SPECIFICATION

FOR
54 MVA, 220/2x27 kV SCOTT CONNECTED
TRACTION POWER TRANSFORMER
FOR
2 x 25 kV AT FEEDING SYSTEM
FOR
RAILWAY ac TRACTION SUBSTATIONS

No. ETI/PSI/124(07/95)

ISSUED BY:

TRACTION INSTALLATION DIRECTORATE
RESEARCH DESIGNS & STANDARDS ORGANISATION
MINISTRY OF RAILWAYS, GOVERNMENT OF INDIA,
MANAK NAGAR, LUCKNOW 226 011, INDIA.
1.0 SCOPE

1.1 This specification applies to 54 MVA, ONAN, 220kV/2x27kV Scott-connected traction power transformer for autotransformer (AT) feeding system for installation in Indian Railway’s unattended traction substation in any part of India.

1.2 The transformer shall be complete with all parts, fittings and accessories necessary for its efficient operation in the unattended traction substation. All such parts, fittings and accessories shall be deemed to be within the scope of this specification, whether specifically mentioned herein or not.

1.3 This specification supersedes the specification No.ETI/PSI/124(8/89)

2.0 GOVERNING SPECIFICATION

2.1 In the preparation of this specification assistance has been derived from the following Standards and Codes of Practices (latest version), and Indian Electricity Rules wherever applicable.

1. IS:5 Colours for ready mixed paints and enamels.
2. IS:335 New insulating oils.
3. IS:1554 PVC insulated (Heavy duty) electric cables for working voltages up to and including 1100 volts.
4. IS:1570 Stainless and heat resisting steels.
5. IS:1576 Solid pressboard for electrical purposes.
7. IS:2026 Power Transformers.
8. IS:2099 Bushing for alternating voltages above 1000 volts.
9. IS:2705 Current transformers.
10. IS:2927 Brazing alloys
11. IS:3024 Electrical steel sheets (oriented)
12. IS:3637 Gas operated relays.
13. IS:3639 Fittings and accessories for power transformers.
14. IS:4253 Cork and rubber.
15. IS:5561 Electrical power connectors.
16. IS:5621 Hollow insulators for use in electrical equipment.
18. IS:6209 Methods for partial discharge measurements.
20. IS:8468 On-load tap-changers.
22. IS:10593 Method of evaluating the analysis of gases in oil-filled electrical equipment in service.
23. IS:12676 Oil impregnated paper insulated condenser bushings—dimensions and requirements.
24. IEC:76 Power transformers.
25. IEC:137 Bushings for alternating voltages above 1000 volts.
27. DIN:7733 Laminated products, pressboard for electrical engineering, types.

2.2 In case of any conflict between the contents of the above specifications and this specification, the latter shall prevail.
2.3 Any deviation from this specification, proposed by the tenderer, calculated to improve the performance, utility and efficiency of the equipment, will be given due consideration provided full particulars of the deviation with justification therefor are furnished. In such a case, the tenderer shall quote according to this specification and the deviations, if any, proposed by him shall be quoted as an alternative/alternatives.

3.0 ENVIRONMENTAL CONDITIONS

3.1 The transformer shall be suitable for outdoor use in moist tropical climate and in areas subject to heavy rainfall, pollution due to industry and marine atmosphere and severe lightning. The limiting weather conditions which the equipment has to withstand in service are indicated below:
1. Maximum ambient air temperature 50°C
2. Average ambient air temperature over a period of 24 hours 40°C
3. Maximum relative humidity 100%
4. Annual rainfall Ranging from 1750 to 6250 mm
5. Maximum number of thunder storm days per annum 85
6. Maximum number of dust storm days per annum 35
7. Number of rainy days per annum 120
8. Basic wind pressure 200 kgf/m2
9. Altitude Not exceeding 1000 m
10. Minimum ambient air temperature 0°C
3.2 The transformer would also be subjected to vibrations on account of trains running on nearby railway tracks. The amplitude of those vibrations which occur with rapidly varying time periods in the range of 15 to 70 ms lies in the range of 30 to 150 microns at present, with the instantaneous peaks going up to 350 microns. These vibrations may become more severe as the speeds and loads of trains increase in future.

4.0 TRACTION POWER SUPPLY SYSTEM (2x25 kV AT FEEDING SYSTEM)

4.1 General Scheme

4.1.1 The electric power for railway traction is supplied in ac 50 Hz, single-phase through 2x25 kV AT feeding system which has a feeding voltage (2x25 kV) from the traction substation (TSS) two times as high as the catenary voltage which is 25 kV with respect to earth/rail. The power fed from the TSS through catenary wire and feeder wire is stepped down to the catenary voltage by means of autotransformers (ATs) installed about every 13 to 17 km along the track, and then fed to the locomotives. In other words, both the catenary voltage and feeder voltage are 25 kV with respect to the earth/rail, although the substation feeding voltage between catenary and feeder wires is 50 kV. The catenary voltage is, therefore, the same as that in the conventional 25 kV system.

4.1.2 Since the power is supplied at 50 kV, the AT feeding system is suitable for a large power supply, and it has the following advantages as compared with the conventional feeding system:

1. Lower voltage drop in feeder circuit.
2. Larger spacing between traction substations.
3. Lower interference to adjacent telecommunication lines, if any.

4.1.3 The power is obtained from the 220 kV or 132 kV or 110 kV or 66 kV, three-phase, effectively earthed transmission network of the State Electricity Board, through single-phase transformers or Scott-connected transformer installed at the TSS. The primary winding of the single-phase transformer is connected to two phases of the transmission network. Where Scott-connected transformer is used, the primary windings are connected to the three phases of the transmission network. The single-phase transformers at a TSS are connected to the same two phases of the transmission network (referred as single-phase connection), or alternatively to different pairs of phases- the three single-phase transformers forming a delta-connection on the primary side. Out of three single-phase transformers, one transformer feeds the overhead equipment (OHE) on one side of the TSS, another feeds the OHE on the other side of the TSS, and the third remains as standby. Thus the two single-phase transformers which feed the OHE constitute an open-delta connection (alternatively, referred as V-connection) on the three-phase transformers network. The Scott-connected transformer and V-connected single-phase transformers are effective in reducing voltage imbalance on the transmission network. The spacing between adjacent substations is normally between 70 and 100 km.
4.1.4 One outer terminal of the secondary windings of the traction transformer is connected to the catenary, and the other outer terminal is connected to the feeder. The two inner terminals are connected to each other, either directly or through series capacitors, and then solidly earthed and connected to the traction rails.

4.1.5 Generally, the load current (current drawn by electric locomotives) from the TSS flows through the catenary and returns to the TSS through the feeder. For a train in an AT-cell (distance between two consecutive ATs), most of the current is fed to the electric locomotive by the ATs of that AT-cell; the current returns in the rails/earth and is boosted up to the feeder through the neutral terminals of the autotransformers.

4.1.6 Approximately midway between adjacent TSSs, a sectioning and paralleling post (SP) is provided. In order to prevent wrong phase coupling of power supply, a dead zone known as neutral section is provided in the OHE opposite the TSS as well as SP. At the TSS, there are two feeder circuit breakers for either side of the TSS for controlling the power fed to the OHE, in a double track section. Out of the two feeder circuit breakers for one side, one feeds the OHE of that side while the other remains (open) as standby. There is also a paralleling interruptor, which is normally closed, for either side of the TSS for paralleling the OHE of the UP and DOWN tracks. For maintenance work and keeping the voltage drop within limit, one or more subsectioning and paralleling post (SSP) are provided between the TSS and SP. In a double track section, as SSP has four sectioning interruptors and one paralleling interruptor, whereas an SP has two bridging circuit breakers (which remain open under normal feeding condition) and two paralleling interruptors. In case of fault in the OHE, the feeder circuit breaker of the TSS trips to isolate it.

4.1.7 Figures showing the principle of AT feeding system and typical power supply diagram and sectioning of the OHE are at the Appendix-1.

4.2 Protection System

4.2.1 The protection system of the traction transformer comprises the following:
1. Differential protection.
2. Instantaneous and IDMT over current, and earth fault protection on the primary side.
3. Protection against phase-failure on the secondary side (i.e. to detect malfunction of feeder/transformer circuit breaker).

4.2.2 The protection system for the OHE comprises the following:
1. Distance protection.
2. Delta-I type fault selective protection.
3. Instantaneous over current protection.
4. Under voltage protection to avoid wrong phase coupling.
4.3 OHE- general data

4.3.1 The OHE consists of (i) a grooved copper contact wire of 107 mm² section suspended directly from a stranded cadmium copper catenary of 65 mm² section by a number of vertical dropper wires, usually at regular intervals (the contact wire and catenary together generally being referred as 'catenary' or 'catenary wire'), and (ii) a feeder wire of stranded all aluminium conductor (size 19/3.99 mm) of 240 mm² section.

4.4 Traction transformer - general data

4.4.1 The transformer is either single-phase of 21.6 MVA (ONAN) rating, or Scott-connected of 54 MVA (ONAN) rating. The percentage impedance voltage of the transformer is 12% at the principal tapping.

4.5 Nature of Traction loads and faults on the OHE system

4.5.1 The traction load is a frequently and rapidly varying one between no-load and over load. The TSS equipment is subject to frequent earth faults/short circuits caused by failure of insulation, snapping of OHE touching the earth, wire dropped by bird connecting the OHE to earth/over line structure, and miscreant activity. On an average the number of faults/short circuits per month is about 40 but in exceptional cases the number could be as high as 120. The magnitude of the fault current may vary between 40% and 100% of the dead short-circuit value. These faults are cleared by the feeder circuit breaker on operation of the distance, delta-I and instantaneous over current relays associated with the concerned feeder circuit breaker.

4.5.2 The ac electric locomotives are fitted, for conversion of ac to dc, with single-phase bridge-connected silicon rectifiers with smoothing reactor for feeding the dc traction motors. The rectifiers introduce harmonic currents in the 25 kV power supply system. On few of the electrified sections, locomotives fitted with phase controlled asymmetrical thyristor bridge, in place of silicon rectifiers are also in use; these introduce further harmonics in the system. The typical percentages of harmonics present in the traction current with electric locomotives are as follows:

<table>
<thead>
<tr>
<th>Harmonics</th>
<th>With diode rectifier</th>
<th>With thyristor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd (150 Hz)</td>
<td>15%</td>
<td>32%</td>
</tr>
<tr>
<td>5th (250 Hz)</td>
<td>6%</td>
<td>18%</td>
</tr>
<tr>
<td>7th (350 Hz)</td>
<td>4%</td>
<td>8%</td>
</tr>
<tr>
<td>9th (450 Hz)</td>
<td>-</td>
<td>4%</td>
</tr>
<tr>
<td>11th (550 Hz)</td>
<td>-</td>
<td>5%</td>
</tr>
</tbody>
</table>
4.5.3 The average power-factor of electric locomotives and electric multiple units generally varies between 0.7 and 0.8 lagging, without reactive power compensation.

4.6 **Short-circuit apparent power of the system**

4.6.1 The Short-circuit apparent power at the transformer location for various system voltages is as under:

<table>
<thead>
<tr>
<th>Highest system voltage (kV)</th>
<th>Short-circuit apparent power, MVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>72.5</td>
<td>3,500</td>
</tr>
<tr>
<td>123</td>
<td>6,000</td>
</tr>
<tr>
<td>145</td>
<td>10,000</td>
</tr>
<tr>
<td>245</td>
<td>20,000</td>
</tr>
</tbody>
</table>

4.7 **Auxiliary power supplies at TSS**

4.7.1 The following auxiliary power supplies are available:

1. 110 V dc from a battery.
2. 240 V ac, 50 Hz, single-phase from a 25/0.24 kV auxiliary transformer.

4.7.2 Alarm/trip devices, relays and motor for the off-circuit tap-changer on the traction power transformer shall operate off 110 V dc.

