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TABLES

1. INTRODUCTION

This document consist of Specification for Medium Power Transformers Used in Power Stations standard

2. SUPPORTING CLAUSES

2.1 SCOPE

This Specification applies to power station oil-filled transformers, having no winding operating above 36 kV, having only off-load tap arrangements and power ratings below 20 MVA.

The specification does not cover dry-type transformers and specialised traction type transformers used to supply converters and inverters.

2.1.1 Purpose

2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions.

2.2 NORMATIVE/INFORMATIVE REFERENCES

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs.

2.2.1 Normative

[1] IEC 60060 *High-voltage test techniques.*

[2] IEC 60076 Power transformers.

[3] IEC 60085 Thermal evaluation and classification of electrical insulation.

[4] IEC 60137 Insulating bushings for alternating voltages above 1 000 V.

[5] IEC 60947-1 Degrees of protection of enclosures for low-voltage switchgear and controlgear.

[6] IEC 60156 Insulating liquids - Determination of the breakdown voltage at power frequency.

[7] IEC 60044 Current transformers.

[8] IEC 60255-21-3 Electrical relays.

[9] IEC 60296 Specification for unused mineral insulating oils for transformers and switchgear.

[10] IEC 60354 Loading guide for oil-immersed power transformers.

[11] IEC 60947 Low-voltage switchgear and controlgear

[12] IEC 60076-10 Determination of transformer and reactor sound levels.

[13] BS 142 Electrical protection relays.

[14] SANS 1091South African National Color Standard.

[15] BS EN 13601Copper for electrical purposes - rod and bar.

[16] BS 1706 Electroplated coatings of zinc & cadmium on iron and steel.

[17] BS 1872 Electroplated coatings of tin.

[18] BS 2562 Specification for cable boxes for transformers and reactors.

[19] BS 3382 Electroplated coatings and threaded components.

[20] BS 3523 Granular desiccant silica gel impregnated with cobalt chloride.

[21] BS 3571 General recommendations for manual inert gas metal arc welding Part 1: MIG welding of aluminium and aluminium alloys.

[22] BS 4360 Specification for weldable structural steels.

[23] BS 4504 Circular flanges for pipes valves and fittings (PN designated).

[24] BS EN 1011 Arc welding of carbon and carbon manganese steels.

[25] DIN EN 1092-1 Flanges Slip-on type for Brazing or Welding; Nominal pressure 10 max.

[26] DIN EN 1092-1 Welding neck flanges; nominal pressure 6 (max).

[27] BS EN50035,50045, 50022 Assembly rails

[28] ISO:9001Quality systems - Model for quality assurance in design development production installation servicing.

[29] EN10240,ISO1461Hot-dip (galvanised) zinc coatings (other than on continuously zinc coated sheet and wire).

[30] SABS 0111-1Engineering Drawing - Part 1: General Principals

[31] SANS 1507-6 Electric cables with extruded solid dielectric insulation for fixed installations (300/500 V to 1900/3300 V).

[32] IEC 60815 Guide for the selection of insulators in respect of polluted conditions

[33] IEC 60034 Rotating Electrical machines

[34] CIGRE W.G.12.19 report Report on the capability of windings to withstand the stresses of various failure modes.

[35] IEEE 57.117.1986 Guide for reporting failure data for power transformers and shunt reactors on electric utility power systems

[36] ESKASAA04, Rev1 (1996) Standard For Electronic Protection And Fault Monitoring Equipment For Power Systems.

[37] ESKPVAADO, Rev 4 (1998) Approval of Non-Destructive Testing Personnel Employed At Eskom Plant

[38] I EC 60068-3-3 (1991) Environmental testing - Part 3: Guidance. Seismic test methods for equipment

[39] ISO 10816-1(1995) Mechanical Vibration – Evaluation Of Machine Vibration By Measurements On Non-Rotating Parts

[40] N RS 002 (2000), 2nd ed Graphical Symbols For Electrical Diagrams

[41] SABS 0142(2003)The Wiring of Premises – Part 1: Low-Voltage Installations

[42] ASTM E376.Coating thickness by magnetic field or eddy current electro-magnetic test methods

[43] BS EN 22063 Metallic and other inorganic coatings.Thermal spraying. Zinc, aluminium and their alloys.

[44] ISO 8501-1.Preparation of steel substrates before application of paints and related products – Visual assessment

[45] SIS 055900 Pictorial surface preparation standard for painted steel surfaces

[46] SABS SM 772:1978 / SANS 5772.Profile of blast-cleaned steel surfaces for painting (determined by micrometer profile gauge).

[47] SABS SM 769: 1978 / SANS 5769.Cleanliness of blast-cleaned steel surfaces for painting.

[48] SANS ISO 1461Hot-dip galvanised coating on fabricated iron and steel articles – Specification and test methods.

[49] SANS ISO 2808: 1999 / SANS 2808 Paints and Varnishes: Determination of film thicknesses.

[50] SABS 555 Unused and reclaimed mineral insulating oils from transformers and switchgear

[51] IEC 60599 Guide to the interpretation of dissolved and free gas analysis

[52] BS 148 Measurement of Furanic Content in oil

[53] IEC 60247 Measurement of relative permittivity, dielectric dissipation factor and dc resistivity of insulating liquids.

[54] ASTM 1500 Oil Colour analysis

[55] ISO6295Measurement of Interfacial tension of insulating liquids.

[56] IEC 60156 Insulating liquids – Determining of the breakdown at power frequency-test method.

[57] ASTM D2240 Accelerated aging of insulating liquids.

[58] IEC 61181 Impregnated insulating materials - Application of dissolved gas analysis (DGA) to factory tests on electrical equipment

[59] SANS 780 Distribution Transformers

2.2.2 Informative

None

2.3 DEFINITIONS

Definition	Description
U_n	System nominal voltage; for the source (Primary) terminal voltage Un= Ur and for the load (Secondary) terminal voltage Un= Ur X 0.95
CTC	Continuous Transposed Copper
Thermally upgraded Paper :	Transformer insulation paper that has a DP of no less than 200 after being exposed to a temperature of 110°C for 150 000hrs

2.3.1 Classification

a. **Controlled Disclosure:** Controlled Disclosure to External Parties (either enforced by law, or discretionary).

2.4 ABBREVIATIONS

Abbreviation	Description

2.5 ROLES AND RESPONSIBILITIES

None

2.6 PROCESS FOR MONITORING

None

2.7 RELATED/SUPPORTING DOCUMENTS

None

3. SPECIFICATION FOR MEDIUM POWER TRANSFORMERS USED IN POWER STATIONS STANDARD

3.1 REQUIREMENTS

3.2 RATINGS AND OPERATING CONDITIONS

3.2.1 Ambient Temperatures and Thermal Performance

This Specification gives detailed requirements for transformers for use under the general conditions specified in Schedule AB.

Due to the higher prevailing ambient temperatures, winding temperature and top oil temperature rises will not exceed the temperature limits specified in Schedule AB. In this respect, the temperature limits differ from those specified in IEC 60076-2.

The Temperature Rise limits applicable are as follows:

- Oil Temperature Rise: (IEC Top Oil Temp Rise) – (IEC Ambient Temp Corrections) – (Employers Safety Factor 5 K) – (Altitude correction)
- Winding Temperature Rise: (IEC Average winding Temp Rise) – (IEC Ambient Temp Corrections) – (Employers Safety Factor 5K) – (Altitude Correction)
- Copper in Contact with Paper Temperature Rise: No higher than 18K above the Oil Temperature rise specified.
- Metal parts in contact with Oil Temperature Rise: Maximum temperature rise of 80K above ambient.

Refer to Schedule AB for the IEC ambient temperature corrections to be applied. The IEC Top Oil Temperature Rise and the IEC Average Winding Temperature Rise are specified in IEC 60076-2 section 4. The necessary altitude correction is also to be performed in accordance with IEC 60076-2 section 4.3.1.

Thermoplastic resins used in CTC and other winding structures shall be able to withstand thermal transients conditions brought about by short circuits and other transient phenomena.

3.2.2 Rated Power

The values of rated power specified in Schedule AB are the continuous ratings in MVA at which each of the windings of the transformer can operate on the principal tapping at a voltage equal to the appropriate nominal system voltage Un. The design ensures that the transformer operates under normal conditions without exceeding the temperature rise limits specified in this Specification.

These loading capabilities are demonstrated by a Temperature Rise Test carried out in accordance with section 3.26.5 The temperature rise limits as set out in section 3.2.1 of this document applies.

3.2.3 Rated Current

The rated current corresponds to the rated power at rated voltage on the principal tap position.

3.2.4 Rated Voltage

The rated voltage of each winding of the transformer on the principal tapping shall be as specified in Schedule AB.

3.2.4.1 Maximum continuous voltage on any tapping

Regardless of the actual location of the tappings in the HV winding, the rated voltage of the HV winding on any tapping is assumed to be equal to the rated voltage on the LV winding multiplied by the voltage ratio on that tapping.

3.2.4.2 Maximum temporary overvoltage

Under switching conditions, the power frequency line voltage may exceed the maximum system voltage (Um). The transformers are designed to withstand the following over voltages without harm unless otherwise specified in Schedule AB.

a. 1.05 Um for 5 minutes;

b. 1.25 Um for 5 seconds;

c. 1.5 Um for 1 second; and

d. 1.7 Um for 0.25 seconds.

Also see the additional requirement to comply with IEC 60076-3, statement in Schedule AB, regarding load rejection criteria.

3.2.4.3 Overfluxing

Within the prescribed maximum equipment voltage (Um) the transformer is able to operate continuously without damage at an overflux value as stated in IEC 60076-1, section (4.4), unless otherwise stated in Schedule AB.

3.2.5 Network Frequency

The transformer is designed for a rated frequency of 50 Hz and a frequency deviation in the following range unless otherwise specified in Schedule AB:

a. 48.5 to 51.5 Hz continuously;

b. 48 to 52 Hz for not more than 10 minutes per incident;

c. 47.5 to 52.5 Hz for not more than 1 minute per incident.

3.2.6 Harmonics

A total Harmonic distortion of not more than 5% and even harmonics not more than 1% on the HV side voltage applies unless otherwise specified in Schedule AB

3.3 ABILITY TO WITHSTAND SHORT-CIRCUITS

Notwithstanding the overcurrent limits tabulated in IEC 60076-5, the transformer is capable of withstanding the thermal, mechanical and other effects of a bolted three-phase bolted fault or phase to earth faults for the duration of the fault per incident. The fault duration is the larger of the time values given in Schedule AB. If the fault clearing times given in Schedule AB are smaller than 2s, the fault duration shall be taken as 2s.

