractor. The Contractor shall also provide all special equipment for erection and testing purpose. Such equipment shall be listed in the Bid.

**4.1.3.2.14    *Delivery and Transport***

The transport to site is the Contractor's sole responsibility. Under road part of the transport, the transport must be in accordance with the rules for road transport in the respective countries. If any special investigations, permits or arrangements are necessary for the road transport these has to be arranged for by the Contractor. Cost for such shall be included in the price.

Shipment of transformer in any position other than the upright one is not permissible.

All shafts, bearings and machined surfaces exposed for transport to the site shall be given a temporary protective coating to prevent corrosion.

If it is necessary to remove bushings or radiators for transport blanking-off plates and a spare set of gaskets shall be provided.

Where the supply of oil is included in the contract, and transport weight limitations permit, the transformer shall preferably be transported with sufficient oil to cover the core and windings. The tank shall be sealed for transport to prevent all breathing. The remainder of the oil to be supplied separately at the time of delivery.

Alternatively, where the above method is not applicable or practicable, the transformer shall be transported filled with dry nitrogen under slight positive pressure. This pressure and the temperature at the time of filling shall be communicated to the Project Manager and a pressure gauge suitably protected is to be fitted to each transformer to facilitate inspection of the gas pressure on arrival at site. Every precaution shall be taken to ensure that the transformer arrive at site in a satisfactory condition so that subsequent to oil filling, they may be put into service without the necessity for further drying out. Should the positive gas pressure disappear during transport and the transformer allowed to breathe, additional drying out at site if required shall be the responsibility of the Contractor.

All accessories and spares which are shipped separately must be clearly marked for identification with the transformer for which they are intended. All pipe work and valves shall have further markings showing the correct points of assembly which shall also be shown on assembly drawing to be supplied.

Full details must be supplied on methods of drying out the windings, if found necessary, on arrival and on the method to be adopted for oil filling and oil purification on site. Any special apparatus required for oil filling must be supplied as part of this contract.

The transformer shall be shipped with an impact recorder having capacity of four months recording. Full details of the proposed methods of transport shall be submitted for approval.

#### **4.1.3.2.15 Evaluation of Losses and capitalization**

##### **4.1.3.2.15.1     *Guaranteed Output and Losses, Liquidated Damages***

Failure to meet the guaranteed outputs and losses will be dealt with as follows:

##### **4.1.3.2.15.2     *Transformer Output***

If the guaranteed continuous output at rated voltage of any transformer has to be reduced below the guaranteed value in order to maintain the temperature rises of any part of the transformer within the guaranteed limits, liquidated damages shall be paid at the rate of USD 2 577 per kVA.

##### **4.1.3.2.15.3     *Transformer Losses***

If the total transformer losses of any transformer, as determined by these, without any tolerances, at rated voltage, frequency and 100% rated kVA (on principal tapping) exceed the guaranteed total losses, the excess in losses shall be capitalised at the rates stated in below and the resulting amount shall be paid as liquidated damages.

The payment on account of failure of one or more transformer to meet the guaranteed output and guaranteed losses shall be applied individually, as the case may be, and shall therefore be understood to be cumulative.

#### 4.1.3.2.15.4 *Rejection Limits*

Should any transformer fail to meet the guaranteed output by more than 5% (five per cent) or the total losses should exceed the total guaranteed losses by more than 1/5 (one fifth), and should the Contractor fail within a reasonable time to modify the transformer in order to increase the output and/or reduce the losses sufficiently, the Purchaser shall have the option to reject the transformer.

#### 4.1.3.2.15.5 *Evaluation of Losses*

Transformer losses will during tender evaluation be evaluated based on the following figures (ref Bid data Sheet):

Load losses:	USD 2577/kW for 25 years
No load losses:	USD 4339/kW for 25 years

If nothing other is specified in Scope of Work, Load losses will be evaluated based on the **ONAF** rating for transformer with combined ONAN/ONAF cooling. The Bidder must submit losses in the Guarantee Schedules **without** tolerances.

#### 4.1.3.2.16 **Transformer Drawings**

The following shall be included with the Bid:

(Note: if complete design drawings are not available, drawings should be submitted of an existing design equivalent in all essential detail to that being offered).