5. **RATING AND GENERAL DATA**

5.1 The rating and general data of the transformer shall be as follows:

1. **Type**: ONAN cooled, Scott-connected (3 phase/2 phase), step down power transformer, double limb wound, core-type for outdoor installation.

2. **Windings**: Primary windings shall be T-connected for three phase supply.

   Secondary windings shall have two phases, Main-phase (M-phase) and Teaser-phase (T-phase), with a phase difference of 90 degree. Each phase shall have two secondary windings, each secondary winding having a rated voltage of 27 kV and a rated current of 500 A.
The primary and secondary windings shall be uniformly insulated.

The terminals of the secondary windings of each of 'M' and 'T' phases shall be brought out separately, for cascade connection externally.

The winding shall be of concentric disc or interleaved for primary, and disc or helical/cylindrical for the secondary.

3. Rated frequency, Hz : 50 +/- 3%
4. Rated primary voltage
   Un, kV : 220
5. Highest system voltage
   Um, kV : 245
6. Rated secondary voltage (at no-load), kV : Two sets of 2 x 27
7. Rated power, MVA : 54 (Each secondary winding shall have a rated power of 13.5 MVA)
8. Rated current at the principal tapping:
   1. Rated primary current, A : 141.7
   2. Rated secondary current, A : 500 (for each secondary winding)
9. Percentage impedance voltages at 13.5 MVA base at principal tapping:
   %Zt = 12 +/- 1.2 %
   %Zf = 12 +/- 1.2 %
   %Zn = - 0.2 % to + 3.5 %
10. Non-cumulative over load capacity after the transformer has reached steady temperature on continuous operation at rated load (i.e. at rated power)
   1. 150 % rated load for 15 min
   2. 200 % rated load for 5 min
11. Polarity : Subtractive

12. Tappings (off-circuit) : Separate tapped winding on each secondary winding to give rated secondary voltage for variation in primary voltage of +10% to -15%, in steps of 5% each.

13. Temperature rise : The temperature rise over an ambient temperature of 50°C both at rated and overload conditions shall not exceed the value indicated below:
   1. Winding: 50 K at rated load, and 60 K for overloads as specified in Clause 5.1(10) (temperature measured by resistance method).
   2. Top oil: 40 K (temperature rise measured by thermometer).
   3. Current carrying parts in air: 40 K (temperature rise measured by thermometer).

14. Maximum permissible losses at the principal tapping:
   1. No-load loss, kW 40.0
   2. Load loss, kW 200.0

15. Ability to withstand short circuit:
   1. Thermal ability 5 s
   2. Dynamic ability 0.5 s

16. Flux density at rated voltage and frequency at principal tapping: Shall not exceed 1.55 tesla.

17. Current density in the windings at rated current: Shall preferable not exceed 2.5 A/mm²

18. Acoustic sound level when energised at rated voltage and at no-load: Not more than 75 dB at a distance of one meter.
19. Bushings:

<table>
<thead>
<tr>
<th>Item</th>
<th>Secondary</th>
<th>Primary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Type</td>
<td>OIP condenser</td>
<td>OIP condenser</td>
</tr>
<tr>
<td>2. Highest voltage for equipment Um, kV</td>
<td>52</td>
<td>245</td>
</tr>
<tr>
<td>3. Rated current, A</td>
<td>1250</td>
<td>800</td>
</tr>
<tr>
<td>4. Minimum creepage distance in air, mm</td>
<td>1300</td>
<td>6125</td>
</tr>
</tbody>
</table>

20. Bushing type current transformers for differential protection of transformer:

<table>
<thead>
<tr>
<th>Item</th>
<th>Secondary</th>
<th>Primary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Highest voltage for equipment Um, kV</td>
<td>52</td>
<td>245</td>
</tr>
<tr>
<td>2. CT ratio</td>
<td>1000/5</td>
<td>300/5</td>
</tr>
<tr>
<td>3. Frequency, Hz</td>
<td>50 +/-3%</td>
<td>PS</td>
</tr>
<tr>
<td>4. Class of accuracy as per IS 2705 (Part IV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Minimum knee-point emf, V</td>
<td>150</td>
<td>125</td>
</tr>
<tr>
<td>6. Maximum excitation current at knee-point voltage, A</td>
<td>0.25</td>
<td>0.75</td>
</tr>
<tr>
<td>7. Maximum resistance of the secondary winding, ohm</td>
<td>0.5</td>
<td>0.25</td>
</tr>
</tbody>
</table>

6.0 SALIENT DESIGN FEATURES

6.1 Overall dimensions

6.1.1 The overall dimensions of the transformer shall be kept as low as possible and in any case shall not exceed the values given below - refer the sketch at Annexure-2:

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Length x width (in mm)</td>
<td>14,000 x 6,500</td>
</tr>
<tr>
<td>2. Height of the topmost point of primary bushing terminal</td>
<td>7500 mm</td>
</tr>
<tr>
<td>3. Height of the topmost point of secondary bushing terminal</td>
<td>5500 mm</td>
</tr>
</tbody>
</table>
6.2 Tank
6.2.1 The tank for the transformer shall be of bell type construction with flanges on the outside, and shall have a flat top. The flanges of the upper and lower tanks shall be jointed by bolts, nuts and washers. The winding and core shall be fully exposed when the bell tank cover is lifted.

6.2.2 The tank shall be constructed from mild steel of a quality that allows welding without any defect/flaw, with a single tier construction so shaped as to reduce welding to the minimum. The welded joints shall be made using the latest welding rigidity to permit hoisting of the transformer filled with oil by crane. The tank body shall be designed to withstand a vacuum of 760 mm of Hg.

6.2.3 The tank shall be fitted with four lifting pads at the lower end to enable lifting of the transformer filled with oil by means of lifting jacks.

6.2.4 The tank shall be fitted with an under carriage and mounted on eight bi-directional swivelling type flanged rollers for being rolled on 1676mm (5' 6") gauge track on which it shall also rest in the final position—reference the sketch at Annexure-2. The rollers shall be provided with detachable type locking arrangement to enable their locking after installing the transformer in the final position, to prevent any accidental movement of the transformer.

6.2.5 There shall be at least five inspection covers of suitable size on the tank to enable inspection of the lower portions of bushings and the leads as well as various connections of the motorised off-circuit tap-changer.

6.2.6 The rubberised cork gaskets used in the transformer shall conform to IS:4253 (Part-II).

6.2.7 All valves used in the transformer shall conform to IS:3639 and shall be of good quality and leak proof. The manufacturer shall ensure that suitable anti-theft measures are provided on these valves so as to prevent theft of oil during transit/service.

6.3 Marshalling box
6.3.1 A vermin proof, weatherproof and well ventilated marshalling box made of sheet steel of thickness not less than 2mm, strengthened with adequate stiffeners, shall be provided on the left hand side of the transformer tank as viewed from, the secondary terminals side. It shall have a hinged door with provision for padlocking- the door opening outward horizontally.

6.3.2 The marshalling box shall have a sloping roof. The top of the marshalling box shall be at a height of about 2 m from the rail level.

6.3.3 The marshalling box shall house the winding and oil temperature indicators and terminal board. To prevent condensation of moisture in
the marshalling box metal clad space heater, controlled by an associated thermostat and switch, shall also be provided. Cable glands shall be provided for the incoming and outgoing cables.

6.3.4 The temperature indicators shall be so mounted that their dials are at a height of not more than 1.6 m from the rail level. Transparent windows of tough acrylic plastic or similar non-fragile transparent material shall be provided on the marshalling box so as to enable reading of the temperature indicators without opening the door of the marshalling box.

6.3.5 All cables from the bushing current transformers, Buchhlz relay, magnetic oil level gauge, pressure relief device and temperature indicators shall be run through suitable conduits/perforated covered cable trays up to the marshalling box. The cables shall be of 1100 V grade, PVC insulated, PVC sheathed, steel wire armoured, stranded copper conductor conforming to IS:1554 (Part-I). The cable shall be adequately insulated for heat from the tank surface and the sun.

6.3.6 All wiring in the marshalling box shall be clearly identified by lettered/figured ferrules of the inter lock type, preferable of yellow colour with black letters/figures. The ac and dc circuits shall be clearly distinguished and well separated from each other.

6.3.7 Suitable legend and schematic diagram plates made of anodised aluminium with black lettering and lines shall be fixed on the inside surface of the marshalling box door.

6.4 Core

6.4.1 The core shall be built-up of high permeability cold rolled grain oriented silicon steel laminations conforming to IS: 3024. The flux density in any part of the core and yokes at the principal tapping with primary winding excited at the rated primary voltages and frequency shall not exceed 1.55 T. The successful tenderer/manufacturer shall furnish calculations to prove that this value shall not be exceeded.

6.4.2 The lamination for the core shall be free from waves, deformations and signs of rust. Both sides of the laminations shall be coated with suitable insulation capable of withstanding stress relief annealing. In assembling the core, air gaps shall be avoided. Necessary cooling ducts shall be provided in the core and yoke for heat dissipation. The core-clamping frame shall be provided with lifting eyes for the purpose of tanking and untanking the core and winding of the transformer.

6.4.3 The core shall be electrically connected to the tank.

6.4.4 Yoke/core clamping bolts shall have adequate threaded length beyond the face of the nuts for tightening at a later stage, if need arises. Each of the core clamping bolts and the core clamping frame work shall be insulated from the core laminations and tested after completion of the
core assembly to ensure that they withstand a voltage of 2 kV r.m.s. with respect to core for duration of 60 s.

6.4.5 The transformer is required to be continuously in service, preferable without requiring any attention from the date of its energisation up to the periodical overhaul (POH) which is generally done after 7 years of service. The need, therefore, for tightening of core clamping bolts should not normally arise before the POH of the transformer. The successful tenderer/manufacturer of the transformer shall take this aspect into account during core assemble/manufacture.

6.5 Windings

6.5.1 The winding shall be of concentric disc or interleaved for the primary, and disc or helical/cylindrical for the secondary windings. The primary and secondary windings shall be uniformly insulated. All the four terminals of the two secondary windings of each of 'M' and 'T' phases shall be brought out separately through 52 kV OIP condenser bushings, for cascade connection externally.

6.5.2 The windings shall be made of continuous electrolytic copper conductor, paper insulated to class-A insulation. The conductor shall not have sharp edges which may damage the insulation.

6.5.3 Normally, no joint shall be used in the winding conductor. If a joint becomes inescapable, if shall be brazed with high silver alloy grade BA Cu Ag6 conforming to IS:2927 or electrically butt-welded.

6.5.4 The ratio of width to thickness of copper conductor used for winding shall be as small as possible but shall not exceed 5:1 so as to avoid tilting of conductors when the windings are subjected to axial and radial forces during short circuits.

6.5.5 Separate tapped winding shall be provided for each secondary winding for connection of the motorised off-circuit tap-changer. The tapped windings shall be distributed in multi sections in order to reduce the imbalance in ampere turns to the minimum at any tap position.

6.5.6 The transformer windings shall be designed for the following rated withstand voltages:

<table>
<thead>
<tr>
<th>Item</th>
<th>Secondary</th>
<th>Primary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Highest voltage for equipment Um, kV</td>
<td>52</td>
<td>245</td>
</tr>
<tr>
<td>2. Rated short duration power frequency withstand voltage, kV</td>
<td>95</td>
<td>395</td>
</tr>
<tr>
<td>3. Rated lightning impulse withstand voltage, kV peak</td>
<td>250</td>
<td>950</td>
</tr>
</tbody>
</table>
6.5.7 The windings shall be so designed that the transfer of lightning and switching surges from primary to secondary windings and vice-versa is kept to the minimum level.

6.5.8 The windings shall be designed to withstand the magnetising inrush currents due to repeated switching on/off the transformer.

6.5.9 The axial pre-compression on the winding shall preferable be double the calculated axial thrust that may be set up under dead short-circuit condition so as to ensure that the winding do not become loose due to frequent short circuits in service.