For the purpose of guarantees, design and possible tests, the supply system is represented by voltage sources having the appropriate values of MAXIMUM system voltages, Um. This supply system is connected to the transformer through impedances having values such that the in feed in kA from the voltage sources to a three-phase fault on any of the transformer terminals is equal to the fault current levels given in Schedule AB. Furthermore, it is assumed that the unit will be on the tap position associated with the minimum impedance. The number of faults the transformer is subjected to is unlimited.

Note: That if no fault level(s) are specified in Schedule AB or if explicitly so stated in Schedule AB the transformer(s) shall be designed to be Self-protected. Self-protected implies that the transformer is connected to an infinite bus when short circuited with no additional network impedance in circuit limit the fault current(s).

The Employer reserves the rights to apply a short circuit test to one transformer of any batch on site or elsewhere where convenient, before taking over the batch, in order to prove the short circuit strength of the windings. Such tests shall follow the guidelines laid down in IEC 60076-5 and subsection 3.25.7 of this Specification.

In the absence of such tests the *Contractor* demonstrates with acceptable design calculations that the transformer meets the requirements for short circuit strength. Transformers larger than 3.125 MVA inner windings are always to be designed for Free Buckling under short circuit conditions.

3.4 IMPEDANCE AND TOLERANCES

The leakage impedance of the transformer of the main power windings at 75 ºC and 50 Hz lies within the limits as specified in Schedule AB. This permissible range of impedance given includes all manufacturing tolerances. The impedances and impedance ranges refer to the nominal impedance of the transformer. Therefore, the impedance on any tapping is the impedance in Ù as viewed from the higher voltage terminals expressed as a percentage of

Ur2 M where:

- Ur is the nominal voltage of the higher voltage system in kV, and
- M is the MVA rating of the HV winding of the transformer.

3.5 ACOUSTIC NOISE

The transformer is designed to meet the dBA sound pressure noise level as specified in Schedule AB, in accordance with IEC 60076-10.

3.6 INTERCHANGEABILITY

All transformers of a specific rating and ratio ordered under the same Contract are identical and interchangeable with one another at short notice. Where replacement transformers are ordered for an existing power station, the Contractor attempts in the design and choice of parts to enhance interchangeability. No alterations to control circuits are permissible for this purpose. All parts of the transformer are made accurately to dimensions so that any corresponding parts will fit into place without the need for adjustments.

The Contractor shall pay special attention in his design to ensure maximum interchangeability between the supplied transformer and others as indicated in Schedule AB. Issues to address are:

a. Interface between signals and the power plant such as tap changer, temperature indications, trips and alarms, pressure relief alarms and trips, Buchholz alarm and trips.

b. Outer dimensions and clearances.

c. Plinth loading.

d. Power and earth terminations.

e. LV busbar interface and

f. Cooling ventilation direction matching.

3.7 CLEARANCES IN AIR

When assembled with the connections as in service, electrical clearances in air are adequate to withstand the assigned impulse withstand test voltages. This is to be demonstrated by the impulse voltage type tests specified in Schedule AB during the performance of which all relevant fittings are in position as for service conditions.

Care is taken to ensure that fittings are located such that there is no interference with the external connection to the bushing terminals, and the clearances to such connections are not be less than the appropriate minimum phase-to-earth clearance given in IEC 60076-3-1

The Voltage rating for the insulation external to the transformer is the same as for the insulation ratings internal to the transformer.

3.8 TESTING ON SITE

The testing and checking procedures includes verification of:

a. all voltage ratios on all phases;
b. vector group;
c. magnetising currents and short circuit test with impedance measurements on all taps;
d. winding and core megger test (minimum 1,5 kV);
e. functional test for all alarm and trip contacts;
f. CT polarities, function and insulation;
g. Fan directions and operation of starting and overload protection relays (where applicable);
h. correct operation and indication of tap changers;
i. winding tan delta (< 0.4%) tests with Doble M4000;
j. correct operation of monitoring equipment; and
k. correct position of all valves in the oil circuits.
l. Frequency Response Analysis Technique (where applicable)
m. moisture content test (Method to be approved by *Employer*)
n. HV and LV winding resistance test
o. Core and core clamp insulation

The results of the above tests are to be documented, signed off as part of the quality process and included in the transformer manuals.

All equipment provided for erection is removed from site when erection is completed and the site cleaned of any debris and oil spillage.

3.9 PAINTING ON SITE

Damage to paint work sustained during transport and/or erection is corrected by the *Contractor*. If site re-spraying is necessary, labels and all other areas not to be painted are carefully masked. Any over-spray which occurs despite this masking is removed by the *Contractor*. Damaged paint areas are cleaned. Rust spots and any other deleterious matter are removed. Spot repairs are carried out such that the patch painting extends at least 25 mm beyond the damaged areas. A spot repair reinstates each of the previous coats and commences directly after surface preparation.

3.10 TRANSPORT

3.10.1 General Conditions, Blanking Plates and Gas-filling

The dimensions of the transformer are to be such that when packed for transport, it will comply with the requirements of the loading and clearance restrictions for the approved route.

All metal blanking plates and covers which are specifically required to transport the particular transformer, is considered part of the transformer and are handed over to the *Employer* after completion of erection. A listing of all these items and relevant drawings is to be included in the manuals, to enable the *Employer* to have the plates manufactured if required. The dimensions and quantity of each item required for transport must be indicated on the drawings.

Where the supply of oil is included in the *Contract* and where transport weight limitations permit, the transformers is to be transported with sufficient oil to cover the core and windings during all transport and storage conditions. The tank is sealed for transport to prevent any breathing. Alternatively, where the above method is not applicable, the transformer and all other turrets/tanks containing insulation material e.g. the HV exit lead to the bushings, are maintained continuously under positive pressure of dry air or nitrogen of at least 10 kPa during transport and storage until final installation. The pressure and the temperature at the time of filling are documented as part of the quality system. A pressure gauge, suitably protected is fitted to each transformer and pressurized part to facilitate checking of gas pressure during transit and on site. If another gas like Nitrogen is used appropriate safety labelling is provided.

Every precaution is to be taken to ensure that the transformer arrives at site in a satisfactory condition so that after proper oil processing and filling it may be put into service without the necessity for extensive drying out.

(Note the requirements of 3.14.3.1 and 3.15.4.)

Full details of the proposed method of transport are submitted for approval.

The costs of any necessary extensions and/or improvements to existing facilities for transporting to site and escort and permit fees are included in the *Contractor's* prices.

3.10.2 Sea Transport

The *Contractor* makes the necessary arrangements for suitable slings apparatus to be available for off-loading at the quay-side and may make use of the equipment provided under the *Contract*, on the condition that it is handed over to the *Employer* in good order. Also see 240-56178825 for requirements.

3.10.3 Road Transport

The transport arrangements includes any necessary extensions and/or improvements to road routes, bridges, and civil works, and also the assurance that any abnormal loads comprising the transformers, their transporters, ancillary apparatus and plant and equipment required for erection passes without obstruction throughout the selected route.

3.11 TRANSFORMER CORES

3.11.1 Electrical Continuity

Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned copper bridging strips are inserted to maintain electrical continuity between sections.

3.11.2 Insulation of the Core

The insulation between the core and the clamping structure, including core bolts and/or bands and buckles, withstand a test voltage of 2 kVac or 3 kVdc for 60 seconds.

For transformers operating at voltages at and higher than 275kV the insulation voltage is 8KV r.m.s in the dry state, prior to oil filling and 16kV after oil filling.

Where core designs require core bolts, the bolts shall be well insulated and non-magnetic in nature.

3.11.3 Earthing

3.11.3.1 Core

The core is earthed to the tank structure at one point only, through a removable external link suitably situated, and protected to allow testing after installation of the transformer.

3.11.3.2 Core clamping structure

The core clamping structure is earthed to the tank structure at one point only, through a removable external link suitably situated, and protected to allow testing after installation of the transformer.

The bottom core clamping structure is in electrical contact with the top core clamping structure through the tie bars, by way of the tank, or by means of a connection placed on the same side and end of the core as the removable core earthing link.

If a copper earthing connection is used between the core clamping structure and the tank, it is flexible, (e.g. laminated, stranded or braided), tinned at the ends, and located on the same side and end of the core clamping structure as the removable core earthing link.

Care is taken to ensure that the contact resistance between mechanical members that form part of any intentional current paths, be it circulating or to earth, is not detrimentally affected by any painting.

\It is ensured that no sparking which may upset the Dissolved Gas Analysis (DGA) monitoring of the transformer occurs between bolted mechanical members during inrush or other transient conditions.

A drawing detailing the specifics of the earthing design is required as part of the manuals.

3.11.3.3 Cross-sectional area of earthing connections

Core earthing connections do not have a smaller cross-sectional area than 80 mm2, with the exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 mm2, where they are clamped between the laminations.

3.11.4 Mechanical construction

3.11.4.1 Lock nuts

The core and core clamping structure are of adequate strength to withstand, without damage, the stresses that are endured during handling, transportation, installation and service.

All nuts are effectively locked by means of locking plates, standard machined lock nuts or other approved means. Pining of bolt-ends and/or threads alone or the use of tempered pressed steel nuts is not acceptable. Gluing or other approved means is used to fix nuts and bolts of insulating material.

3.11.4.2 Mechanical supports

Where the core and winding assembly is attached to the transformer cover plate, it is nevertheless supported by the tank bottom. Hand holes are provided in the attachment to the cover plate, for regulation of the mechanical distances.

Members to support the cover or side walls during vacuum are adequate to withstand transport movements without damage. All components which will be in contact with oil for transformers designed to be vacuum filled must be capable of withstanding the required maximum vacuum strength. This includes the conservator, coolers and protection devices like the bucholtz relay.

Special parts for the above functions which are removed after vacuum or transport are considered part of the transformer and are handed over to the Employer. Drawings detailing the designs of these parts as well as a description of their use are included in the manuals.

3.11.4.3 Lifting and jacking facilities

Lifting lugs or other means are provided for conveniently lifting the core and windings. During lifting, no undue stress is imposed on any core frame or the core's insulation or on the tank cover plate.