- a. Dimensioned outline drawings of the transformer and any auxiliary plant showing:
  - The arrangement and position of all fittings and accessories.
  - Any section to be removed for shipment and their separate dimensions and weights.
  - Principal dimensions and minimum clearances (phase/phase and phase/earth).
  - Weight, sling angles and height from ground level to crane hook applicable for lifting:
    - The tank cover
    - The complete transformer
    - The cores and coils out of the tank
    - Position and function of all valves.
    - Position and function of all access openings.
    - Total weight and distribution of weight to enable foundations to be designed (to be designed by the Employer).
- b. Drawings showing the arrangement of the core and windings including core clamping arrangement.
- c. Detailed drawings of the tapping switch showing internal details of switch and mechanism, tapping connections and change-over link board.
- d. Fully dimensioned drawings of all proposed bushings including cross-sections and full electrical characteristics.
- e. Schematic wiring diagrams of automatic voltage control, cooler control, and protection systems with fully detailed description of the operation.
- f. Drawings of proposed rating and diagram plates.
- g. Catalogues of all accessory equipment and fittings.



#### 4.1.3.3 Distribution and Auxiliary Transformers

##### 4.1.3.3.1 General

This specification covers the manufacture; testing, supply and delivery of pole mounted distribution type transformer and spares for the substation auxiliary supply.

##### 4.1.3.3.2 General Design

Transformer shall be of the mineral oil immersed “core” (wound core or shell type shall not be provided) type suitable for outdoor use with Oil Natural Air Natural (ONAN) cooling. Primary and secondary bushings shall be located on top cover

Transformer shall be designed to deliver full rated power continuously on any tapping within the specified tapping range under the following conditions: -

- i) With the voltage of the untapped winding at rated value, without the need to de-rate the transformer at the extreme tap positions and without exceeding IEC temperature limits.
- ii) With voltage applied up to 10% more than the rated tapping voltages and without injurious overheating.

Transformer shall be connected in accordance with IEC 60076 or equivalent: three phase transformers to Vector Group reference Dyn11.

All L.V. neutrals shall be brought out of the tank to a readily accessible terminal and shall not be earthed inside the tank, unless otherwise specified in the enquiry.

Transformer on a particular contract with similar voltage ratios and connections shall be suitable for parallel operations on all relevant taps under which conditions they should share the load in proportion to their ratings subject to the tolerances on impedance laid down in IEC 60076.

Low impedance transformer are preferred, a maximum of 5% being envisaged on any size with no plus tolerance.

When requested in the enquiry, sealed designs shall be offered and the following details shall apply:

- i) Unless otherwise approved, sealing shall be effected by means of a bolted cover design employing non standard bolts on the top cover (keys shall be supplied for each transformer).
- ii) Any holes or plugs used to facilitate vacuum/pressure testing, leak testing or oil filling of the transformer shall finally be sealed by welding.
- iii) The expansion of the oil level shall be accommodated by the tank itself (i.e. no gas filled pillow will be accepted). The bidder must submit documentation showing tests simulating 40 years of expansion and contraction of the tank without impairment of the rib welding.

An oil level gauge shall be provided.

Pressure valves, pressure/vacuum gauges, non-return valves and drain valves shall not be fitted.

Earth stud required at both H.V. and L.V. ends of transformer.

The transformer shall operate without undue noise and every care shall be taken in the design and manufacture to reduce noise to the level of that obtained in good modern practice. The noise level of the transformer shall not exceed 60 dB(A) when tested in accordance with IEC Publication 60551.

#### 4.1.3.3.2.1 *Windings*

Tapping shall be provided in the H.V. windings, preferably in the centre of the windings, to permit variation of the number of H.V. turns without significant variation in the kVA rating.

The variations shall be effected by means of a manually operated tapping switch (tapping ganged mechanism) to be provided.

The HV windings shall be made from grade 3 enamelled copper wires, whereas LV windings shall be made from copper foil/strips. Graded windings insulation and Aluminium windings shall not be accepted for this project.

All windings and terminations shall be fully insulated and those for service above 1000 volts shall be designed for impulse voltage tests. Conductor material shall be copper. No foil windings shall be used.

Designs shall be such that electrical stresses are as uniform as possible throughout the windings under impulse conditions.

Windings shall be vacuum impregnated and insulating materials shall not be liable to soften, shrink, become brittle, carbonise, deteriorate, or collapse in any way during service.

#### 4.1.3.3.2.2 *Cores*

The magnetic circuit shall be earthed to the core clamping structure, at one point only, and the core assembly to the tank. Where transformers are not sealed readily accessible removable bolted links shall be employed for the earthing connections.

The general construction of the cores, framework and the clamping arrangements shall be robust and such that they will be capable of withstanding completely any stresses which may occur due to handling, transport or service. All cores and yokes shall be terminated and clamped by means of a suitable framework. Suitable means shall be provided for lifting the cores from the tanks.

It shall not be possible for the core to move relative to the tank during handling or transport.

Particular attention shall be paid to maintaining low core loss consistent with sound design.