6.5.10 During short circuits, the stresses actually set up in conductors, spacers, and blocks, clamping rings and such other parts of the transformer shall not exceed one third of the maximum permissible values.

6.5.11 Pre-compressed spacers shall be used between disc shaped coils of the windings to transmit the axial forces generated due to the short circuits.

6.5.12 Wood insulation, if used, on the core and winding shall be seasoned, dried and well compressed and shall have adequate strength.

6.5.13 A uniform shrinkage shall be ensured during the drying of the individual coils or assembly of coils by providing a uniform clamping force with the help of hydraulic jacks or similar such devices.

6.5.14 In order to cater for shrinkages that may occur in service, substantial clamping rings shall be provided at the tops of the windings, being pressed down upon them by means of adjustable pressure screws or oil dash pots or any other suitable device, so as to maintain a constant pressure and obviate the need for any retightening in between successive periodical overhauls.

6.5.15 The coil and core assembly shall be retightened after oil impregnation. The successful tenderer/manufacturer shall ensure that there is no further shrinkage of the coil assembly in any additional cycle after the final curing.

6.5.16 The successful tenderer/manufacturer shall furnish details of various stages of drying of coils, coil assembly up to and including oil impregnation and final tightening of the coil assembly. Values of pressure, duration, temperature and degree of vacuum maintained at various stages of drying shall also be indicated.

6.5.17 In order to keep unbalanced axial forces due to non-uniform shrinkage/unequal height of the coils to the minimum, wedges of pre-compressed wood or similar such material shall be used.

6.5.18 To prevent displacement of the radial spacers used in the windings, closed slots shall be provided and a vertical locking strip shall be passed through these slots.

6.5.19 The vertical locking strips and slots of the radial spacers shall be so designed as to withstand the forces generated due to short circuits.
6.5.20 The vertical locking strips and radial spacers shall be made of pre-compressed pressboard conforming to grade PSP:3052 of DIN 7733.

6.5.21 To prevent end blocks from shifting, pre-compressed pressboard ring shall be provided in between the two adjacent blocks. Coil clamping rings made of densified wood or mild steel shall be located in position with pressure screws.

6.5.22 Leads from the windings to the terminals, from the tap switch to the tappings of the secondary windings and other interconnections shall be properly supported and secured.

6.5.23 The following particulars/documents in respect of the radial spacer blocks (winding blocks), vertical locking strips (axial ribs), end blocks, insulating cylinder, angle rings, paper insulation of the conductor and coil clamping plates used in the manufacture of the conductor and coil clamping plates used in the manufacture of the windings shall be furnished.

1. Reference to specification and grade of material.
2. Source(s) of supply.
3. Test certificates.

7.0 INSULATING OIL

7.1 The transformer shall be supplied with new insulating oil conforming to IS:335 In addition, 10 % extra oil, by volume, shall be supplied in non-returnable steel drums. The characteristics of the insulating oil before energisation of the new transformer and during its maintenance and supervision in service shall conform to IS: 1866.

8.0 BUSHINGS AND TERMINAL CONNECTORS

8.1 Both the primary and secondary side bushings shall conform to IS:2099. On the primary side, sealed draw lead type oil impregnated paper (OIP) condenser bushings shall be used. On the secondary side, sealed solid stem type OIP condenser bushings shall be used. The dimensions of the bushings shall conform to IS:12676.

8.2 The bushings on the primary side shall be designed for a rated current of 800 A, whereas the bushings on the secondary side for a rated current of 1250 A. The temperature rise of any part of the bushing shall not exceed 40 K over an ambient temperature of 50°C while carrying the rated current continuously.

8.3 The porcelain housing of bushing shall be of a single piece construction i.e. there shall be no joint in the porcelain. The shed profile shall have a lip at the extremities but free from ribs on the underside so as to avoid accumulation of dust and pollutants and to permit easy cleaning.

8.4 The bushings shall have a non-breathing oil expansion chamber. The expansion chamber shall be provided with an oil Level indicator, which shall be so designed and dimensioned that oil level is clearly visible from ground level.
8.5 A test tap shall be provided for dielectric or power factor measurement.

8.6 The bushings shall be designed for the following insulation Level:

<table>
<thead>
<tr>
<th></th>
<th>Highest voltage for equipment</th>
<th>Um, kV</th>
<th>245</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rated short duration wet power frequency withstand voltage, kV</td>
<td>95</td>
<td>460</td>
</tr>
<tr>
<td>2</td>
<td>Rated Lightning impulse withstand voltage, kV peak</td>
<td>250</td>
<td>1050</td>
</tr>
</tbody>
</table>

8.7 Adjustable arcing horns shall be provided on both the primary and secondary bushings. The horn gap setting shall be variable as indicated below:

<table>
<thead>
<tr>
<th></th>
<th>Highest voltage for equipment</th>
<th>52</th>
<th>245</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Horn gap setting variable between, mm</td>
<td>150 and 300</td>
<td>1200 and 1500</td>
</tr>
</tbody>
</table>

8.8 The design and construction of the bushing shall be such that stresses due to expansion and contraction in any part of the bushings shall not lead to its deterioration/breakage.

8.9 The bushings shall be free from corona and shall not cause radio interference.

8.10 The bushing terminals shall be provided with terminal connectors of bimetallic type and conform to the following:

1. Primary side : Rigid type terminal connector to suit 28.62 mm overall dia. ACSR conductor (Zebra), size 54/7/3.18 mm, based on the Research, Designs and Standards Organisation (RDSO)'s standard drawing No. ETI/PSI/P/11010.

2. Secondary side : Rigid type terminal connector to suit 23.25 mm overall dia. all aluminium conductor (Butterfly), size 19/4.65 mm, shall be as per the firm's drawing approved by RDSO.

8.10.1 The terminal connectors shall conform to IS:5561. The design shall be such as to be connected to the equipment terminal stud with a minimum of four 12 mm diameter bolts, nuts, spring and flat washers. The fasteners shall conform to Clause 14.0 of this specification.

9.0 BUSHING TYPE CURRENT TRANSFORMERS

9.1 The 52 kV and 245 kV bushings shall be so arranged as to accommodate bushing type current transformers (BCTs) for the biased differential protection of the transformer. The BCTs shall conform to IS:2705 and meet with the stipulations in Clause 5.1(20) of this specification.
9.2 The BCTs shall be so designed as to withstand thermal and mechanical stresses resulting from frequent short circuits experienced by the transformer on which these are fitted.

9.3 Apart from the BCTs required for the biased differential protection, BCT of accuracy class 5 and conforming to IS:2705, with suitable tappings, shall be mounted inside one bushing of the left-hand side (as viewed from the secondary terminals side) secondary winding (which feeds the catenary and would carry a higher current in service as compared to the other secondary winding which feeds the feeder) of each of 'M' and 'T' phases for use with the winding temperature indicators.

9.4 The BCTs and the bushings shall be so mounted that removal of a bushing without disturbing the current transformers, terminals and connections or pipe work is easy and convenient.

9.5 The leads from the BCTs shall be terminated in terminal boxes provided on the bushing turrets. Suitable links shall be provided in the terminal boxes for shorting the secondary terminals of the BCTs, when not connected to the external measuring circuits.

9.6 The leads from the secondary winding of the BCTs terminated in the terminal box on the bushing turret upto the marshalling box shall be of 1100 V grade, PVC insulated, PVC sheathed, steel wire armoured, stranded copper cable of cross-section not less than 4 mm$^2$ to IS:1554 (Part-I).

9.7 Cable glands of proper size shall be provided in the terminal boxes to lead in/lead out the cables.

10.0 CLEARANCES

10.1 The relative orientation in space of the bushings fitted with terminal connectors, the main tank, radiators, conservator, pressure relief device, oil piping and other parts when mounted on the transformer shall be such that the various clearances in air from bushing live parts shall not be less than the appropriate values given hereunder:

<table>
<thead>
<tr>
<th></th>
<th>Highest voltage for equipment Um, kV</th>
<th>52</th>
<th>245</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Minimum clearance, mm</td>
<td>500</td>
<td>1900</td>
</tr>
</tbody>
</table>

The same distance shall apply for clearances phase-to-earth (including oil piping work, conservator, pressure relief device and such other parts), phase-to-phase, and towards terminals of a lower voltage winding.

11.0 MOTORISED OFF-CIRCUIT TAP-CHANGER

11.1 The transformer shall be fitted with a motor operated off-circuit rotary type tap-changer to cater for the voltage range specified in Clause 5.1(12) of this specification. The motor drive unit shall be installed in a weather and corrosion proof, adequately ventilated cubicle made of sheet steel not
less than 2 mm thick with adequate stiffeners to prevent deformation during transit and handling. The cubicle shall have a sloping roof. The top of the cubicle shall be at a height of about 1.5 m from the rail level. The cubicle shall be so positioned that the hinge of the operating handle— for manual operation—is at a height of about 1.1 m from the rail level.

11.2 To prevent condensation of moisture in the cubicle, metal clad space heater, controlled by an associated thermostat and switch, shall be provided.

11.3 All wiring in the cubicle shall be clearly identified by lettered/figured ferrules of the interlock type, preferable of yellow colour with black letters/figures. The ac and dc circuits shall be clearly distinguished and well separated from each other.

11.4 Suitable legend and schematic diagram plates made of anodised aluminium with black lettering and lines shall be fixed on the inside surface of the cubicle door.

11.5 A tap position indicator shall be provided to indicate the tap position which shall be clearly visible to an operator standing on the ground.

11.6 The tap-changer shall be of 52 kV voltage class with a continuous current rating of 1250 A and a short-circuit current withstand capability of 12.5 kA r.m.s. for 5 s. The tap-changer motor shall be suitable for operation off 110 V from a battery. The voltage at the battery terminals may vary between 110% and 85% of the normal value. The voltage at the tap-changer motor terminals is likely to be less than 85% of the normal value of 110 V due to voltage drop in control cable.

11.7 Once the tap changing operation has been initiated, it must be completed automatically (snap action) even if there is a failure of 110 V dc supply. In case off-circuit tap-changer with snap action is not readily available, on-load tap-changer (without the diverter and other such parts necessary for the on-load tap changing), shall be provided so as to have the snap action.

11.8 The tap-changer shall be provided with suitable interlocking arrangement to prevent its operation (including manual tap changing) when either one or both circuit breakers on the primary as well as on the secondary sides of the transformer is/are in closed condition.

11.9 The tap-changer and its control circuit shall be designed for operation from the Remote Control Centre (RCC) by the Traction Power Controller (TPC) as well as from the tap-changer cubicle. A local/remote switch as well as necessary terminations for telesignals and telecommands from and to the tap-changer-for-operation from the RCC—shall therefore be provided in the tap-changer cubicle.
12.0 COLLING EQUIPMENT

12.1 The transformer shall be designed for ONAN type of cooling.

12.2 The radiators shall consist of a pressed steel plate assembly formed into elliptical oil channels as per IEEMA (Indian Electrical & Electronic Manufacturers Association)'s standard or a series of separate elliptical tubes. The radiators shall be designed in such a manner that the temperature-rise limits specified under Clause 5.1 (13) of this specification are not exceeded.

12.3 The radiators shall be removable (after isolating the same from the main tank) to facilitate transportation of the transformer. A drain plug of size 19 mm and an air-release plug of size 19 mm shall be provided at the bottom and at the top of each radiator bank for draining and filling of oil respectively. Each radiator bank shall also be provided with shut-off valves of size 80 mm.

12.4 The radiators shall preferable be supported directly on the transformer tank. Each radiator bank shall be fitted with lifting lugs.

13.0 PARTS, FITTINGS AND ACCESSORIES

13.1 Apart from the parts, fittings and accessories specifically detailed in the foregoing Clauses, the parts, fittings and accessories detailed hereunder shall be supplied with each transformer.