Unless otherwise approved in writing, continuous (no joints) vertical tie rods or plates are provided between the top and bottom core clamping structures.

3.11.5 No-load Losses and Current

All core, shunts and construction parts are designed to withstand the fluxing conditions resulting from the continuous and temporary over voltage conditions as well as frequency deviations, as specified.

The no-load losses and the no-load current of each transformer are measured as specified in 3.26.10, as well as at an agreed over flux condition to demonstrate compliance with this specification.

3.12 WINDINGS AND CONNECTIONS

3.12.1 Connections

Direct connection from copper to aluminium is not allowed. All existing copper to aluminium connections must be checked to ensure that appropriate transition washers are installed. Where no appropriate precautions have been taken to ensure long term suitable operation of aluminium connections, a method approved by the Employer is applied.

3.12.2 Bracing of Windings

All winding insulation is processed to ensure that there is no detrimental shrinkage after assembly. DP values for the paper before and after dry-out are stated shall be statted in Schedule AB. Windings are provided with clamping arrangements that will distribute the clamping forces evenly over the ends of the winding.

The bracing of the windings and connections are such that these parts safely withstand the cumulative effects of stresses that may occur during handling, transportation, installation and service, including three-phase, line-to-line and line-to-ground faults.

Where blocking is used to support the windings adequate provision is made to prevent dislocation of such blocking. A typical example is to use pins locating the blocking. The type of block locating will be presented to the Employer during the design review.

3.12.3 Methods of Making Winding Connections

3.12.3.1 Soldered and brazed connections

Soft solder shall not used in making winding connections.

If brazed connections are used, all traces of acidity are removed on completion of the process.

3.12.3.2 Welded connections and joints in winding body

All welded copper connections are made by the metal-inert gas method or other specifically approved method. This applies particularly to conductor joints in the body of windings. The making of all such joints is properly controlled by an approved quality control procedure.

3.12.3.3 Bolted connections

The mating faces of bolted connections are appropriately finished and prepared for achieving good long lasting, electrically stable and remarkable contacts which can be disconnected and reliably re-connected.

All nuts are locked by standard machined lock nuts, or by means of approved locking plates.

3.12.3.4 Crimped connections and other methods

Connections made by "compression" and "cold-welding" techniques may be used where approval of the particular method has been obtained from the Employer.

All lugs for crimping are of the correct size for the conductors.

All crimped joints are properly controlled by an approved quality control procedure.

3.12.4 Winding Terminations onto Bushings

Winding terminations that interface with bushings are designed to allow for repeatable and safe connection under site conditions without jeopardising the integrity of the transformer in service.

The winding-end termination, insulation system and transport fixings are so designed that the integrity of the insulation system is not easily compromised during repeated work in this area.

In particular, rotation or straining of insulated connections shall avoided during the fastening of conductor pads from the winding onto the termination surfaces of the bushing.

Suitable inspection and access facilities into the tank shall provide to minimise the possibility of creating faults during the installation of bushings, where applicable.

3.12.5 Insulation Tests, Fault and Creepage Levels for Bushings

IEC60076-3 specifies the insulation levels, corresponding to the highst equipment voltage. Refer to Schedules AB for the specific insulation value choices made from table 2 and 4 in IEC60076-3 by the Employer. Note that the Neutral has the same insulation level values as the Low-voltage terminals. The required creepage levels are specified in IEC 60815, unless otherwise stated in Schedule AB. Refer to Schedule AB for the site pollution level, which determines the creepage distance to be use in accordance with IEC 60815.

3.13 OIL

3.13.1 Type and Quality

Only Virgin oil as specified in Schedule AB shall be used in the transformer conforming to IEC 60296 requirements. First impregnation of the windings is done using oil that has not been in contact with refurbished transformers. Only oil used for impregnation and testing of new transformers is to be used.

Under no circumstances is the transformer filled with oil not conforming to IEC 60296 and then processed to bring it up to the required standard.

The Contractor provides independent test certificates for the transformer oil used for Impregnation, Testing and as Final In Service oil. The certificates display the following minimum test results in accordance with IEC:

- Dielectric Strength,
- Color,
- Tan Delta,
- Moisture Content,
- Acidity,
- Interfacial Tension,
- Corrosive Sulphur (Extended Doble),
- Oxidation stability,
- Sludge content,
- Furanic content (For Fingerprinting purposes),
- Oil Density,
- Gassing tendency,
- Inhibiter used and amount,
- PCB content
- Oil type and Brand verification test (FTIR).
- Silicon content (ppm)

3.13.2 Dielectric Strength

The power frequency dielectric breakdown strength of the oil in any part of the transformer meets the transformer manufacturer's requirement, but is in any case, not less than 70 kV/2,5 mm.

Dielectric strength is determined in accordance with the method prescribed in IEC 60156.

3.13.3 Moisture Content

The moisture of the oil before filling into the transformer does not exceed 10 ppm.

An oil sample is taken 7 days after the completion of the oil impregnation treatment to demonstrate, by using the Piper oil/paper moisture equilibrium chart (or other chart approved by the Employer) that the moisture contents in the paper insulation is less than 0.5%.

3.13.3.1 Insulation test blocks for moisture measurement

Insulation test blocks are made of the thickest insulation material used in the transformer and sized accordingly.

Five test blocks are required by the Employer, which are placed and fixed in a position for easy access through a hand- or manhole in the transformer tank cover.

The location of the test blocks are indicated on a drawing that is part of the transformer manual.

The Contractor places additional test blocks on the transformer active part/coils before the heat treatment/drying process. These blocks are removed and analysed demonstrating to the Employer the integrity of the active part insulation material after drying/heating. Details of the positioning and approved test methods/analysis are agreed on with the Employer.

3.13.4 Oil-filling / Impregnation under Vacuum

When a transformer is designed to be oil-filled under vacuum, an instruction to this effect features prominently on the rating-and-diagram plate or on a separate plate mounted adjacent to it.

All transformers installed in vacuum-proof tanks are oil impregnated and filled under vacuum.

Oil impregnation or drying under vacuum is done with the transformer and oil at a temperature of at least 60 °C.

The duration of the treatment is demonstrated as adequate by means of water measurement with a cold trap.

3.13.5 Preparation for Storage

The *Employer* makes use of one of the following storage methods:

a. fully erected, oil filled with dehydrating breather;

b. fully erected, oil filled with bagged conservator;

c. partially erected, oil filled with a bagged conservator;

The method of storage is specified in Schedule AB (under special requirements).

Any special procedures for long-term storage and commissioning after such long-term storage are included in the manual.

All cabling ends that are not connected for operation are sealed off from weather influences by means of weatherproof, UV-resistant covers.

All site tests are done with units fully erected.

For partially erected units those tests that are possible and agreed with the Employer are done.

3.13.6 Preservation System

See Schedule AB for the oil preservation system requirements.

3.13.7 PCB Content

All oils used in the transformer and its accessories shall be free of PCBs (not measurable). A formal test certificate to this effect is included in the manual.

3.13.8 Contact with Bare Copper

Bare copper in contact with transformer oil is minimised by using appropriate paper covering or a coating.

3.14 MAIN TERMINALS

3.14.1 Position of Open Terminals

3.14.1.1 HV and LV terminals

The general arrangement of the terminals is shown in figure 1 unless otherwise stated in Schedule AB.

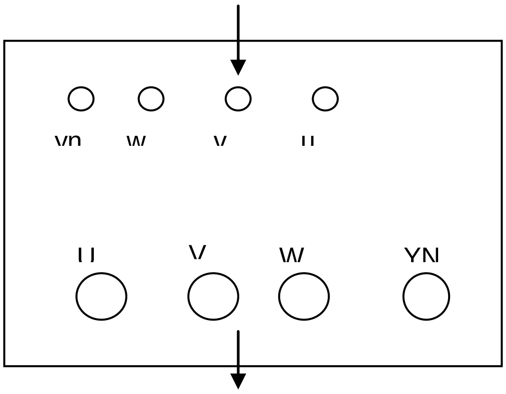


Figure 1: Position of terminals for system transformers (Top view of transformer)

3.14.2 Terminal Markings

The terminal markings on the diagram plate shall be in accordance with IEC. Terminals are positioned as indicated in 3.15.1.

Terminal markings characters must be in relief adjacent to their appropriate terminals.

The characters may be of brass, steel or other acceptable metal and are permanently fixed to the tank by means of brazing or welding.

3.14.3 Bushings

3.14.3.1 Terminals

Bushings shall in general comply with the requirements set out in SANS 1037.

3.14.3.2 Short-time current

Bushing conductors are capable of safely carrying, for 3 seconds, the short-circuit currents resulting from the faults detailed in 3.3 This time factor allows for the possibility of having repetitive system short circuits in quick succession.

3.14.3.3 Insulation levels and creepage distances

The creepage distances shall be according to IEC 60137 section 4.7, unless specified differently in Schedule AB Protected creepage distance called for in Schedule AB is the value of creepage distance in the rain shadow at an angle of precipitation of 90º to the bushing axis.

3.14.3.4 Bushing types

3.14.3.4 (a) Outdoor immersed bushings

Unless otherwise stated in Schedule AB all open bushings are outdoor immersed bushings.

3.14.3.4 (b) Completely immersed bushings

Connections from winding leads into cable boxes or oil filled disconnecting chambers are shall be realised by means of completely immersed bushings.

3.14.3.4 (c) Resin impregnated bushings

Proven resin impregnated paper bushings are acceptable and may be specified for their advantage in reducing fire risks.

3.14.3.5 Safe mounting height

For compliance with safety regulations, open bushings are arranged and mounted on the transformer in such a manner that the minimum vertical working clearances listed IEC 60076-3, table 7 are provided from finished ground level to live conductors.

3.14.3.6 Mechanical forces

The minimum withstand values of cantilever load which may be applied to the external bushing terminals of standard transformers as specified in IEC 60137, table 1 as per the loading level specified in Schedule AB.

3.14.3.7 Gaskets

Gaskets shall be Nitrile rubber or better material. All gaskets are replaced after they have been disturbed but designs shall nevertheless be forgiving should this not be done.

Nitrile rubber gaskets shall not bear directly on porcelain.

3.14.3.8 Tests

The tests detailed in IEC 60137 shall apply unless otherwise stated in Schedule AB. Type test certificates for all types of bushings are submitted with the tender. All routine tests as described in IEC 60137 are applicable.