#### 4.1.3.3.2.3 *Tapping Switches*

The transformer shall be provided with approved off-circuit type tap changing equipment. Tapping ranges shall be  $\pm 2 \times 2.5\%$  with a maximum of 5 tap positions.

A fully insulated off-circuit, externally manually operated ganged tapping switch shall be supplied, capable of withstanding the specified impulse voltage when connected to the transformer windings.

Clearly visible tap position indication shall be provided. The tapping switch shall be operated by means of an external handle that can be positively located and locked in each operating position.

The switch shall be mechanically robust and provided with a device between the handle and the switch to permit operation without strain in the event of imperfect alignment between switch and handle; the switch operating shaft shall be fully insulated as between tank and switch and shall be provided with a suitable oil and vacuum tight gland where it passes through the tank.

The use of wood shall be avoided wherever possible and all the supports and terminal boards shall be completely unaffected by hot oil and non-moisture absorbent.

High grade insulating materials shall be used in the construction of tapping switches which shall be designed with special attention to the elimination of points where tracking is likely to occur.

Tapping switches shall be mounted on supports made of suitable high strength insulating material and shall be provided with self-aligning spring loaded wiping contacts capable of maintaining good electrical contact without the need for periodic maintenance.

All clearances between tapping switch contacts and leads shall be indicated on drawings submitted at the time of Bidding and such clearances shall be sufficient to prevent tracking or flashover in the event of carbon or sludge deposits forming on leakage paths.

H.V. tapping: Minus 2.5% - 0% - Plus 2.5% - Plus 5% - Plus 7.5%.

#### 4.1.3.3.2.4 *Outdoor Bushings*

All line terminals and neutral connections where specified, shall be brought out to porcelain outdoor type terminal bushings in accordance with DIN 4253 with minimum creepage distance 31 mm/kV in Coast and industrial area and 25 mm/kV in inland installations. Arcing horns shall be fitted on all transformer bushings. As an alternative factory mounted surge arresters are acceptable.

#### 4.1.3.3.3 **Tanks and Conservators**

##### 4.1.3.3.3.1 *General*

Drain valves may be either screwed or flanged whilst conservator isolating valves shall be flanged. Drain valves shall be complete with captive plugs that shall be either of non-ferrous metal or galvanised.

All internal steel surfaces or tanks and conservators shall be shot blasted and cleaned, and a coat of protecting compound, unaffected by hot oil, should be applied.

All external surfaces and parts made of steel are to be thoroughly shot blasted and cleaned, after which two coats of priming paint, preferably of zinc chromate, one intermediate coat and one coat of finishing paint are to be applied. The Project Manager shall approve the colour.

Transformers on which the paints are found to flake off or deteriorate within the guaranteed period shall be suitably cleaned and repainted free of charge by the supplier.

#### 4.1.3.3.3.2 *Tanks*

Each transformer shall be housed in a tank of welded steel plate construction suitably stiffened where necessary but with a flat base. Wheels or rollers are not required.

Each tank shall be provided with the accessories specified Table 1, the lifting lugs called for shall be suitable for lifting the transformer bodily by means of a hoist or crane when it is completely assembled and ready for service.

All transformers shall be provided with four fixing lugs on the base drilled with 15 mm holes for bolting to a platform. The fixing holes shall project beyond the ends of the tank and be placed to provide the most practical stable arrangement.

No radiators or tube coolers shall be used. ribbed tanks shall, if needed, be supplied in order to achieve the necessary cooling under the conditions prevailing at site.

#### 4.1.3.3.3.3 *Conservators*

Conservators shall be of dimensions such that oil expansion may occur over the working range temperature from no load with the transformer cold at minus 5 °C ambient air temperature to full load at plus 45°C ambient air temperature while the sump pipe remains covered and the oil level is visible or indicated.

The fittings detailed in Table 1, shall be provided on all transformer conservators.

Drain plugs shall preferably incorporate approved sampling facilities, and shall be mounted at the lowest part of the conservator tank and so designed that the sampling device can be readily cleared in the event of its being blocked by an accumulation of sludge etc., without the necessity of having to dismantle the device completely.

Oil level gauges on conservator tanks shall be of the refracting plate glass or other approved type, marked with the level at 20°C at no-load and capable of indicating the level of oil over the specified working range.

Where dehydrating breathers are specified they shall be of the Silica gel type (cobalt free), in accordance with DIN 42567, which give indication of moisture absorption by change in colour of the charge. The breather shall be covered by a metal tube to avoid vandalism. An inspection window shall be provided and mounted in a position convenient for inspection. The breather is to incorporate an oil seal to prevent contact with the external air when breathing is not taking place. The breather to be fitted on the L.V. end of the transformer.