13.1.1 Conservator tank: It shall be of adequate capacity and complete with supporting bracket or structure, oil filling cap and drain valve of size 25 mm. The cylindrical portion of the conservator tank shall be of single piece construction without any gasketed joint.

13.1.2 Oil level gauge: It shall be of magnetic type having a dial diameter of 250 mm. The gauge shall have markings corresponding to minimum oil level, maximum oil level and oil level corresponding to oil temperature of 30°C, 45°C and 85°C. The oil level indicator shall be so designed and mounted that the oil level is clearly visible to an operator standing on the ground.

13.1.3 Silicagel breather: It shall be complete with oil seal and connecting pipes. The connecting pipes shall be secured properly. The container of the silicagel breather shall be of transparent flexiglass or similar material suitable for outdoor application.

13.1.4 Pressure relief device: It shall operate to release internal pressure at preset value without endangering the equipment or operator and shall be of instantaneous reset type.
13.1.5 Filter Valves: The bottom and upper filter valves shall be of 50 mm size and suitably baffled to reduce aeration of oil. The valves shall be flanged to seat 40 mm adopter threaded to thread size P 1-1/2 for connection for connection to oil filtration plant.

13.1.6 Drain valve: It shall be of size 80 mm fitted with an oil sampling device of size 15 mm.

13.1.7 Earthing terminals: Two earthing terminals shall be provided on the tank for its earthing with the help of 3 mild steel flats, each of size 75 mm x 8 mm. The terminals shall be clearly marked for earthing.

13.1.8 Buchholz relay: It shall be of double float type, with two shut-off valves of 80 mm size, one between the conservator tank and the Buchholz relay and the other between the transformer tank and the Buchholz relay. The relay shall have one alarm contact and one trip contact, none of the contacts being earthed. The contacts shall be of mercury-switch type, electrically independent and wired up to the marshalling box. A testing petcock shall be brought down through a pipe for the purpose of sampling the gas, if any, collected in the Buchholz relay.

13.1.9 Oil temperature indicator (OTI): It shall have one alarm contact, one trip contact and two normally open spare contacts none of the contacts being earthed. The contacts shall be electrically independent.

13.1.10 Winding temperature indicator (WTI): Two WTIs shall be provided, one for the M-phase and the other for the T-phase. Each WTI shall have one alarm contact, one trip contact and two normally open spare contacts, none of the contacts being earthed. The contacts shall be electrically independent.

13.1.11 Thermometer pockets: A separate thermometer pocket with cap shall be provided on the bell tank for measuring the top oil temperature in the tank.

13.1.12 Rating plate: The rating plate shall indicate the ratings of the transformer, the connection diagram of the windings, the particulars of the bushing current transformers and other details as per IS:2026. The rating plate shall be both in English and Hindi version.

13.2 All valves shall be of the double flange type and fitted with suitable blanking plates on the outer face of the exposed flange.

13.3 The capillary tubes for temperature indicators shall be able to withstand normal bending. They shall be supported properly without sharp or repeated bends or twists.

13.4 The parts, fittings and accessories for the transformer shall be only of those manufacturers approved by RDSO. If any item from fresh manufacturers/sources are proposed to be used, it shall have to be type tested in the presence of RDSO's representative and approval obtained before obtaining the item for use.
14.0 FASTENERS

14.1 All fasteners of 12 mm diameter and less exposed to atmosphere shall be of stainless steel and those above 12 mm diameter shall preferable be of stainless steel or of mild steel hot dip galvanised to 610 g/m² of zinc. The material of the stainless steel fasteners shall conform to IS: 1570 (Part-V), Grade 04Cr17Ni 12Mo2.

15.0 PAINTING

15.1 Shot blasting/sand blasting shall be done on the transformer tank to remove all scales, rust and other residue before applying the paint inside the tank. All steel surfaces which are in contact with insulating oil shall be painted with heat resistant oil-insoluble insulating varnish. All steel surface exposed to weather shall be given, one primer coat of zinc chromate and two coats of grey paint to shade No. 631 of IS:5 An additional coat of paint shall be applied at site by the manufacturer.

16.0 TESTING OF TRANSFORMER

16.1 General

16.1.1 Once a purchase order is placed for supply of a transformer the designs and drawings together with the Quality Assurance Plan (QAP) shall be furnished to the purchaser/Director General (Traction Installation), Research Designs and Standards Organisation (DG(TI), RDSO), Lucknow, as the case may be, within the period stipulated in the order. Only after all the designs and drawings as well as the QAP have been approved for prototype tests and a written advice given to that effect, shall the successful tenderer/manufacturer take up manufacture of the prototype of the transformer. It is to be clearly understood that any change or modification required by the above authorities to be done in the prototype shall be done expeditiously, notwithstanding approval having already been given for the designs and drawings. Such change or modification shall be incorporated in the drawings. Such change or modification shall be incorporated in the drawings as indicated in Clause 17.4 of this specification.

16.1.2 Prior to giving a call to the Purchaser/ DG(TI), RDSO Lucknow, for inspection and testing of the prototype, the successful tenderer/manufacturer shall submit a detailed test schedule consisting of schematic circuit diagrams for each of the tests and the number of days required to complete all the tests at one stretch. Once the schedule is approved, the tests shall invariably be done accordingly. However, during the process of type testing or even later, the purchaser reserves the right to conduct any additional test(s), besides those specified here in on any equipment/items as to test the equipment/item to his satisfaction or for gaining additional information and knowledge, In case any dispute or disagreement arises between the successful tenderer/manufacturer and representative of the Purchaser/DG(TI), RDSO, Lucknow, during the process of testing as regards the procedure for type tests and/or the interpretation and acceptability of the results of type tests, it shall be brought to the notice of the Purchaser/DG(TI), RDSO, Lucknow, as the case may be, whose decision shall be final and binding. Only after the prototype transformer is
completed and ready in each and every respect, shall the successful tenderer/manufacturer give the actual call for the inspection and testing with at least 15 days notice for the purpose.

16.1.3 The type tests shall be carried out on the prototype transformer at the works of the successful tenderer/manufacturer or at a reputed testing laboratory in the presence of the representative of the purchaser/DG(TI), RDSO, Lucknow, in accordance with the relevant specifications and as modified or amplified by this specification.

16.2 Tests during manufacture

16.2.1 Though the tests described below shall form part of the type tests, the manufacturer shall carry out these tests on each and every unit during the process of manufacture and submit the test reports to the Purchaser's Inspector deputed for witnessing the routine tests:

1. Oil leakage test.
2. Vacuum test.
3. Pressure test.
4. Insulation test for core bolts.
5. Test for pressure relief device.

16.2.1.1 Oil leakage test: The transformer with its radiators, conservator tank and other parts, fittings and accessories completely assembled shall be tested for oil leakage by being filled with oil conforming to IS:335 at the ambient temperature and subjected to a pressure corresponding to twice the normal static oil head or to the normal static oil head plus 35 kN/m² (0.35 kgf/cm²) whichever is lower, the static oil head being measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 h, during which time no leakage shall occur.

16.2.1.2 Vacuum test: The transformer tank only shall be tested at a vacuum of 3.33 kN/m²(0.0333 kgf/cm²) for 60 min. The permanent deflection of flat plates after release of vacuum shall not exceed the values specified below:-
<table>
<thead>
<tr>
<th>Horizontal length of flat plate</th>
<th>Permanent deflection, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>upto and including 750 mm</td>
<td>5.0</td>
</tr>
<tr>
<td>751 mm to 1250 mm</td>
<td>6.5</td>
</tr>
<tr>
<td>1251 mm to 1750 mm</td>
<td>8.0</td>
</tr>
<tr>
<td>1751 mm to 2000 mm</td>
<td>9.5</td>
</tr>
<tr>
<td>2001 mm to 2250 mm</td>
<td>11.0</td>
</tr>
<tr>
<td>2251 mm to 2500 mm</td>
<td>12.5</td>
</tr>
<tr>
<td>2501 mm to 3000 mm</td>
<td>16.0</td>
</tr>
<tr>
<td>above 3000 mm</td>
<td>19.0</td>
</tr>
</tbody>
</table>

16.2.1.3 **Pressure test**: Every transformer tank, radiator and conservator tank shall be subjected to an air pressure corresponding to twice the normal static head of oil or to the normal static oil head pressure plus 35 kN/m² (0.35 kgf/cm²) whichever is lower, as measured at the base of the tank. The pressure shall remain constant for 1 h to indicate that there is no leakage.

16.2.1.4 **Insulation test for core bolts**: This test shall be done as described in Clause 6.4.4 of this specification.

16.2.1.5 **Test for pressure relief device**: Every pressure relief device shall be subjected to gradually increasing oil pressure. It shall operate before the pressure reaches the test pressure specified in Clause 16.2.1.3 hereof and the value at which it has operated shall be recorded.

16.2.1.6 **Measurement of capacitance and tan-delta values**: The measurement of capacitance and tan-delta (dielectric loss factor) of the transformer windings shall be made by Schering bridge.

16.2.2 The Purchaser may, if so desires, carry out any checks or tests on the quality of manufacture at any stage during coil winding, drying of coils, assembly of coils on core and method of drying, vacuum impregnation, tightness of core clamping bolts, adequacy of pressure on coils or any other aspects as deemed necessary so as to ensure that proper quality is maintained.

16.3 **Type Tests**

16.3.1 The type tests shall be carried out on the prototype transformer at the works of the successful tenderer/manufacturer or at any reputed laboratory in the presence of the representative of the Purchaser/DG(TI), RDSO, Lucknow, and in accordance with the relevant specifications and as altered, amended or supplemented by this specification. The following shall constitute the type tests:

1. Temperature-rise test.
2. Lightning impulse test.
3. Test with lightning impulse, chopped on the tail.
5. Measurement of acoustic sound level.

16.3.2 Temperature-rise test

16.3.2.1 The temperature-rise test shall be done with the tap-changer on the lowest tap position (-15%) in accordance with IS:2026(Part II) except as modified hereunder.

1. At rated load.
2. At 150% rated load for 15 min after continuous operation at rated load for 1 h.
3. At 200% rated load for 5 min after continuous operation at rated load for 1 h.

The tests shall be done continuously without any power supply interruption. In case interruptions of power supply do take place for some reason, then the entire test shall be repeated after steady state conditions are attained.

16.3.2.2 The points to be ensured during the temperature-rise test shall be:

1. The ambient temperature shall be measured using alcohol in glass thermometers only.
2. The winding temperature shall be determined by the resistance method only.
3. The temperature of the top oil shall be measured by an alcohol in glass thermometer placed in an oil-filled thermometer pocket.
4. The average oil temperature shall be calculated as the difference between the top oil temperature and half the temperature drop in the cooling equipment (radiators).
5. The temperature of the hot-spot in the winding shall be the sum of the temperature rise of the winding above the average oil temperature.

16.3.2.3 The test shall be carried out as described below:

16.3.2.3.1 **100 % load**

1. A quantum of power equal to the sum of the measured losses viz. no-load and load losses measured at minus 15% tap position, corrected to 75°C plus 10% of such sum shall be fed to the primary winding of the transformer with the secondary windings short-circuited.
2. The power so fed to the transformer shall be continuously maintained till such time as the steady state temperature is reached i.e. the top oil
temperature rise does not vary by more than 1°C during four consecutive hourly readings.

3. On attaining the steady state temperature, the current in the primary winding of the transformer shall be brought to the rated current which shall be maintained for 1 h. At the end of the period the power supply to the transformer shall be switched off and the time of switching off recorded.

4. The measurement of hot resistance shall commence as soon as is possible after switching off. The first reading of the resistance shall be taken before the expiry of 90 s from the instant of switching off and the first ten readings shall be taken at intervals of 15 s apart. Thereafter, another ten readings shall be taken at intervals of 30 s apart.