3.14.4 Cable Sealing Boxes and Disconnecting Chambers

3.14.4.1 General

Cable boxes are supplied and fitted where specified in Schedule AB. Cable boxes shall comply with BS 2562-1 and 2.

Cable boxes shall be complete with all the fittings necessary for attaching and connecting the cables specified in Schedule AB.

3.14.4.2 Construction of cable-box shells

Because cable box shells are constructed to minimise the danger of fragmentation under internal arcing fault conditions, cast metal construction is not acceptable.

Where mild steel is used, the thickness of the metal shall not be less than that specified in Table below.

Table 1: Minimum thickness of mild steel plate for cable box shells

Part	Thickness (mm)
Shell	3
Gland plate	3
Cover plate	5
Bushing plate	8

3.14.4.3 Filling orifice (Where applicable)

Notwithstanding the requirements of 6a of BS 2562-2, the filling orifice shall not smaller than 80 mm in diameter, and has a bolted and gasketed cover, arranged such to protect the outer edges of the gasket from the weather.

The filling orifice is placed such as to permit the filling medium to fall directly to the bottom of the cable box.

3.14.4.4 Independent mounting

Where independent mounting of cable boxes is specified in Schedule AB, the cable boxes are mounted on an independent floor-mounted supporting structure provided by the Contractor. The foundation height for this structure is the same as that for the transformer.

After making the necessary disconnections in the disconnecting chamber(s), it is possible to remove the transformer from its operating position without disturbing the sealing or the position of the cable boxes.

All cable boxes are arranged on the same side of the transformer. If this is not possible it may be necessary to employ sectional construction of the disconnecting chambers in order to facilitate their removal in order to provide access for the completely immersed bushings

3.14.4.5 Cable-entry and connections

Unless otherwise specified, cables enter cable boxes from vertically below. Where cable stands are provided, these are equipped with suitable cable saddles vertically aligned with the cable gland positions on the cable boxes and spaced to suit the cable manufacturer's recommendations, but in any case not more than 1 m apart.

Copper strip used for the laminate of flexible connections do not exceed 0,5 mm in thickness.

3.14.4.6 Armour cable clamps

Cable boxes for armoured cables are provided with suitable armour clamps.

3.14.4.7 Single-core cables and cables with insulated sheaths

Suitable 10 mm earthing terminals fitted with all the required washers, nuts, lock nuts and removable copper earthing links are provided on the cable boxes and on the insulated cable glands required for single-core cables, for the purpose of bridging the gland insulation.

Stud holes do not break through the metal of the gland or cable box to the inside.

Notwithstanding the requirements of 10a of BS 2562-1 and 2; where a higher insulation level is required for the glands for cables having anti-electrolysis finish, the gland insulation withstands a test of 5 kVdc for 60 seconds.

3.14.4.8 Oil conservator, level gauge and breather (Where Applicable)

Where specified in Schedule AB, cable boxes are provided with oil conservators fitted with magnetic type oil level gauges of the dial type and dehydrating breathers. The active volume of the oil conservators is a minimum of 8% of the total oil volume of the oil space served by it and in all cases not less than that required by the specified temperature range of the transformer. The dehydrating breather has a minimum of 2 kg of silica gel.

3.14.4.9 Interchangeability

For identical transformers, the cable boxes and disconnecting chambers are jig drilled and fabricated to permit interchangeability of the transformer.

3.14.4.10 Phase-isolated cable boxes (where applicable)

Where phase-isolation is called for in Schedule AB, the appropriate transformer windings are terminated in three separate cable boxes, each fitted with a suitable cable gland.

Where disconnecting chambers are specified in Schedule AB, a disconnecting chamber is provided for each cable box.

3.14.4.11 Corrosion proofing and colour

Surfaces of cable boxes and disconnecting chambers are cleaned of all oxide, scale and grease by sand or shot blasting or other approved method.

Internal surfaces under oil are given a suitable white protective coat. Other internal surfaces are given a suitable priming coat and surfaces above the level of the filling medium are finished with air drying anti corrosion white paint.

External surfaces are treated and finished to correspond with the transformer in all respects.

3.14.4.12 Sealing during transport and storage

All apertures giving access to the interior of cable boxes, disconnecting chambers and cable glands are sealed during transport and storage, to prevent the ingress of water and foreign particles.

3.14.4.13 Filling, draining and venting of disconnecting chambers

Where a disconnecting chamber is specified, it is fitted with easily removable, bolted links to facilitate separate testing of the cable without disturbing its connections, and a suitable and easily accessible earthing terminal for connection of the transformer windings to earth during this process.

For paper-insulated cables, this chamber is oil-filled and is provided with a suitable brass drain valve at its lowest point and with a vent plug at its highest point. It is also oil-filled from the transformer tank by a connecting pipe fitted with a suitable brass-isolating valve with a position indicator. This connecting pipe is arranged to vent all gas in the chamber to the Buchholz type relay via the transformer tank, and doest not obstruct the access covers provided for disconnecting the bolted links.

The oil in the disconnecting chamber is sealed off from the cable box and only communicates with that in the transformer tank by the aforementioned connecting pipe

3.14.4.14 Independent sealing of disconnecting chambers and cable box

Where disconnecting chambers are specified, the cable box bushings are attached to the back plate of the cable box (or a separate backing plate) to permit removal of the disconnecting chamber from the cable box (and cables) without the necessity of draining oil or compound from the cable box.

3.14.4.15 Insulating barriers between cable boxes and disconnecting chambers

If oil barriers or bushings of synthetic materials are used, the dielectric loss angle of each such item is determined and recorded on the transformer test certificates.

These items withstand the temperature, vacuum and kerosene of vapour phase treatment.

The materials are thermally, chemically and electrically stable under all operating conditions for the life of the transformer.

These items withstand, without damage, the application to the transformer tank of a complete vacuum against the normal operating head of oil or filling medium plus the atmospheric pressure at sea level on the other side.

If the material is likely to be damaged by excessive pouring temperature of the filling medium, a suitable, prominent and indelible warning notice is affixed adjacent to the filling orifice.

3.15 CURRENT TRANSFORMERS

3.15.1 Number and Location

The number, ratings, location and type of current transformers associated with each power transformer, are specified in Schedule AB.

3.15.2 Applicable Standard

Current transformers comply with the requirements of IEC 60044-1 (Class PX), except where otherwise stated in this Schedule AB.

3.15.3 Transformer Short-circuits and Overload

Current transformers are capable of withstanding mechanically and thermally the same overcurrents and overload, for the same periods, as the associated windings of the power transformer

3.15.4 Insulation Levels and Short-circuiting for Testing

Current transformers withstand all dielectric tests applied to the power transformer windings, and are installed in position and in circuit during the power transformer voltage withstand and impulse tests.

Open circuits are avoided during testing of the transformer.

All current transformers are shorted in the factory and delivered as such to site.

3.15.5 Tests

The current transformers are tested and test certificates provided as specified in 3.1.25.16.5.

3.15.6 Connections

3.15.6.1 Terminals and locknuts

Current transformer secondary terminals, where applicable, comply with the requirements of 3.1.16.5 and they are indelibly marked for identification as indicated in 3.1.14.8.1 and All current transformer terminals inside the power transformer are of the stud type and all connections are securely locked by means of lock nuts or locking plates. Steel lock washers are not acceptable.

3.15.6.2 Secondary connection wiring and termination

The beginning and end of each secondary winding and all secondary tappings are wired to terminals in a terminal box accessible from ground level and then to the free standing marshalling box, as specified in section 3.1.16.3 of this Specification.

a. Termination of leads

Particular attention is paid to the termination of leads inside the transformer tank with a view to ensuring secure connection of current carrying lugs, and the elimination of all possible tension in the leads (see 3.1.16.3.6).

b. Conduit or armour

Where the secondary leads of a current transformer are routed through a conduit or armoured cable, all the leads from one winding run in the same conduit or armoured cable.

3.15.7 Protective Current Transformers

3.15.7.1 Type

Protective current transformers are of the low-reactance type on all ratios.

3.15.7.2 Ratio

The nominal ratios for protective current transformers are specified in Schedule AB.

3.15.7.3 Turns compensation

Protective current transformers are not turns compensated.

3.15.7.4 Required data

The following information relating to protective current transformers is submitted for approval:

a. magnetization curve;

b. secondary winding resistance; and secondary winding leakage reactance.

3.15.7.5 Designation

Where more than one protective current transformer is provided in any one phase, the current transformer designated "main protective current transformer" is located furthest from the transformer windings.In addition, protective current transformers together with current transformers in general, are given designations as indicated in in section 3.1.14.8.1 of this Specification.

3.15.7.6 Current transformers for delta-connected windings

The arrangement of protective current transformers associated with delta-connected power transformer windings, is indicated in in section 3.1.14.8.1 of this Specification.

3.15.7.7 Winding temperature indication for delta windings

Where the current transformer for a winding temperature indicator is associated with a delta-connected winding, it is located inside the delta so that it can detect all overcurrent conditions of the delta winding, including those circulating current conditions resulting from external earth faults on the associated power systems.

3.15.7.8 Type and accessibility

Current transformers are preferably of the bushing type. Separately mounted CTs must be located above the core and winding assembly and be provided with adjacent hand holes in the tank side or cover of a size adequate for their removal or replacement.

3.15.8 Data for Rating and Diagram Plates

Where current transformers are built into the transformer, the combined rating and diagram plate provides full details of each current transformer's location, polarity, secondary terminal markings and also all the information required by IEC 60044-1 as applicable, with the provision that no information is duplicated

The following symbols may be used on rating and diagram plates:

a. IL = Secondary insulation Level (3 kV dc)

b. Hz = Rated frequency

c. Ith = Rated short-time current and rated time kA-s;

d. R_s = Secondary winding resistance at 75 ºC;

e. N = Turns ratio

f. Vk = Kneepoint voltage

g. I_m = Magnetising current

h. Ip = Primary current

i. I_s = Secondary current

VA = Output in (VA).

3.15.8.1 Terminal markings

The system of marking for identifying the terminals for current transformers supplied with power transformers, shown in below, indicates:

a. the polarity of the primary and the secondary terminals, or, where no primary terminals exist as such, the orientation of the current transformer; and

b. the current transformer designation, which is:

   i. the connection in which it appears (e.g. a phase or neutral connection);

   ii. the sequence relative to other current transformers appearing in the same connection.