Where only a vent pipe without a breaker and incorporating a filling hole is specified, it shall preferably be fitted with a cap and provided with very fine mesh incorrodible anti-vermin gauze.

**4.1.3.3.3.4      *Accessories and Fittings***

All transformers shall be provided with accessories and fittings in accordance with Table 1, unless otherwise specified in the enquiry.

Rating and diagram plates shall be of engraved steel, brass or other approved incorrodible material.

Where a thermometer pocket is provided, it shall be of a thin walled metal mounted in the tank cover.

The pocket shall project 25mm outside of the tank and shall be threaded along the whole projecting portion, a screwed cap shall be provided to cover the pocket when not in use.

Lightning arresters equipped with galvanised brackets suitable for bolting to a vertical surface shall be mounted directly on to the transformer tank. The mounting surface shall be such that the centre lines of the arresters are parallel with the centre lines of the associated bushings, and at the same spacing as the bushings.

**4.1.3.3.3.5      *Insulating Oil***

The transformer shall be filled with low viscosity mineral insulating oil, which complies in every respect with the provision of IEC 60296.

**Table 1 ACCESSORIES AND FITTINGS FOR DISTRIBUTION TRANSFORMERS**

<b>Distribution transformers: 50 to 315 kVA</b>	
<b><u>Transformer Tank Fittings</u></b>	
1. Conservator (Sealed type)	N
2. Drain valve with captive sealing plug	N
3. Lifting lugs	Y
4. Thermometer Pocket	N
5. Rating and diagram plate	Y
6. Hanger irons	N
7. Platform mounting lugs	Y
8. Earthing Terminal	Y
9. Lightning arrester brackets	Y
10 Arcing Horns	Y
11. HV Surge arrestors	Y
11.Dial type thermometer	Y
12 Jacking pads 1000 kg or more transformer mass	N
13.Oil gauge	Y
14. Pressure relief device	Y
15.Lashing down facilities	Y
16.Marshalling box for Item 10 of Tank fittings and Item 7 of Conservator fitting	N
<b><u>Conservator Fittings</u></b>	
1. Drain plug	Y
2. Sampler	Y
3. Separate filling hole with cap.	Y
4. Dehydrating breather	Y
5. Plain breather	N
6. Oil gauge	Y
7. Gas & oil actuated relay	N
8. Conservator isolating valve	N

**Y = Required****N = Not Required**

#### 4.1.3.3.4 Tests

The following tests shall be carried out:

- a) Routine covering test certificates shall be submitted, immediately after completion of tests in the factory, for each and every transformer.
- b) As a type test, temperature rises test on each different rating of transformer.
- c) As a special test, an impulse voltage withstands test including chopped waves on each different rating of transformer.

Note: If tests to b) and c) above have been carried out satisfactory on designs identical in all essential details, these tests may be waived on the production of acceptable covering test certificates.

#### 4.1.3.3.5 Packing and Transport

Transformer shall be transported to destination with their tanks full of oil up to the service level.

Bushings and any accessories or fittings likely to be damaged shall be protected adequately against damage in transit.

#### 4.1.3.3.6 Drawings and Diagrams

##### 4.1.3.3.6.1 *To be submitted with Bid*

The following drawings shall be supplied with any Bid unless identical drawings have been previously supplied, in which case a statement in the Bid of the applicable drawing subjects, numbers and revisions will suffice together with details of the references under which previous supply was made:

- a) General arrangement drawing of each rating of transformer offered showing: -
  - i) Minimum clearance (phase to phase and phase to earth) on H.V. and L.V. bushings including clearance H.V. to L.V.
  - ii) Positions and identification in a separate legend of all fittings with type numbers.
  - iii) Size and position of all fixing holes.
  - iv) Total weights with and without oil and core lifting height and weight.
- b) Detail dimensioned drawings of tapping switch illustrating type of material, clearances, between tapping points and to earth and method of operation.
- c) Detailed dimensioned drawing of bushings, silica gel or plain oil seal type breather, and conservator.

Note: Where sealed transformers are offered, a cross arrangement drawing shall be submitted with the Bid showing, in particular, details of the tank construction and internal tank finish and the depth of the expansion space above the oil.

**4.1.3.3.6.2 To be submitted with Contract**

Latest issues of the drawing shall be supplied under the contract; if no modifications are applicable to the drawings supplied with the Bid, this shall be confirmed in writing under the contract and further drawings need not be supplied.

Rating and diagram plate drawing shall be supplied.

**4.1.3.3.7 Evaluation of Losses**

The loss evaluation/ capitalization shall be as for the Power transformers