5. The time at which each of the resistance values is read shall also be recorded.

6. The temperatures of the ambient, top oil, the top and bottom radiator header oils shall also be recorded at half-hourly intervals throughout the test starting from the instant power supply is switched on to commence the test till it is switched off.

7. The WTI and OTI readings shall also be recorded at half-hourly intervals right from the instant the power supply is switched on to commence the test till it is switched off.

8. After power supply is switched off, the readings of OTI and WTI shall be recorded at intervals of 1 min apart for 30 min.

16.3.2.3.2 150% load

1. After completion of the test at 100% load, the transformer shall be fed with power which shall be a value so as to cause circulation of the rated current in the primary winding with secondary windings short-circuited. This current shall be circulated for 1 h.

2. The current shall thereafter be increased to 150% of the rated current and maintained for a period of 15 min. At the end of the 15 min period, the power supply shall be switched off and the time of switching off recorded.

3. Thereafter the readings as indicted in Clauses 16.3.2.3.1(4) to (8) shall be recorded.

4. The temperatures of ambient, top oil, the top and bottom radiator header oils and the temperatures indicated by OTI and WTI shall also be recorded at the time of switching off the power supply.

16.3.2.3.3 200% load

1. After completion of the test at 150% load, the transformer shall be fed with power which shall be a value so as to cause circulation of the rated current in the primary winding with secondary windings short-circuited. This current shall be circulated for 1 h.
2. The current shall thereafter be increased to 200% of the rated current and maintained for a period of 5 min. At the end of the 5 min period the power supply shall be switched off and the time of switching off recorded.

3. Thereafter the readings as indicated in Clauses 16.3.2.3.1(4) to (8) shall be recorded.

4. The temperatures of ambient, top oil, top and bottom radiator header oils and the temperatures indicated by OTI and WTI shall also be recorded at the time of switching on 200% load as well as at the time of switching off the power supply.

16.3.2.4 Determination of thermal time constant of the windings: The thermal time constant of the primary and secondary windings, under both rated load and over loads shall be verified during the temperature-rise tests.

16.3.2.5 The temperature rise of the oil, windings and current carrying parts in air under both the overload conditions stipulated in Clauses 16.3.2.3.2 and 16.3.2.3.3 above shall not exceed the values stipulated in Clause 5.1(13) of this specification. The winding hot-spot temperature under the overload conditions shall not exceed 115°C.

16.3.2.6 Testing and calibration of the temperature indicators: The functioning of the OTI and WTI shall be verified during the tests described above. Both the OTI and WTI shall be recalibrated, if necessary, to reflect the respective temperatures correctly. In particular, the reading of the WTI shall be the same as the calculated value of the hot-spot temperature of the winding.

16.3.2.7 Determination of the thermal time constant of the WTI: the thermal time constant of the WTI shall be determined for comparison with the thermal time constant of the winding of the transformer with respect to the transformer oil. For this purpose, the indications of the WTI and the OTI shall be recorded every 1 or 2 min during the first 1 h from the instant the transformer is loaded. From the slope of the curve plotted with the time on the X-axis and the difference between the readings of the WTI and OTI at the particular time on the Y-axis, the thermal time constant of the WTI shall be determined. This value shall not vary appreciably from the thermal time constant of the winding as calculated theoretically and as ascertained from the slope of the cooling curves.

16.3.3 Lightning impulse test

16.3.3.1 This test shall be done in accordance with IS:2026 (Part III). Each of the terminals of the primary and secondary windings shall be tested with the following voltages:

1. Highest voltage for equipment Um, kV: 52, 245
2. Lightning impulse withstand voltage, kV peak: 250, 950
16.3.4 Test with lightning impulse, chopped on the tail

16.3.5.1 This test shall be done in accordance with IS:2026 (Part III) with the appropriate test voltage as stipulated in clause 16.3.3.1 above.

16.3.5 Short-circuit test

16.3.5.1 The short-circuit test shall be conducted in accordance with IS:2026 (Part-I) with the following schedule:

16.3.5.2 Prior to commencement of the test, the following measurements/tests shall be made:

1. Insulation resistance of the windings with respect to the earth and between the windings.
2. No-load current.
3. No-load loss.
5. Percentage impedance voltages.
7. Voltage ratio.
8. Di-electric tests comprising:
   1) Separate-source voltage withstand test, and
   2) Induced over voltage withstand test.
9. Recording if recurrent surge oscillogram (RSO) at the breakers on the secondary side of the transformer after energizing the primary windings at its rated voltage.

16.3.5.3 The test shall preferable be done by closing the breakers on the secondary side of the transformer after energizing the primary windings at its rated voltage.

16.3.5.4 The transformer shall be subjected to a total of seven shots in the following sequence:

<table>
<thead>
<tr>
<th>Shot</th>
<th>Asymmetrical and symmetrical currents in M-phase and T-phase respectively</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Shot</td>
<td>Asymmetrical and symmetrical currents in M-phase and T-phase respectively at the highest tap (+10%)</td>
</tr>
<tr>
<td>2nd Shot</td>
<td>Symmetrical and asymmetrical currents in M-phase and T-phase respectively at the highest tap (+10%)</td>
</tr>
<tr>
<td>3rd Shot</td>
<td>Asymmetrical and symmetrical currents in M-phase and T-phase respectively at the principal tap</td>
</tr>
<tr>
<td>4th Shot</td>
<td>Symmetrical and asymmetrical currents in M-phase and T-phase respectively at the principal tap</td>
</tr>
<tr>
<td>5th Shot</td>
<td>Asymmetrical and symmetrical currents in M-phase and T-phase respectively at the lowest tap (-15%)</td>
</tr>
<tr>
<td>6th Shot</td>
<td>Symmetrical and asymmetrical currents in M-phase and T-phase respectively at the lowest tap (-15%)</td>
</tr>
</tbody>
</table>
16.3.5.5 The duration of each shot shall be 0.5 s.

16.3.5.6 Measurements shall be done after each shot for the following:

1. Percentage impedance voltages.
2. No-load current.
3. No-load loss.

16.3.5.7 Further testing and inspection of the transformer subjected to the short-circuit test shall be carried out as per IS:2026 (Part-I) with the modification that:

1. The dielectric routine tests shall be at 100% of the original test value.
2. The percentage impedance voltages measured after the short-circuit test shall not vary by more than 2% from those measured before the short-circuit test.

16.3.5.8 On completion of the short-circuit test the transformer shall be untanked for inspection of the core and windings. In case the inspection of the core and windings do not reveal any apparent defects and the results of the short-circuit test, the values of percentage impedance voltages as also the results of the routine tests done after the short-circuit test are in order, the transformer shall be deemed to have passed the short-circuit test. If any of the results of the tests are not in order or the inspection of core and windings reveals any defect, then the transformer shall necessarily have to be dismantled completely for detailed inspection.

16.3.6 Measurement of acoustic sound level

16.3.6.1 Measurement of acoustic sound level of the transformer energised at rated voltage and frequency shall be carried out either as per Indian Electrical & Electronics Manufacturers Association (IEEMA) or as per National Electrical Manufactures Association (NEMA) procedure.

16.3.7 Measurement of Partial discharge quantity

16.3.7.1 Partial discharge quantity of the windings shall be measured in accordance with IS:6209 and IS:2026(Part-III).

16.3.8 Measurement of harmonics of no-load current

16.3.8.1 The magnitude of harmonics of no-load current, as expressed in percentage of the fundamental, shall be measured by means of a harmonic analyser, in accordance with IS:2026(Part-I).
16.4 Type tests on parts, fittings and accessories

16.4.1 Motorised off-circuit tap-changer

16.4.1.1 Though there is no Indian Standard Specification at present for motorised off-circuit tap-changer, the following tests shall be carried out thereon in accordance with IS:8468.

16.4.1.2 Test for temperature rise of contacts: The test shall be carried out at rated current of 1250 A. The temperature rise shall not exceed the limit specified in IS:8468.

16.4.1.3 Mechanical endurance test: With the tap-changer in oil, 100 operations shall be done manually and 10,000 operations shall be done with the motor drive unit. An operation shall comprise moving the tap-changer from one tap position to the next higher or lower tap position. All the taps of the tap-changer i.e. +10% position tap to the -15% position tap shall be covered during the test. While testing with the motor drive unit the d.c. voltage for the motor drive unit shall be adjusted to the value indicated below, and the number of operations at each value of voltage shall be as indicated against each.

1. At the minimum voltage of 93.5 V dc 2,500 operations
2. At the maximum voltage of 121 V dc 2,500 operations
3. At the rated voltage of 110 V dc 5,000 operations

16.4.1.4 Milli-volt drop test: The test shall be done both before and after the mechanical endurance test to assess the condition of the contacts. The variation in the milli-volt drop values shall be not more than 20%.

16.4.1.5 Short-circuit current test: The test shall be done in accordance with IS:8468 with short-circuit currents of 12.5 kA r.m.s., each of 5 s duration.

16.4.1.6 Dielectric tests: The tests shall be done in accordance with IS:8468.

16.4.1.7 Auxiliary circuits insulation tests: Auxiliary circuits including the motor and other auxiliary equipment shall be tested in accordance with IS:8468.

16.4.2 Condenser bushings

16.4.2.1 The type tests shall be carried out in accordance with IS:5621 on porcelain housing of the condenser bushings. The following shall constitute the type tests:

1. Visual inspection.
2. Verification of dimensions.
3. Electrical routine test.
4. Porosity test.
5. Temperature cycle test.
16.4.2.2 The type tests shall be carried out in accordance with IS:2099 on the prototype of the condenser bushings. The following shall constitute the type tests:

1. Wet power frequency withstand voltage test.
2. Dry lightning impulse voltage withstand test.
3. Thermal stability test.
4. Temperature-rise test.
5. Thermal short time current withstand test.
7. Cantilever load withstand test.
8. Tightness test.
9. Test of tap insulation.
10. Tightness test at flange or other fixing device.

16.4.3 **Bushing type current transformers**
16.4.3.1 The bushing type current transformers shall be tested in accordance with IS:2705(Part-I & IV).

16.4.4 **Buchholz relay**
16.4.4.1 The Buchholz relay shall be tested in accordance with IS:3637.

16.4.5 **Terminal connectors**
16.4.5.1 The terminal connectors shall be tested in accordance with IS:5561.

16.4.6 **Temperature indicators**
16.4.6.1 The following tests shall be conducted on prototypes of OTI and WTI:

1. Accuracy with reference to a standard instrument.
2. Calibration of the indictors to reflect the actual temperature of the oil/winding.
3. Dielectric test at 2.5 kV for 60 s.
5. Dust and water splash test to IP 55 degree of protection.

16.4.7 **Pressure relief device**
16.4.7.1 The following tests shall be conducted on the prototype of pressure relief device:

1. Air pressure test.
2. Leakage test.
3. Contact rating and operation test.
4. Dielectric test on contacts at 2.5 kV for 60 s.
16.4.8 Radiators

16.4.8.1 The radiators shall be tested for air leakage at a pressure of 2.5 kg/cm². The pressure shall remain constant for 1 h to indicate that there is no leakage.

16.5 Insulating oil

16.5.1 The following tests shall be carried out in accordance with IS:335 on the sample of new insulating oil for use in the prototype transformer:

1. Density at 27°C.
2. Kinetic viscosity at 27°C.
3. Interfacial tension at 27°C.
4. Flash point.
5. Neutralisation value (acidity).
6. Electric strength (with 2.5 mm gap).
7. Dielectric dissipation factor (tan-delta).
8. Specific resistance at 27°C and at 90°C.
10. Water content.

16.6 Routine tests

16.6.1 The following routine tests shall be performed on each transformer including the prototype unit in accordance with IS:2026:

2. Insulation resistance test.
8. Polarity test.
10. Dielectric test comprising:
   1) Separate-source voltage withstand test, and
   2) Induced over voltage withstand test.