The current transformer winding (primary and/or secondary) and its polarity are denoted by the letter P and/or S and the figures 1 and 2 as specified in IEC 60044-1.

The convention to be used always places P1 (and/or S1) nearer the external terminal of the transformer and P2 (and/or S2) nearer the winding.

The winding alpha-numerics and the polarity alpha-numerics are prefixed by letters denoting the phase or neutral connection (see) in which the current transformers appear. These alpha-numerics are prefixed by numerals giving the sequence of the current transformers relative to other current transformers in the particular phase or neutral connection, as indicated in below.

These numbers are counted in the case of star-connected windings, from the power transformer external terminal towards the neutral point connection, and in the case of delta-connected windings in a direction from the external terminal through the particular phase winding towards the junction with another phase.

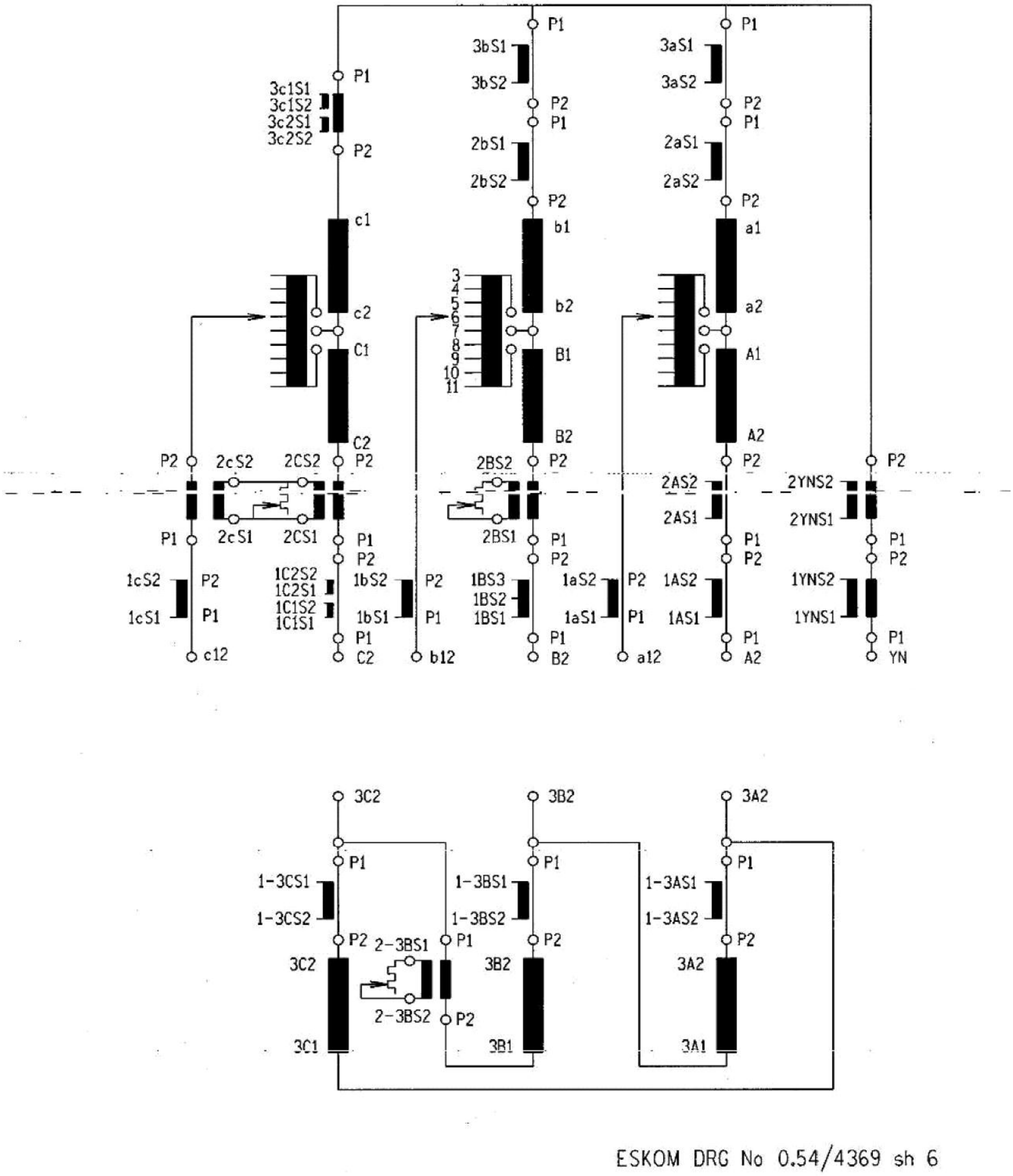


Figure 2: Current transformer terminal markings

NOTES to Current transformers having a wound primary are shown on the rating-and-diagram plate as exemplified by current transformers 1YN and 2B Ring type current transformers with an integral bar primary are shown in the same way as current transformers 1-3B and 1B. Ring type current transformers mounted on bushings or positioned over an independent connection are shown as exemplified by current transformers “1a” and “1c”

Table 2:In-built current transformers (Class "X" specification core details)

TURNS RATIO Np/Ns	CLASS "X" CORE SPECIFICATION		
	Im (mA) (MAX)	Vk (Volts) (MIN)	Rs (Ohms) (MAX)
1/ 100	500	150	0,4
1/ 200	500	200	0,8
1/ 300	330	300	1,2
1/ 400	250	400	1,6
1/ 500	200	500	2
1/ 600	170	600	2,4
1/ 800	125	600	3,2
1/1000	100	650	4
1/1200	83	650	4,8
1/1400	71	650	5,6
1/1600	63	700	5,6
1/2000	50	700	8
1/2400	42	750	9,6
1/3000	35	780	12
1/4000	25	860	16
Im = CT excitation current Vk = knee-point voltage			
The knee-point of the excitation curve is the point where an increase of 10 % of the secondary emf results in a 50 % increase of excitation current.			

3.16 VOLTAGE VARIATION AND CONTROL

3.16.1 Tapping Ranges

Refer to Schedule AB for the applicable tapping range and step voltage required.

3.16.2 Off-circuit Tapping Switch

When specified, the transformer is provided with a ganged off-circuit tapping switch, operated by means of an external handle situated in an unobstructed position, not more than 2 m above ground level. Instead of a ganged off-circuit tapping switch, operated by means of an external handle a Link-Board System can be used depending on the requirement in Schedule AB.

With a Link-Board System no external wheel is supplied, instead links are changed to change tap positions.

The contacts are positively self-locating in each tapping position without constraint from the operating mechanism, which is padlockable in each position in the case of a ganged off-circuit tapping switch, operated by means of an external handle.

The tapping positions are indelibly marked to correspond with the data given on the rating-and-diagram plate, and these markings are legible for a person standing at ground level.

The tapping positions provide the tapping range and steps as specified in Schedule AB.

3.17 AUXILIARY SUPPLIES, TERMINAL BOXES, WIRING AND CABLING

3.17.1 Auxiliary Supplies (where applicable)

The auxiliary ac power supply is specified in Schedule AB. The unearthed dc supply is as specified in Schedule AB.

The quality of supply that the transformer Auxiliary equipment will be subjected to is specified in Schedule AB. The equipment may not be damaged by the specified voltage deviations or cause loss of cooling to the transformer.

3.17.2 Terminal Boxes

3.17.2.1 Terminal boxes and covers

Marshalling boxes and terminal boxes are vermin-, dust- and weather-proof and are provided with easily removable covers fixed by not more than two screws.

Marshalling Kiosks and other electrical boxes (cubicles) are to be fitted with Anti-Condensation heaters, of which the on and of switching temperatures are selectable, so as to prevent condensation within the cubicles.

Covers for terminal boxes may be of the slip-on type, and those for marshalling boxes are

preferably hinged in a vertical plane.

Covers in a vertical plane are, in addition to a gasketed seal, provided with a double-curved flange along the top edge and sides. The door opening in the box has a double-curved flange around its entire perimeter, the outer face of which forms the gasketed joint. The top of the box is made to overhang the cover, except in the case of slip-on covers. These are double-curved and fitted with drip ledges for internal corrosion proofing.

Where applicable, access to equipment is provided at the rear to the *Employer's* approval.

NOTE: Hinged panels are acceptable

3.17.2.2 Venting and draining

Marshalling boxes and terminal boxes, arranged in a vertical plane, are provided with a 25 mm vent and drain hole covered by a fine mesh of non-corrodible wire, fitted at the lowest point. This fitting is flush inside to permit total drainage.

3.17.2.3 Earthing terminal

An earthing terminal of M16 or larger is provided in each terminal and marshalling box with a stud on both the inside and outside.

3.17.2.4 Spare terminals

Each marshalling box is provided with not less than 10 % spare terminals with a minimum number of twelve, unless otherwise agreed.

3.17.2.5 Incoming auxiliary circuits

To prevent entry of water, the auxiliary wiring from the gas- and oil-actuated relay, current transformers and other auxiliary apparatus, are arranged for side or bottom entry into the marshalling box. If bottom entry is adopted, the gland plate used is independent of that provided for the *Employer's* outgoing cables.

3.17.2.6 Provision for outgoing cables

The marshalling box is provided with a separate, removable, undrilled gland plate to take the *Employer's* cable glands, mounted at least 100 mm below the bottom of the terminal blocks, or other equipment, in such a manner as to facilitate the entry of the *Employer's* cables.
The gauze covered drain and vent hole may be fitted to this gland plate.

3.17.2.7 Contactors

Contactors are not mounted directly on the back plate of winding temperature or oil temperature indicators, as vibration can cause these indicators to read incorrectly.

3.17.3 Wiring

3.17.3.1 Insulation

Wiring insulation is oil- and moisture-proof, and, where affected by temperatures above that of the ambient air, has thermal characteristics at least equal to class 'A' as specified in IEC 60085.

3.17.3.2 Insulation test voltage

All auxiliary circuits withstand a test voltage of 2 kV rms to earth and to all other circuits.

3.17.3.3 Type of conductor

All secondary wiring used on the transformer for current transformer secondaries and other auxiliary equipment have a minimum cross-section of 2,5 mm2 and have a minimum of 30 strands, flexible, 660/1000 V grade wire in accordance with SABS 1507-6 or to the Employer's approval.