11. Recording of recurrent surge oscillorgam (RSO).
12. Tests on motorised off-circuit tap-changer.

16.6.2 Visual examination: A general examination shall be made to check that the transformer conforms to the approved drawings, various items are accessible for maintenance, the quality of workmanship and finish are of acceptable standards and all parts, fittings and accessories are provided.

16.6.3 Insulation resistance test: The insulation resistance of the windings with respect to the earth and between the windings shall be measured using a 5 kV megger.
16.6.4 Measurement of no-load current: Measurement of no-load current referred to the primary side shall be done at:
   1. 90%, 100% and 110% of the rated voltage at the principal tapping, and
   2. the appropriate tap voltage at the +10% and -15% tap positions.

16.6.5 Measurement of no-load loss: Measurement of no-load loss referred to the primary side shall be done at:
   1. 90%, 100% and 110% of the rated voltage at the principal tapping, and
   2. the appropriate tap voltage at the +10% and -15% tap positions.

16.6.6 Measurement of resistance of windings: The resistance of the windings shall be measured at all tappings and computed at 75°C.

16.6.7 Measurement of percentage impedance voltages: The percentage impedance voltages at principal, +10% tap and -15% tap positions shall be measured at rated current and at ambient temperature and computed at 75°C. The measuring and calculation methods shall be as indicated in Annexure-1.

16.6.8 Measurement of load loss: Load losses at rated current shall be measured at principal, +10% and -15% tap positions at ambient temperature and computed at 75°C.

16.6.9 Polarity test: The polarity (subtractive) and marking of the terminals for the polarity shall be verified.

16.6.10 Voltage ratio test: Voltage ratio shall be measured at all tap positions.

16.6.11 Dielectric tests

16.6.11.1 Induced over voltage withstand test: The test shall be done by applying the test voltage across the entire secondary winding as per IS:2026 (Part-III).

16.6.11.2 Separate-source voltage withstand test: The test voltage to be applied shall be as under:

<table>
<thead>
<tr>
<th></th>
<th>Highest voltage for equipment Um, kV</th>
<th></th>
<th>Rated short duration power frequency withstand voltage, kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>245</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>95</td>
<td>395</td>
<td></td>
</tr>
</tbody>
</table>
16.6.12 Recording of recurrent surge oscillogram (RSO): The oscillograms shall be taken at the +10%, -15% and principal tappings.

16.6.13 Tests on motorised off-circuit tap-changer: The tests shall be conducted in accordance with IS:8468.

16.6.14 During the routine tests on any unit if it is found that the sum of the measured losses (i.e. no-load and load losses) measured at -15% tap position (corrected to 75°C) exceeds the value defined in Clause 16.3.2.3.1(1), or if the no-load loss/ load loss at the principal tapping exceeds the maximum guaranteed figures, then the transformer shall be rejected.

16.7 If the prototype of a transformer conforming to this specification has already been approved in connection with previous supplies to Indian Railways, fresh type testing may be waived at the discretion of the Purchaser, provided that no changes whatsoever in the design or material(s) used or the process of manufacture have been made. However, the Purchaser reserves the right to conduct type tests if he gained from previous supplies.

16.8 Only after approval of the original tracings of drawings incorporating changes, if any, as a result of the prototype tests and clear written approval of the results of the tests on the prototype is communicated by the Purchaser/DG(TI), RDSO, Lucknow, to the successful tenderer/manufacturer, shall he taken up bulk manufacture of the transformer-which shall be strictly with the same materials and process of manufacture as adopted for the prototype. In no circumstances shall materials other than those approved in the design/drawings and/or during the prototype testing be used for bulk manufacture on the plea that they had been obtained prior to the approval of the prototype.

16.9 The tenderer may quote separately his charges for short-circuit and temperature-rise tests. No charges shall be payable for any other type and routine tests.

17.0 TECHNICAL DATA AND DRAWINGS

17.1 The tenderer shall furnish along with his offer, in the proforma at Annexure-3, the Schedule of Guaranteed Performance, Technical and Other Particulars (SOGP) for the transformer. The particulars shall be complete in all respects. If there is any entry like "shall be furnished later" or a blank is left against any item, the offer is not likely to be considered as the evaluation of the offer is rendered difficult and cannot be compared with other offers, if any.

17.2 The tenderer shall specifically indicate in a "Statement of Compliance" attached with the offer his compliance with each and every Clause of this specification. In case to tenderer wishes to deviate from any Clause of this specification, he may do so giving reference to the Clause(s) with the reasons/justification for the deviation. This shall be in the form of a separate statement called the "Statement of Deviations". If there is no deviation at all, specific "NIL" "Statement of Deviations" shall be attached with the offer. If the "Statement of Compliance" and Statement of Deviations" are not attached with the offer, it is not likely to be
considered for the reason that it is an incomplete offer which cannot be properly evaluated and compared with other offers, if any.

17.3 The tenderer shall furnish the following information along with his offer:-

17.3.1 Calculations for:

1. Temperature rise of winding at rated current.
2. Hot-spot temperature of the winding at 150% and 200% rated loads for 15 min and 5 min respectively.
3. Thermal withstand capacity of the windings for a short circuit of 5 s duration.
4. Mechanical forces in respect of the following as per IEEMA (Indian Electrical & Electronic Manufacturer's Association) formulae given in Annexure-4:
   1) Asymmetrical short-circuit current
   2) Hoop stress in primary and secondary windings.
   3) Compressive pressure in the radial spacers.
   4) Internal axial compressive force.
   5) Axial imbalance force.
   6) Radial bursting force.
   7) Resistance to collapse.
   8) Bending stress on clamping ring and densified wood.
   9) Maximum allowable torque on pressure screws for coil clamping bolts at the time of tightening, if any.
5. Flux density with the characteristic curve.

17.3.2 Drawings for:

1. Outline general arrangement drawing giving complete details of the transformer.
2. Arrangement of the core, windings and magnetic path.
4. Drawing showing elevation of the core and winding and other insulation materials.
5. A sectional view showing the position of core, cylinders, winding blocks, vertical ribs and other insulating materials.
6. Details of coil clamping arrangement.
7. General arrangement of the off-circuit tap-changer.

17.4 The successful tenderer/manufacturer shall submit to DG(TI), RDSO, Lucknow for approval the following detailed dimensioned drawings as
per Indian Railways standard in sizes of 210 mm x 297 mm or any integral multiples thereof:

1. Outline general arrangement of the transformer indicating plan, front elevation, side elevation with all parts, fittings and accessories, electrical clearances as well as salient guaranteed particulars.
2. Internal arrangement of the transformer indicating primary and secondary bushing lead connections, core to core-clamp earthing, core-clamp to tank earthing, core-clamp to core-base bolting, and the locking arrangement of the core & coil assembly with the tank.
3. Cross sectional view of the core and windings with material specifications and makes.
4. Details of the pressure screws/oil dash-pot/coil clamping bolts or other devices and their location with materials specifications and makes.
5. Schematic view of the valves used on the transformer and the antitheft device so as to prevent theft of oil.
6. Transport outline dimensional diagram.
7. General arrangement of the off-circuit tap-changer assembly with salient technical parameters.
8. Tap-changer cubicle layout.
9. Schematic diagram for driving of motorised off-circuit tap-changer from remote control centre by telecommand and corresponding telesignalling.
10. Name and rating plate of motorised off-circuit tap-changer.
11. General arrangement of marshalling box indicating protection and control equipment.
12. Wiring diagram of marshalling box.
13. Schematic diagram of protection and control circuits in marshalling box with cable schedule.
14. Legend plate showing protection and control circuits for fitment in the marshalling box.
15. OIP condenser bushing for primary side including cross sectional view, shed profile and salient electrical and mechanical characteristics.
16. OIP condenser bushing for secondary side including cross sectional view, shed profile and salient electrical and mechanical characteristics.
17. Dimensional drawing, V-I characteristic and rating plate for bushing type current transformers.
18. Rigid type terminal connector for primary side bushing terminal.
20. Rating plate with diagram of connections, both in English and Hindi versions.
21. Details of radiators.
22. Details of breather.
23. External cable run with cable schedule.
24. Any other drawings considered necessary by the successful tenderer/manufacturer and/or Purchaser.

17.4.1 The format of the title sheet to be adopted for preparation of the drawings is attached at Appendix-2
17.4.2 After approval, six copies of each of the approved drawings along with two sets of reproducible prints for each drawing shall be supplied to each consignee(s). Besides, two copies of drawings along with one set of reproducible prints shall be supplied to DG(TI), RDSO, Lucknow.

17.4.3 Two copies of the "Operation/ Maintenance Manual" for each transformer shall be supplied to the consignee(s). Two copies of the manual shall be supplied to the DG(TI), RDSO, Lucknow.

18.0 CAPITALISATION OF TRANSFORMER LOSSES

18.1 The capitalised value of transformer losses shall be as low as possible, and commensurate with optimum no-load and load losses. The capitalised value shall be computed as detailed at Annexure-5 and furnished with the offer.

19.0 SPARES

19.1 The tenderer shall quote separately for the following essential spares for every lot of up to 5 transformers or part thereof:

1. One set of primary coil, secondary coil and tapping coil.
2. One primary bushing complete with parts, fittings and bushing type current transformer.
3. One secondary bushing complete with parts, fittings and bushing type current transformer.
4. One complete set of gaskets of all sizes required for use in the transformer.
5. One breather unit with silicagel.
6. One set of radiator banks.
7. One Buchholz relay.
8. One complete off-circuit tap-changer.
9. One each of terminal connectors for primary and secondary side bushing terminals.
10. One set of valves.
11. One pressure relief device.

19.2 A separate quotation shall be furnished for any other spares that the manufacturer considers as necessary for maintenance of the transformer.

20.0 ERECTION, TESTING AND COMMISSIONING

20.1 The transformer shall be erected and commissioned by the Purchaser. The successful tenderer/manufacturer shall invariably make available at site the services of an engineer of his to ensure, by his continued presence, that the process of erection, testing and commissioning of the transformer is in accordance with established practices. For this purpose prior intimation regarding the dates/period and locations at which the transformers are to be erected and testing/commissioning done shall be given by the Purchaser to
the successful tenderer/manufacturer. No charges shall be payable by the purchaser to the successful tenderer/manufacturer for the services of his engineer in this regard.

20.2 If any transformer has been received at site in a damaged condition and in the opinion of the Railway's engineer at site it is required to be repaired at the successful tenderer/manufacturer's works, the transformer shall be taken back to the works promptly and after repairs, all necessary tests including the routine tests shall be done on the complete transformer in the presence of and to the satisfaction of the Railway's Engineer prior to returning the transformer to site. Such tests are necessary to ensure that the quality of the workmanship during repairs is satisfactory and shall be done free of cost. Any tests, as decided by the Railway's engineer at site shall also be conducted on the transformer at site free of cost.

21.0 TRAINING OF INDIAN RAILWAY'S ENGINEERS

21.1 The offer shall include the training of two Engineers of the Indian Railways free of cost at the manufacturer's works and at the maintenance depots/workshops on a railway system or other public utility where transformers of similar design are in operation. The total duration of training for each Engineer shall be 12 weeks of which approximately 6 weeks shall be at the manufacturer's works and 6 weeks on a railway system or other public utility. The cost of travel to the place of manufacture and back shall be borne by the Indian Railways. Other details shall be settled at the time of finalizing the contract or Purchaser order.

22.0 AFTER SALES SERVICE

22.1 The successful tenderer/manufacturer shall make necessary arrangements for closely monitoring the performance of the transformer(s) through periodical (preferable once in two months during the warranty period) visits to the locations where they have been erected for observations and interaction with the operating and maintenance personnel of the Indian Railways. Arrangements shall also be made by the successful tenderer/manufacturer for emergency/standby spare parts being kept readily available to meet exigencies warranting replacement so as to keep the transformers in service with least down time.