As an alternative 4 mm2 wires, with a minimum of 7 strands may be used.

3.17.3.4 Protection of external wiring

External wiring is either in conduit, in a metal protective channel or in the form of armoured cable. Mineral insulated copper sheathed cables are not acceptable.

3.17.3.5 Fixing of wiring

All wiring presents a neat appearance and is either braced, clipped and/or laced or placed in rustproof troughs or conduit. Armoured cables are supported away from the transformer surfaces on cable rails.

All terminals and labels are easily accessible after wiring and cabling has been completed.

3.17.3.6 Termination of wiring

3.17.3.6 (a) Connections

Where insulation is stripped from the wires in order to make connections, the conductors are left clean and undamaged. Only the required minimum length of insulation is removed, preferably with a thermal stripping device.

3.17.3.6 (b) Termination of internal wiring and terminal boxes

All wiring connected to the terminals of auxiliary apparatus within the transformer tank is terminated at the terminals of a terminal box on the tank wall or cover plate.

These terminals, or tags permanently attached to them, are indelibly marked with the terminal marking of the corresponding terminal of the internal apparatus and its wiring designation (see 3.1.14.8.1).

The terminal marking tags, where used, and the terminals themselves are fixed in such a way to their respective bushings or barrier board that there is no possibility of slackening of the internal connection, or of the terminal, or of the removal of the terminal marking tag during the process of applying or removing the external connection.

3.17.3.6 (c)Termination of external wiring

All wiring from alarm and tripping contacts, current transformer secondary terminal boxes or any other apparatus on the transformer requiring connection to external circuits, are terminated in a marshalling box situated on the transformer at a height of approximately 1,5 m above ground level.

3.17.3.7 Identification of wiring

All equipment boundary/interface terminals and the equipment wires connected to those terminals have a unique wire/terminal number in accordance with the *Contractor's* drawings approved by the *Employer*. The wires are marked with black letters impressed on a white background or black letters on a yellow background providing that the colour selected is consistent throughout the panel and/or suite of panels and is to the *Employer's* approval.

Interlocking "slip-on" types of ferrules are preferred and it matches the size of wire onto which they will be fitted.

For heavy conductors and very light wiring (telephone type) where the preferred type of marking ferrules is not available, other methods may be approved.

Ferrules are arranged to read upright on cable terminal strips and to read from terminal to insulation in the case of relay apparatus and instrument connections.

3.17.4 Auxiliary Cabling

3.17.4.1 Cabling by the Contractor

Where a separately mounted outdoor control cubicle is provided near the transformer and where the Contractor is responsible for erection, the Contractor provides and connects all cabling between this control cubicle, the transformer marshalling box and the auxiliary apparatus on the transformer together with all necessary cable fittings, attachments and identification of cables and cable cores.

All cables are conductor/PVC/PVC/SWA/PVC. The Contractor supplies details of any cable trenches required at the time of submitting the outline drawings for foundation works. (SWA = Steel Wire Armouring)

Cabling for on-load tap changers may be terminated at the appropriate mechanism box. All other cabling terminates at one point, which is the marshalling box or the separately mounted outdoor control cubicle, where the latter is provided.

3.17.4.2 Cabling by the Employer

Multi-core cabling to the remote control point is provided by the Employer.

3.17.4.3 Identification of fuses

All fuses are labeled; indicating the rating and circuit name.

3.17.5 Secondary Terminals

3.17.5.1 General

All terminals for connection to external circuits are subject to the *Employer's* approval. Not more than two conductors are connected to any side of a terminal; the sizes of all terminals are suitable for the termination of two external cables of 4 mm^2 each.

All terminals except those with soldered lugs, are suitable for use with crimped or compression type terminations.

3.17.5.2 Materials and construction

a. Moulding materials are self-extinguishing, or resistant to flame propagation, substantially non-hygroscopic, and do preferably not carbonise when tested for tracking. The mouldings are dimensionally stable and have a high impact strength.

b. Mouldings are mechanically robust, and withstand the maximum possible torque which may be applied to the terminal screws. Terminals where pressure is applied to the moulding when tightening the terminal screw or nut are not acceptable.

c. Steel parts, other than stainless steel, are plated and passivated. Current carrying parts are non-ferrous and plated. All plating is compatible with other parts and terminations. Screws into steel are steel, stainless steel or phosphor bronze. Steel screws are plated and passivated. All plating complies with BS 1706 and BS 3382 Parts 1, 2 and 5.

d. The minimum external creepage distance between adjacent terminals and between terminals and earth is not less than 8 mm when determined in accordance with BS 142 annex G.

e. Tapped holes do not have less than 3 full threads. Separate terminals are provided on each unit for incoming and outgoing connections, and their contact pressures are independent of each other.

f. Manufacturers provide the maximum and minimum torque to be applied to the terminals' screws.

g. Terminal covers or shrouds are of insulation material, self-extinguishing or resistant to flame propagation and preferably clips onto the moulding.

3.17.6 Mounting of Terminal Blocks

Rail mounted terminal blocks comply with the following requirements:

3.17.6.1 Dimensions

The dimensions of mounting rails are in accordance with BS EN 50035, 50045, 50022.

3.17.6.2 Retaining

The units are spring retained on the assembly rail and when mounted and wired as in service, are close fitted to avoid the accumulation of foreign matter between adjacent units. End barriers or shields are provided for open sided patterns.

3.17.6.3 Replacement

It is possible to replace any unit in an assembly without dismantling adjacent units; it is permissible however to loosen any clamping device. Screw retention of any component from the rear of the mounting rail is not acceptable.

3.17.7 Type of Terminal Block

3.17.7.1 Spring loaded

A rail mounted screw clamp/spring loaded insertion type terminal block suitable for the reception of hooked blade type wiring lugs is provided (see Figure 6).
The terminal blocks are of the type that compresses the terminations between two plates by means of terminal screws. Terminals are also spring loaded such that the action of the spring is independent of the action of the terminal screw.

a. Terminal screws are captive within the mouldings and the heads do not project above the moulding when fully released. Each terminal accepts up to two hooked blade type terminations.

b. Terminal entries are shrouded such that no current carrying metal is exposed when hooked blade terminations are fitted.

c. Springs are aged and withstand corrosion which might affect performance during their working life. Springs do not carry current.

d. Cross connection facilities are provided to common two or more adjacent terminal blocks, without interfering with the terminal openings.

3.17.7.2 Heavy duty stud type

a. For use in circuits up to 500 V maximum, at maximum continuous current ratings of 30 A for M5, and 50 A for M6 stud sizes.

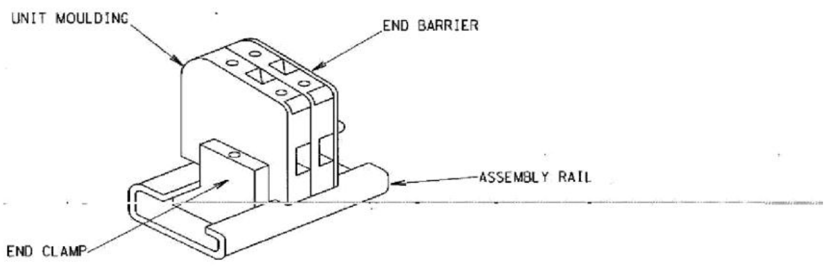
b. Figure shows the general arrangement.

c. Two terminal studs are provided for each way, and these are of sufficient length to accommodate two ring tongue or flanged spade terminations in addition to a full nut and all necessary plain and spring washers.

d. M5 studs are phosphor bronze or stainless steel. M6 studs are brass, phosphor bronze or stainless steel. Solid studs only are provided. Studs which are slotted or drilled to receive the conductor are not acceptable.

e. Loose links, where provided, are secured by a nut and washers, and are of tin plated copper or brass.

f. Barriers of insulation material, self-extinguishing or resistant to flame propagation and substantially non-hygroscopic are provided between terminal ways. These barriers project at least 3 mm above the studs.



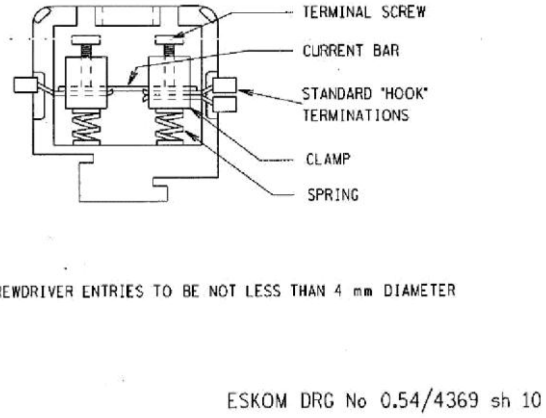
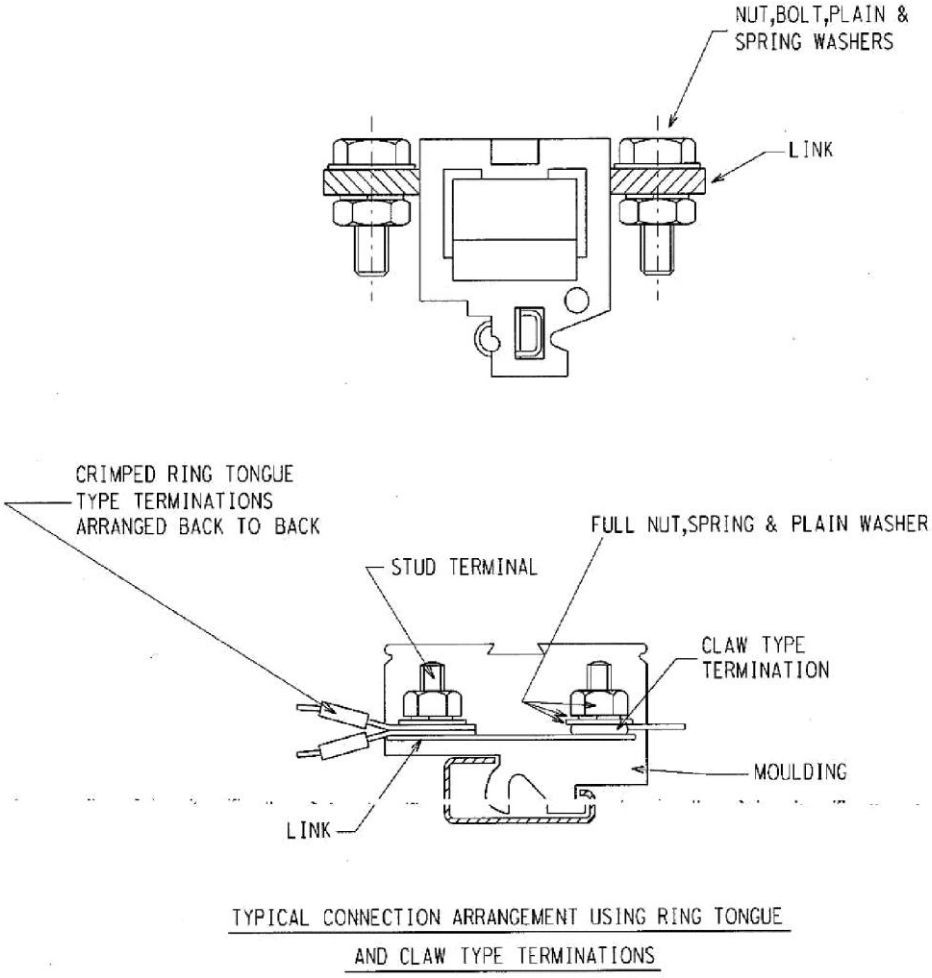