22.2 The successful tenderer/manufacturer shall respond promptly and in a workman-like manner to any call given by Indian Railways for any assistance by way of attending to failures, investigation into the causes of failures including tests, if any, to be done and such other items with a view to seeing that the transformer serves the purpose for which it is intended. Besides technical guidance to ensure proper operation and maintenance of the traction transformer shall be constantly rendered.
23.0 WARRANTY

23.1 The successful tenderer/manufacturer shall warrant that all equipment shall be free from defects and faults in design, material, workmanship and manufacture and of the highest grade consistent with the established and generally accepted standards for the equipment of the type ordered and in full conformity with the specifications and shall operate properly.

23.2 This warranty shall survive inspection of, payment for and acceptance of the equipment, but shall expire 24 (Twenty Four) months after the delivery at ultimate destination in India, or 18 (Eighteen) months from the date of commissioning and proving test of the equipment at ultimate destination in India, whichever period expires earlier, except in respect of complaints, defects and/or claims notified to the successful tenderer/manufacturer within 3 (Three) months of the expiry of such date. Any approval or acceptance by the Purchaser of the equipment shall not in any way limit the successful tenderer/manufacturer's liability.

23.3 The successful tender/manufacturer's liability in respect of any complaint, defects and/or claims shall be limited to the furnishing and installation of replacement parts free of any charge or the repair of defective parts only to the extent that such replacement or repairs are attributable to or arise from faulty workmanship or material or design in the manufacture of the goods, provided that the defects are brought to the notice of the successful tenderer/manufacturer within 3 (Three) months of their being first discovered during the warranty period or 3 (Three) months from the date of expiry of warranty period, or at the option of the Purchaser, to the payment of the value, expenditure and damage as hereafter mentioned.

23.4 The successful tenderer/manufacturer shall, if required, replace or repair the equipment or such portion thereof as is rejected by the Purchaser free of cost at the ultimate destination or at the option of the Purchaser, the successful tenderer/manufacturer shall pay to the Purchaser value thereof at the contract price or in the absence of such price at a price decided by the Purchaser and such other expenditure and damages as may arise by reason of the breach of the conditions herein specified.

23.5 All replacements and repairs that the Purchaser shall call upon the successful tenderer/manufacturer to deliver or perform under this Warranty shall be delivered and performed by the successful tenderer/manufacturer promptly and satisfactorily and in any case within 2 (Two) months of the date of advice to this effect.

23.6 If the successful tenderer/manufacturer so desires, the parts that are removed may be taken over by him or his representative for disposal as he deems fit at the time of replacement with good parts. No claim whatsoever shall lie on the Purchaser thereafter for the parts so removed.
23.7 The Warranty herein contained shall not apply to any material which shall have been repaired or altered by the Purchaser or on his behalf in any way without the consent of the successful tenderer/manufacturer, so as to affect the strength, performance or reliability or to any defects to any part due to misuse, negligence or accident.

23.8 The decision of the Purchaser in regard to successful tenderer/manufacturer's liability and the amount, if any, payable under this warranty shall be final and conclusive.

24.0 SHIPMENT OF THE TRANSFORMER

24.1 The transformer shall be transported depending upon the transport facilities available for the route i.e. by rail or truck or ship.

24.2 The transformer shall be dispatched with its core and windings along with the tap-changer assembly in the transformer tank filled with oil and the space above the oil filled with pure dry air or inert gas like nitrogen at a pressure slightly above atmospheric pressure. However, if there are limitations on account of weight, the tank shall be filled with nitrogen under pressure and the oil for the first filling shall be supplied separately in steel drums. In case the tank is filled with inert gas the temperature and pressure at the time of filling shall be marked conspicuously on the transformer.

24.3 All openings created on the tank by removal of any items shall be closed with suitable blanking plates. All the parts, fittings and accessories such as conservator tank, bushings, silicagel breather, radiator, Buchholz relay, temperature indicators and other items shall be packed/crated separately along with a packing list in each crate containing the following particulars:

<table>
<thead>
<tr>
<th>Crate No.</th>
<th>Description of item/component in the crate</th>
<th>Approx. gross weight in kg</th>
<th>Approx. outside dimensions in mm</th>
</tr>
</thead>
</table>

24.4 The packing shall be done properly so that no damage occurs during transit.

24.5 All the parts, fittings and accessories for each transformer shall be so dispatched that they arrive at site together to enable erection of the complete transformer without delay.

24.6 Necessary instructions for handling and storage of all items shall be included along with the packing lists.

24.7 In case of overseas supply, packing shall be seaworthy.

*******************
ANNEXURE-'3'

(For Specification No. ETI/PSI/124(07/95)

SCHEDULE OF GUARANTEED PERFORMANCE, TECHNICAL AND OTHER PARTICULARS (GUARANTEED PARTICULARS ARE TO BE ESTABLISHED BY ACTUAL TESTS/TEST REPORTS)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>DESCRIPTION</th>
<th>UNIT OF MEASUREMENT</th>
<th>VALUE/INFORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A RATINGS/PARTICULARS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Name of the Manufacturer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Country of manufacture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Reference to specification based on which performance data is prescribed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Rated power</td>
<td>MVA</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Primary current at:</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Rated load</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) 150% rated load for 15 min</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) 200% rated load for 5 min</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Secondary current at:</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Rated load</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) 150% rated load for 15 min</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) 200% rated load for 5 min</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Rated voltage :</td>
<td>kV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Secondary (at no-load)</td>
<td>kV</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Rated frequency</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Temperature rise above ambient temperature of 50°C :</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(i). Oil :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) At rated load</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) At 150% rated load for 15 min</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) At 200% rated load for 5 min</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>
(ii) Winding:
   a) At rated load  
   b) At 150% rated load for 15 min.  
   c) At 200% rated load for 5 min

10. Hot-spot temperature of winding over ambient temperature of 50°C
   a) At rated load  
   b) At 150% rated load for 15 min.  
   c) At 200% rated load for 5 min

11. Interval of time between two successive overloads after continuous working at full load, at maximum ambient temperature of 50°C:
   a) Between two consecutive overloads of 50% for 15 min.  
   b) Between two consecutive overloads of which one is of 50% for 15 min and the other of 100% for 5 min.

12. No-load current referred to primary side at rated frequency and at:
   a) 90% rated voltage  
   b) Rated voltage  
   c) 110% rated voltage

13. Power factor of no-load current at rated voltage and rated frequency

14. Value of the inrush current at rated voltage on primary side, the secondary side being open circuited

15. Losses:
   (i). No-load loss at rated frequency and at:
   a) 90% rated voltage at the principal tapping.  
   b) rated voltage at the principal tapping.  
   c) 110% rated voltage at the primary tapping.
d) Appropriate voltage at the - 15% tapping.  

kW

e) Appropriate voltage at the +10% tapping/ 

kW

(ii) Load loss (at 75°C) at rated current and frequency 

kW

a) Principal tapping  
kW

b) -15% tapping  
kW

c) +10% tapping  
kW

(iii) Total losses at rated current and frequency 

kW

a) Principal tapping  
kW

b) -15% tapping  
kW

c) +10% tapping  
kW

16. Resistance voltage (at 75°C) at rated current  

% 

17. Reactance voltage (at 75°C) at rated current and frequency  

% 

18. Impedance voltage (at 75°C) at rated current and frequency  

% 

19. Resistance (at 75°C) of ohm primary winding  

20. Resistance (at 75°C) of ohm secondary winding  

21. Reactance of winding :  

H 

i) Primary  

H

II) Secondary at  

a). Principal tapping  

H

b). +10% tapping  

H

c). -15% tapping  

H

22. Regulation (at 75°C) with rated current and at power factor of:  

% 

a) Unity  

b) 0.8 lagging  

%
23. **Efficiencies:**
   (i). Efficiency (at $75^0C$) at unity power factor at:
   a). 100% load  
   b). 75% load  
   c). 50% load  
   d). 25% load
   (ii). Efficiency (at $75^0C$) at 0.8 power factor lagging at:
   a). 100% load  
   b). 75% load  
   c). 50% load  
   d). 25% load
   (iii). Percentage of rated load at which maximum efficiency occurs.

24. **Ability to withstand short-circuit:**
   a). Thermal  
   b). Dynamic

25. **Thermal time constant (calculated):**
   (i). for winding with respect to oil at:
   a). rated current  
   b). 150% rated current  
   c). 200% rated current
   (ii). Complete transformer at rated current

26. **Temperature gradient between oil and winding at:**
   a). Rated current  
   b). 150% rated current for 15 min  
   c). 200% rated current for 5 min.

27. **Temperature rise of oil:**
   (i). Calculated average temperature rise of oil at:
   a). Rated current  
   b). 150% rated current for 15 min
c). 200% rated current for 5 min 

(ii) Estimated temperature rise of top oil at:

   a). Rated current 

   b). 150% rated current for 15 min 

   c). 200% rated current for 5 min 

28. Details of core:

   (i) Type of core

   (ii) Flux density at rated voltage and frequency tesla

   (iii) Flux density at 110% rated voltage and frequency tesla

   (iv) Thickness of steel stampings mm

   (v) Grade of core material and conforming specification

   (vi) Exciting VA/kg for core stampings at:

       a) Flux density of 1.55 tesla VA/kg

       b) Flux density at rated voltage VA/kg

       c) Flux density at 110% rated voltage VA/kg

   (vii) Exciting VA/kg for assembled core at:

       a) Flux density of 1.55 tesla VA/kg

       b) Flux density at rated voltage VA/kg

       c) Flux density at 110% rated voltage VA/kg

   (viii) Type of insulation between core laminations.

   (ix) Type of joint between the core limbs and yoke.

   (x) core bolt Insulation withstand voltage kV

   (xi) Core bolt insulation flashover voltage kV
29. Details of windings:

(i) Type of winding
   (a) Primary
   (b) Secondary
   (c) Number of turns of primary winding
   (d) Number of turns of secondary winding
   (e) Number of parallel paths in primary winding
   (f) Number of parallel paths in secondary winding.
   (g) Is interleaving/inter shielding of the winding adopted to ensure better impulse voltage distribution? Yes/No

   (i) Primary
   (ii) Secondary

   (h) Is the insulation of end turns of winding reinforced? Yes/No
      (i) Primary
      (ii) Secondary

   (i) Type of coil
   (ii) Mode of connection (i.e. in series or in parallel) of the portions of the windings on the two limbs of the core, if applicable.
   (iii) Dimensions of the copper conductor used in the winding:
      a) Primary mm x mm
      b) Secondary mm x mm
      c) Tapped winding. mm x mm
   (iv) Current density at rated current.
(v) Insulation used over the conductor (details of material and specification there for)

(vi) Type of joints, if any, in the windings

(vii) Dielectric strength of windings:

a) Full wave lightning impulse withstand voltage:

   a) Primary winding kV peak
   b) Secondary winding kV peak

b) Lightning Impulse chopped on the tail withstand voltage:

   i) Primary winding kV peak
   ii) Secondary winding kV peak

(c) Separate source power frequency withstand voltage kV

   i) Primary
   ii) Secondary

(d) Induced over voltage withstand value kV

(viii) Minimum flashover distance to earth in oil of :

   a) Secondary winding to core
   b) Primary winding to yoke
   c) Primary winding to tank

(ix) Material used for coil clamping rings and specification there for

(x) Magnitude of axial pre-compressive force on the winding

   a) Primary
   b) Secondary
(xi) Calculated maximum axial thrust in the winding due to dead short circuit at the terminals t
(a) Primary
(b) Secondary

(xii) Calculated short circuit forces:
   a) Hoop stress in primary winding kgf/cm²
   b) Hoop stress in secondary winding kgf/cm²
   c) Compressive pressure in the radial spacers kgf/cm²
   d) Internal axial compressive force kgf
   e) Axial imbalance force kgf
   f) Resistance to college kgf
   g) Bending stress on clamping ring kgf/cm²
   h) Radial bursting force kgf

(xiii) Arrangement to maintain constant pressure on the windings kgf

(xiv) Maximum permissible torque on pressure screws for coil clamping at the time of tightening, if any. N.m

(xv) Can either end of each secondary winding (25 kV) be connected directly to earth? Yes/No.

30. Motorised off-circuit tap changer:
   a) Name of the manufacturer
   b) Country of origin.
   c) Type designation
   d) Governing specification.
   e) Is a separate taped winding provided in each secondary.
   f) Number of tappings:
      i) Plus tappings
      ii) Minus tappings
   g) Percentage variation of voltage on different tapping.
   h) Minimum contact pressure between moving and stationery kgf
contacts
i) Maximum rated through current A
j) Voltage class kV
k) Rated voltage of control circuit V(dc)
l) Tap changer motor particulars:
   i) Make and type V(dc)
   ii) Rated voltage A
   iii) Rated current kW
   iv) Rated power rpm.
v) Speed
vi) Class of insulation

31. Bushings:
(i). Primary side:
   a) Name of the manufacturer
   b) Country of origin
   c) Governing specification
   d) Type designation (specify as to whether it is OIP condenser bushing)
   e) Voltage class kV
   f) Rated current A
   g) Visible power frequency discharge voltage kV
   h) Wet one minute power kV peak frequency withstand voltage
   i) Lightning impulse withstand mm voltage
   j) Creepage distance
   k) Weight of assembled bushing kV

(ii). Secondary side
   a) Name of the manufacturer
   b) Country of origin
   c) Governing specification
   d) Type designation
   e) Voltage class kV
f) Rated current \( A \)
g) Visible power frequency discharge voltage \( kV \)
h) Wet one minute power frequency withstand voltage \( kV \)
i) Lightning impulse withstand voltage \( kV \) peak voltage
j) Creepage distance \( mm \)
k) Weight of assembled bushing \( kgf \)

32. Bushing type current transformers:
   (i). Primary side:
   a) Name of the manufacturer
   b) Governing specification
   c) Transformation ratio
   d) Accuracy class and rated accuracy limit factor
   e) Rated current \( A \)
f) Rated output \( VA \)
g) Exciting current at the rated knee point emf \( mA \)
h) Rated knee point emf \( V \)
i) Secondary winding resistance \( \Omega \) corrected to 75\(^{0}\)C.
j) Short time thermal current and duration \( kA,s \)

(ii). Secondary side:
   a) Name of the manufacturer
   b) Governing specification
   c) Transformation ration
   d) Accuracy class
   e) Rated current \( A \)
f) Rated output \( VA \)
g) Exciting current at the rated knee point emf \( VA \)
h) Rated knee point emf \( V \)
i) Secondary winding resistance \( \Omega \) corrected to 75\(^{0}\)C.
j) Short time thermal current and duration \( kA,s \)

33. Insulating oil:
   a) Governing specification
   b) Grade of oil
   c) Source of supply
   d) Specific resistance at:
      \( 27^{0}\)C \( \Omega \) cm
      \( 90^{0}\)C \( \Omega \) cm
40. Details of pressure relief device:
   a) Make and type
   b) Governing specification
   c) Does it reset itself

41. Bimetallic terminal connectors:
   (i). Primary side:
   a) Source of supply
   b) Governing specification
   c) Type
   d) Rated current
   e) Temperature rise over an ambient temperature of 45°C while carrying rated current.
   f) Short time current and duration

   (ii). Secondary side:
   a) Source of supply
   b) Governing specification
   c) Type
   d) Rated current
   e) Temperature rise over an ambient temperature of 45°C while current rated current
   f) Short time current and duration

42. Acoustic sound level at a distance of 1 m, when energised at rated voltage and rated frequency without load.

43. Partial discharge value at 1.5Um/ 3 kV r.m.s.

44. Weights and dimensions:
   (i) Net weight of core
   (ii) Net weight of cooper:
       a) Primary winding
       b) Secondary winding
   (iii) Net untanking weight of core frame and coils
   (iv) Net weight of insulating oil
e) Dielectric, dissipation factor (tan-
delta) at 90°C
f) Dielectric strength
kV

Water content
ppm

h) Interfacial tension
N/m

i) Neutralisation value
mg KOH/gm

j) Flash point
°C

34. Type of transformer tank

35. Details of radiators:
a) Make and type
b) Type of mounting
c) Overall dimensions (LxWxH) mm
x mm x mm

36. Details of Buchholz relay:
a) Make and type
b) Governing specification
c) Provision of shut-off valves on
   either side of the relay
   Yes/No
d) Provision of alarm contact
   Yes/No
e) Provision of trip contact
   Yes/No
f) Rated current of contacts
   A

37. Details of winding temperature indicator.
a) Make and type
b) Governing specification
c) Number of contacts provided
d) Rated current of contacts
   A
e) Dielectric withstand value of
   contacts
   kV

38. Details of oil temperature indicator
a) Make and type
b) Governing specification
c) Number of contacts provided
d) Rated current of contacts
   A
e) Dielectric withstand value of
   contacts
   kV

39. Details of Magnetic oil level gauge:
a) Make and type
b) Governing specification
c) Diameter of dial
   mm
d) Number of contacts provided
e) Rated current of contact
   A
f) Dielectric withstand value of
   contacts
   kV
(v) Volume of insulating oil l
(vi) Total weight of cooling equipment t
(vii) Total weight of transformer t without oil
(viii) Total shipping weight of complete transformer including all detachable parts, fittings and assemblies t
(ix) Shipping weight of largest package t
(x) Crane lift (excluding slings) for unloading tanking core and coils mm
(xi) Crane lift (excluding slings) for removal of primary side bushings mm
(xii) Dimensions of the complete transformer including all parts, fitting and accessories:
   a) Overall length mm
   b) Overall breadth mm
   c) From rail level to the topmost point mm
(xiii) Minimum thickness of steel plate/sheet used:
   a) Bell tank mm
   b) Tank bottom mm
   c) Conservator mm
   d) Radiator mm
   e) Marshalling box. mm
(xiv) Overall shipping dimensions of the largest package (Length x width x height) mm
(xv) Mode of transportation of transformer unit (filled with oil/nitrogen gas.)
Other particulars

45. Is the transformer tank fitted with lifting pads? If yes, what is the number of pads?
   Yes/ No

46. What is the number of inspection covers provided?

47. Are comfits/ trays provided for cable run?
   Yes/ No

48. Is the core electrically connected with the tank?
   Yes/ No

49. Will the gaskets to be used in the transformer give trouble free service for at least 7 years? If not, indicate the life.
   Yes/ No

50. Is the core construction without core bolts?
   Yes/ No

51. Are the core bolts grounded, and if so, how?
   Yes/ No

52. What is the number of radial spacers used in the winding?

53. What is the number of joints provided in the winding?

54. Are the spacers/blocks/angle rings of pre-compressed press boards? If no, indicate the material with specification.

55. Are arrangements made for ensuring automatic constant pressure on the coils? If no, give the reasons.
   Yes/ No

56. Are closed slots provided on outermost winding for locking the vertical strips? If no, give the reason.
   Yes/ No

57. What is the periodicity for tightening of coil clamping arrangement?
   Years
58. What are the designed values of short-circuit current for:
   a) Symmetrical:
      i) Primary winding A
      ii) Secondary winding A
   b) Asymmetrical:
      i) Primary winding A
      ii) Secondary winding A

59. What is the over flux withstand capability of the transformer (Maximum permissible limit of flux density) ? Tesla

60. Are windings pre-shrunk ? Yes/No

61. Have the details of drying cycles of the coils/coil assembly including final tightening values of pressure, temperature and degree of vacuum at various stages of drying been furnished? Yes/No

62. Are arcing horns provided for line and neutral bushings ? Yes/No

63. Is a test tap provided in the line bushing ? Yes/No

64. Are the porcelain housing of the bushings of single piece construction? Yes/No

65. Is the shed profile of porcelain housing of the bushing free from under-ribs but has a lip? Yes/No

66. Is the busing type current transformer of low reactance type? Yes/No

67. Is Clause by Clause "Statement of compliance" attached? Yes/No

68. Is "Statement of deviation", if any, attached? Yes/No

69. Does the tap changer have snap action ? If not, give reason.
70. Is the Buchholz relay provided with two shut-off valves, one on either side? Yes/ No
71. Is separate conservator tank & Buchholz relay provided for tap changing equipment? Yes/ No
72. Are fasteners of 12 mm diameter and less exposed to atmosphere of stainless steel to Grade 04Cr17 Ni12Mo to IS 1570 Part-V? Yes/ No
73. Are the fasteners of more than 12 mm diameter exposed to atmosphere of stainless steel or MS hot dip galvanised? Yes/ No
74. Are test certificates for tests as per Clause 15.0 attached? Yes/ No
75. Are all the calculations required as per clause 16.3.1 attached? Yes/ No
76. Are all the drawings required as per clause 16.3.2 attached? Yes/ No
77. (a) Are all the parts, fittings and accessories from RDSO's approved manufacturers? Yes/ No
(b) If not, list the items which are to be type tested in the presence of RDSO's representative Yes/No
78. Is adequate space provided in the marshalling box for housing the wiring and components? Yes/ No
79. Is warranty as per clause 22.0? Yes/ No
80. Is the list of spares furnished or no?
ANNEXURE-5

CAPITALISATION OF TRANSFORMER LOSSES

Following formula shall be used for the purpose of calculating the present worth of the transformer after taking in account capitalization of its losses.

\[ K = \frac{D(1+i)^n-1}{i(1+i)^n} \]

Where,

- **K** = Present worth of transformer in Rupee.
- **D** = Annual cost of combined no-load and load losses in Rupee.
- **i** = Rate of compound interest on unit price of transformer @ 12% per annum.
- **n** = Life of transformer.

Substituting value of **D**, which is:

\[ D = \frac{(I + F^2 C) 365 \times 24 \times T}{1000} \]

where,

- **I** = Maximum No-load loss in watt.
- **C** = Maximum Load-loss in watt.
- **F** = Load factor.
- **T** = Tariff.

Assuming values of **n** as 25 year, **F** as 50% and **T** as Rupee 2 per kwh, the value of **K** is,

\[ K = \frac{17.52 (I + 0.25 C) (1+0.12)^{25}-1}{0.12 (1+0.12)^{25}} \]

\[ K = 137.41 (I + 0.25 C) \]
Appendix-I
(a) Principle of AT Feeding System
Appendix I

(b) Power Supply Diagram
NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE.
2. FOUNDATION CONCRETE SHALL BE OF M-100 GRADE AND SHALL CONFORM TO IS:456-1964 XXXX LATEST VERSION.
3. THE FOUNDATION IS DESIGNED FOR SOIL HAVING SAFE BEARING CAPACITY OF 11000 Kg/m².
4. DENSITY OF SOIL IS TAKEN AS 1600 Kg/m³.
5. AFTER CASTING FOUNDATION THE BACK FILLING SHOULD BE DONE WITH GOOD SOIL AND COMPACTED PROPERLY.
6. VOLUME OF CONCRETE IS 9.936 m³.
7. THIS SKETCH HAS BEEN EXTRACTED FROM R D S O’S DRAWING No. ETI/C/0209.
<table>
<thead>
<tr>
<th>CONTRACTOR'S ORG. No.</th>
<th>DATE</th>
</tr>
</thead>
</table>

**FORM - 3**

**NOTE:**
This title sheet is applicable to all contractor's drawings.

*Col. 3 No. of Identification No. to be filled up only for component or fitting drawings.

<table>
<thead>
<tr>
<th>TITLE OF DRAWING</th>
</tr>
</thead>
</table>

**INDIAN RAILWAYS**

<table>
<thead>
<tr>
<th>IDENT No.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>DEP.</th>
<th>SHEET No.</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DATE</th>
<th>DIP.</th>
<th>DIP.</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12/70</td>
<td>12/70</td>
<td></td>
</tr>
</tbody>
</table>