Figure 3: General arrangement of terminal block

3.17.7.3 Pinch screw type

Terminals in which the screw or the means of applying the securing pressure bears directly on the termination or conductor as found on domestic electrical fittings, are not acceptable for use in control/relay panels



STUD SIZE	MAX CURRENT RATING (A)
5 mm	30
6 mm	50

Figure 4: General arrangement of type "E" terminal block

3.18 TANKS

3.18.1 Component Approvals

The components and fittings associated with transformers covered by this Specification are subject to the Employer's approval. Samples, technical literature, drawings, test reports and lists of the names of the principal users, with experience gained, are supplied on request. The burden however, lies with Contractor to only submit a list of components for approval to the Employer if the components have been approved by the Contractor for use on their transformer. Standardised, approved components currently in use by the Employer are preferred to minimise spares holdings.

3.18.2 Materials and Welding

Unless otherwise approved, metal plate, bar and sections for fabrication comply with BS 4360. Welding complies with BS EN 1011. Welds exposed to the atmosphere are continuous. Dye-penetrant tests are carried out on load bearing joints.

3.18.3 Corrosion Protection and Paint Finish

3.18.3.1 Colour

All external surfaces, with the exception of galvanised radiators and the oil conservators are finished with an outer coat of colour in accordance with BS 381C, Dark Admiralty Grey (632), unless otherwise specified in Schedule AB.

The conservators are finished with an outer coat of white unless otherwise specified in Schedule AB.

3.18.3.2 Requirements

3.18.3.2 (a) Preferred/Recommended Products

Depending on the specification in Schedule AB. The detailed specification to be used for corrosion protection is as defined in Table 6 for the items of equipment being protected. Before alternatives may be used, the Employer's prior approval is obtained.

The coating specifications as referred to by table 3 can be found in Appendix A.

Alternative coating systems or methods of corrosion protection known to the Contractor is supported by detailed technical evidence that the proposed alternatives will meet the Employer's performance requirements.

Table 3: Detailed Coating specifications

ITEM/S	Exposure Conditions	SPECIFICATIONS
Corrosion Protection of New Power and Station Auxiliary Transformers		
Transformer tank, roof, tap changer, pipes, conservator tanks, etc.	**(Non-corrosive to High Corrosive Environments)**	**SPECIFICATION DS460.1**
	(Very High Corrosive Environments)	**SPECIFCATION DS460.2** And **SPECIFCATION DS460.4**
Radiators	**(Non-corrosive to High Corrosive Environments)**	**SPECIFCATION DS460.3**
	(Very High Corrosive	**SPECIFCATION DS460.3** And **SPECIFCATION DS460.4**

	Environments)	(Preferred specification for overcoating of galvanised surfaces) Or **SPECIFCATION DS460.5**
Maintenance Painting of In-service Power and Station Auxiliary Transformers		
Spot repair and overcoating of existing coatings	(Non-corrosive to Very High Corrosive Environments)	**SPECIFCATION DS460.6**
Previously galvanised components	(Non-corrosive to Very High Corrosive Environments)	**SPECIFCATION DS460.7**
Nuts and Bolts		**SPECIFCATION DS460.8**
Spot repairs after installation.		**SPECIFCATION DS460.9**

3.18.3.2 (b) Preferred /Recommended Manufacturers

Equipment manufacturer proprietary finishes may only be used if the Employer's prior approval has been obtained.

Approved/recommended coating materials manufacturers are indicated per each detailed coating specification. Where alternative coating manufacturers are preferred, the Employer's prior approval is obtained.

3.18.3.3 (c) Material Composition

A signed copy of the coating manufacturer's data sheet(s) is submitted with the tender. This is to ensure that the manufacturer is aware of this specification, the conditions under which it will be applied and to allow for technical back-up where required.

The coating materials are homogeneous and designed for the proposed application method. If the Contractor considers that the proposed application method is not suitable for the materials specified, he notifies the Employer in writing. His proposed alternative method is only be used after approval has been obtained from the Employer.

All coats on a given system come from the same manufacturer. In the case of items of plant or equipment being primed overseas and final coated on site, this requirement may be waived provided that the site applied finishing coats are compatible with the applied primer. Where the substrate had received a primer coat in the factory, the Contractor checks the compatibility of the coatings, which he proposes with the primer coat, and is responsible for this choice.

During application solvents may be used when they are compatible with the base material. And the percentage added does not exceed the limits given by the paint manufacturer in the date sheet.

3.18.3.2 (d) Packaging

Coating materials is supplied in sealed, robust containers of a size large enough to allow mixing in the containers and labelled with all the information necessary to ensure coating storage, application and traceability.

3.18.3.2 (e) Forwarding and Storage

The containers is kept in approved stores, which are dry, enclosed, covered and kept at a temperature compatible with good preservation of their contents.

If any container shows traces of leakage before use on site, the contents of that container is not be used.

3.18.3.2 (f) Surface preparation and substrate

Before applying the coating system the substrate is prepared by cleaning, in accordance with each specification requirements and as described in greater detail below.

3.18.3.2 (g) Degreasing

All harmful deposits of oil or grease spots and all other matter, which is detrimental to the adhesion of coatings to the surface, is removed.
According to the degree and nature of contamination, degreasing is carried out using an alkaline cleaning solution, alkaline detergent or cold solvents.
Rinsing with water to remove all traces of residues follows the degreasing operation. Items is allowed to dry completely prior to coating.

3.18.3.2 (h) Cleaning with acids

Cleaning with acids is followed by neutralization, passivation and rinsing with clean, potable water.

3.18.3.2 (i) Abrasive blast cleaning

Prior to blast cleaning, all welds are free of slag, slag inclusions and pinholes. Adjacent areas are free of weld spatter, which is removed by grinding or scraping.
All oil and grease deposits are removed prior to blast cleaning as detailed in 4.18.3.1(f).i. In this regard special attention is paid to drillings, bolt holes, etc.

If required, the Contractor submits, for approval, two samples of grade of blast cleaning specified. The samples are over coated with a clear lacquer to prevent deterioration of the surface.
Following approval, the samples are used as the reference standard of blast cleaning to be obtained by the Contractor.

Blast cleaning is carried out on dry surfaces using dry air, free from impurities (in particular grease or oils), in an atmosphere where relative humidity is less than 85 %, and the ambient temperature above +5 °C. The Employer may require t he Contractor to demonstrate that the air is clean and dry.
Blast cleaning on site is carried out only in areas approved by the Employer.

All surfaces that are blast cleaned are coated with a primer coat within 4 hours. Alternatively, provided the surface cleanliness requirements of ISO 8501-1 or SIS 055900 are maintained, the primer coat may be applied within the same working shift. Under no circumstances is blast cleaned surfaces be left uncoated overnight.

Care is taken to ensure adequate protection of machined parts or any other part not requiring blast cleaning and coating. Every precaution is taken to avoid deformation of the substrate and damage to welds.

Blast cleaning may be carried out using grit or slag that complies with the following quality requirements:

- The abrasive blasting media does not have a pH below 6,20.
- The conductivity of the water-soluble salts of the abrasive does not exceed 150 µS/cm.
- The conductivity is less than 100 µS/cm.
- The moisture content for the material when delivered in bags or in bulk does not exceed 0,5%.
- The abrasive is not be polluted with oil and grease.
- The abrasive has a minimum hardness of 6 on MOH's scale.
- The Specific Gravity has a minimum of 2,5.
- The maximum free silica content of the abrasive is 1 % by weight.

Irrespective of the material used for blast cleaning, it is in all cases free of foreign matter such as clay, humus, chlorides and bitumen.

In all cases, after blast cleaning, all traces of blasting media and dust are removed from the surface by compressed air or vacuum cleaning. Cleaned surfaces are not to be contaminated with oil, grease, rust or other deposits before coating.

The materials do not have any adverse effects on the health of personnel when Occupational Safety and Health Administration Guidelines are observed.

3.18.3.2 (i).i Mechanical wire brushing or grinding

Mechanical wire brushing or grinding may only be used where the condition of the substrate metal is such that efficient brushing or grinding can be achieved and where the coating system is designed for application to brushed or ground surfaces.

Prior to wire brushing, all welds are free of slag, slag inclusions and pinholes. Adjacent areas are free of weld spatter, which are removed by grinding or scraping.
All oil and grease deposits are removed prior to wire brushing as detailed in 3.18.3.2 (f). A Special attention is paid to bolt and other holes.

Following the degreasing as described above, all surfaces of steelwork and plant under this category is scraped and wire brushed to remove all loose scale, rust and deleterious matter.

The Contractor may utilize manual wire brushing provided the required standard of finish is achieved. The finish is in accordance with ISO 8501-1 or SIS 055900 to the particular standard grade specified in the detailed specification. Where necessary, mechanical brushing is used. Burnishing of the surface are not be permitted.

In all cases, after wire brushing or grinding, all traces of loose material is removed from the surface by compressed air or vacuum cleaning. Cleaned surfaces is not contaminated with oil, grease, rust or other deposits before coating.

3.18.3.2 (j) Application of Coatings

Unless otherwise specified, coating systems are only applied to dry surfaces. During application, the relative humidity does not exceed 85% and ambient temperatures are between 5°C and 30°C. Special coatings, e.g. ethyl inorganic zinc silicate are applied in approved environmental conditions.

The maximum/minimum substrate temperature at the time of coating application is in accordance with the materials data sheet.

Care is taken to ensure adequate coating of all boltholes, edges and other areas normally prone to corrosion attack. Where appropriate, these areas are stripe coated.

The colour of each coat is different from the colour of the previous coat. However, two finishing coats of the same colour may be applied to achieve complete colour uniformity. All finishing colours are to the Employer's approval. However, in the case of a two-coat system, each coat is a different colour. In the case where aesthetic requirements are secondary, repairs after final testing is carried out using a different colour.

Steel that is to be embedded in concrete and the undersides of base plates, which will be grouted into position, is not coated unless otherwise stated.

Steel surfaces, which are to rest on concrete or other floors, and any other surfaces inaccessible after erection receives the full specified coating system prior to erection.

The Contractor makes good, paintwork damaged during transport or erection. When site respraying is necessary, labels and all other areas not to be painted are carefully masked. The Contractor removes any overspray, which occurs despite this masking.

Damaged paint areas are cleaned. Rust spots and any other deleterious matter are removed. Spot repairs are carried out such that the patch painting extends at least 25 mm beyond the damaged areas. Spot repairs reinstate each of the previous coats and commence directly after surface preparation.

Where paint is allowed to age before finishing, the Employer may require that the surface be prepared by light sanding, scrubbing with potable water using a bristle brush and drying before over coating.

Care is taken to ensure that all machined parts are adequately protected against contamination and corrosion during paint application, transport/shipping and pre-commissioning storage.

3.18.3.2 (k) General Conditions of workmanship

All work is carried out under the supervision of an experienced supervisor. All quality control test work is carried out by a SAQCC qualified coatings inspector.

All coatings are evenly applied to form a smooth, continuous, unbroken coating free from sags, runs and other defects. Film thicknesses are as specified and each coat provides complete coverage.
No cleaning or coating applications takes place when site conditions are likely to adversely affect these operations. The Contractor is responsible for providing all protective equipment necessary to prevent contamination of the coatings and to minimize delays due to such site conditions.

All newly primed steelwork prior to erection is stored clear of the ground on trestles or other suitable material. The steelwork is placed in such a manner as to ensure adequate drainage of rainwater and condensation. The storage of galvanized components complies with SABS ISO 1461.

Equipment nameplates and identification plates are protected from coatings. No coatings are applied over any surfaces where these will adversely affect the performance of the item or component.

Before commencement of work, the Contractor produces, if requested, reasonable proof regarding compatibility and adhesion between base coats and finishing coats.

3.18.3.2 (I) Quality Requirements

3.18.3.2 (I).i Control of Coatings

Coatings are regularly tested in the coatings manufacturers' factories. The Contractor satisfies himself that regular quality control tests are carried out to ensure that good quality of the coatings is maintained.

A record of the details (batch number, date of manufacture, etc.) of each type of system used is retained by the Contractor. He also ensures that the coatings manufacturer retains a sample of each batch for at least the guarantee period. Where shelf life is a parameter, the expiry date of the retained sample is recorded.

All materials, i.e. paint, thinners and cleaning solvents for a specific paint system is supplied by the same manufacturer

3.18.3.2 (I).ii Quality Control of Surface Preparation

During blast cleaning, the relative humidity does not exceed 85% and the ambient temperature is above 5°C.

The standard of finish for wire brushed and blast cleaned surfaces is in accordance with ISO 8501-1 or SIS 055900.

Where surfaces are blast cleaned, the roughness of the blast profile is measured in accordance with SABS test method number 772 and is as specified by the material manufacturer’s technical note. It is important that the blast profile does not exceed the specified thickness of the primer or first coat. Blast cleaning of severely corroded surfaces may result in high roughness profiles (i.e. > than 100 micrometers). In these cases, an additional primer coat will be required. However, agreement should be reached between the Contractor and Coating Manufacturer as to the most suitable profile range for a specific coating application/system. Table 7 can be used as a guideline with respect to blast profile requirements.

Immediately before coating, blast cleaned steel does not exhibit more than 0,3% dust and debris when tested in accordance with SABS test method number 769.

Table 4:Peak of valley profiles

Coating Thickness (Total)	Minimum profile	Maximum profile
90 to 180 µm 120 to 225µm 150 to 300µm 300 to 500µm >500µm	30 micrometers 40 micrometers 50 micrometers 75 micrometers 75 micrometers	60 micrometers 75 micrometers 100 micrometers 100 micrometers 125 micrometers

3.18.3.2 (I).iii Quality Control of Coating Application

The application, method of application and drying times is as specified in the product data sheet submitted with the tender and approved by the Employer.

Coating thickness on metal substrates is measured in accordance with ASTM E376 or SABS ISO 2080. These measurements are made on surfaces free of all contaminants. Calibrated electronic instruments are used for determination of film thicknesses. In cases of dispute, both the Employer’s appointed inspector’s and the Contractor’s dry film thickness machines are re-calibrated and the percentage variation between the two machines is applied as being the standard deviation for each reading.

Coating thickness on non-metallic substrates is checked by verification of the quantity of coating consumed.

The thicknesses of each coat are defined in the detailed specification. 90 % of random readings is equal to or greater than the specified thickness. No individual reading is less than 90 % of the specified thickness. No individual reading is greater than 120% of the specified thickness. In the areas where stripe coating is carried out the maximum total specified dry film thickness range allows for the additional coat.

All deficient film thickness is rectified to the Employer's approval at the Contractor's expense.

Where excessive film thickness can be detrimental to the integrity of the coating, the manufacturer's recommended maximum applies.

3.18.3.2 (m) Defects during the guarantee period

Paintwork will be considered defective if, during the guarantee period, latent defects appear which could lead to a general breakdown of the coating system.

3.18.3.2 (n) Systems containing liquids and gasses

For the internals of circuits or systems containing liquids or gases, the conditions of the coated surfaces should not be detrimental to the full and correct functioning of the circuit or system as envisaged in the applicable design criteria of that circuit or system.

3.18.3.2 (o) Records

In all cases the Contractor is responsible for the quality control requirements and keeps records of all his inspections and tests.

The Employer may witness the final inspection and may also elect to have witness and hold points other than the final inspection. Prior to the commencement of work, the Contractor confirms with the Employer in writing, the date of the commencement of work and The Employer's inspection requirements.

3.18.3.2 (p) Tests

The Employer may require destructive tests to be carried out by notifying the Contractor in writing of the nature and extent of the testing to be done.

3.18.4 Tank Construction

3.18.4.1 Shape

The shape of the transformer tank and fittings, including the underbase are such that no water can be retained at any point on their external surfaces. Furthermore the lid on the inside is shaped to ensure that all free gas generated inside the transformer escapes to the conservator by way of the gas and oil actuated relay.

3.18.4.2 Cooling corrugations

Corrugated tanks are not acceptable unless approved in writing. 3.1.17.4.3 Guides for core and winding assembly

Guides are provided inside the transformer tank to correctly locate the core and winding assembly in the tank.

3.18.4.3 Bolts and Nuts

The Bolts and Nuts used for fastening the various components of the transformer must be of the metric type.

3.18.5 Tank Strength and Oil Tightness

3.18.5.1 Rigidity

Transformer tanks and their associated components have adequate mechanical strength and rigidity to permit the complete transformer, filled with oil, to be lifted, jacked and hauled in any direction, and to be transported without structural damage or impairment of the oil tightness of the transformer, and without the necessity for the special positioning of sliding rails in relation to the tank. Tank stiffeners do not cover welded seams, to enable the repair of possible oil leaks

3.18.5.2 Internal pressure and vacuum

Transformer tanks, complete with all fittings and attachments normally in contact with the transformer oil, and filled with oil of the specified viscosity, withstand the pressure and the leakage tests prescribed in 3.1.25.17.2. When empty of oil they withstand the vacuum test prescribed in section 3.1.25.17.2.

In the case of type tests for strength and oil tightness, the fittings (e.g. pressure relief valves and bushing stems) may be tested separately.

The ability of the tank to withstand overpressure is coordinated with testing the pressure relief valves (see section 4.17.10).

3.18.6 Magnetic flux effects

Thermometer pockets are located to avoid errors in temperature indication due to the heating effects resulting from stray flux.

3.18.7 Underbase

The underbase is suitable for the movement of the transformer in any direction, by sliding on greased rails, and is provided with four hauling eyes not less than 50 mm in diameter, as near as possible to the extremities of the length and width of the tank, and having not less than 100 mm working clearance above them.

Unless otherwise approved, transformer underbases have a thickness not less than that specified in Table . Fabricated bases do not retain water. The position of the axial and transverse centre lines as shown on the dimension and foundation drawings are accurately stamped onto the tank at the base level, on both sides and at both ends, and indicated by means of a red enamelled mark at each point.

For foundation plinth tolerances refer to 1.1.

Table 5: Minimum thickness of transformer tank base plates — mild steel

Length of tank (m)	Minimum plate thickness (mm)
Fabricated bases: not exceeding 2,5 exceeding 2,5	 10 12
Flat bases: not exceeding 2,5	 12

over 2,5m but less than 5 over 5m but less than 7,5	20 26
exceeding 7,5	32

3.18.8 Jacking Pads (where applicable)

Four suitably and symmetrically placed jacking pads are provided in positions which are accessible when the transformer is loaded on to the transport vehicle, except where jacking pads are utilised as transport pads on vehicles having built-in jacking.

Each jacking pad is designed to support, with an adequate factor of safety at least half of the total mass of the transformer filled with oil, allowing maximum possible misalignment of the jacking force in relation to the centre of the working surface.

Unless otherwise approved, the heights of the jacking pads above the bottom of the transformer base, and the unimpeded working surface of the jacking pads are indicated inTable 6, read in conjunction with Figure 5.

Table 6: jacking pads

Transformer mass complete with oil (metric tons)	Min/max height of jacking pad above base "A" (mm)	Overhang to centre of jacking pad "B" (mm)	Unimpeded working surface of pad "C" (mm)	Width of symmetrical unimpeded access to jacking pad "D" (mm)
60 and below	460/530	115	170 x 170	230
Above 60	650/700	150	210 x 210	300
Access in the direction 'E' must be unrestricted.				

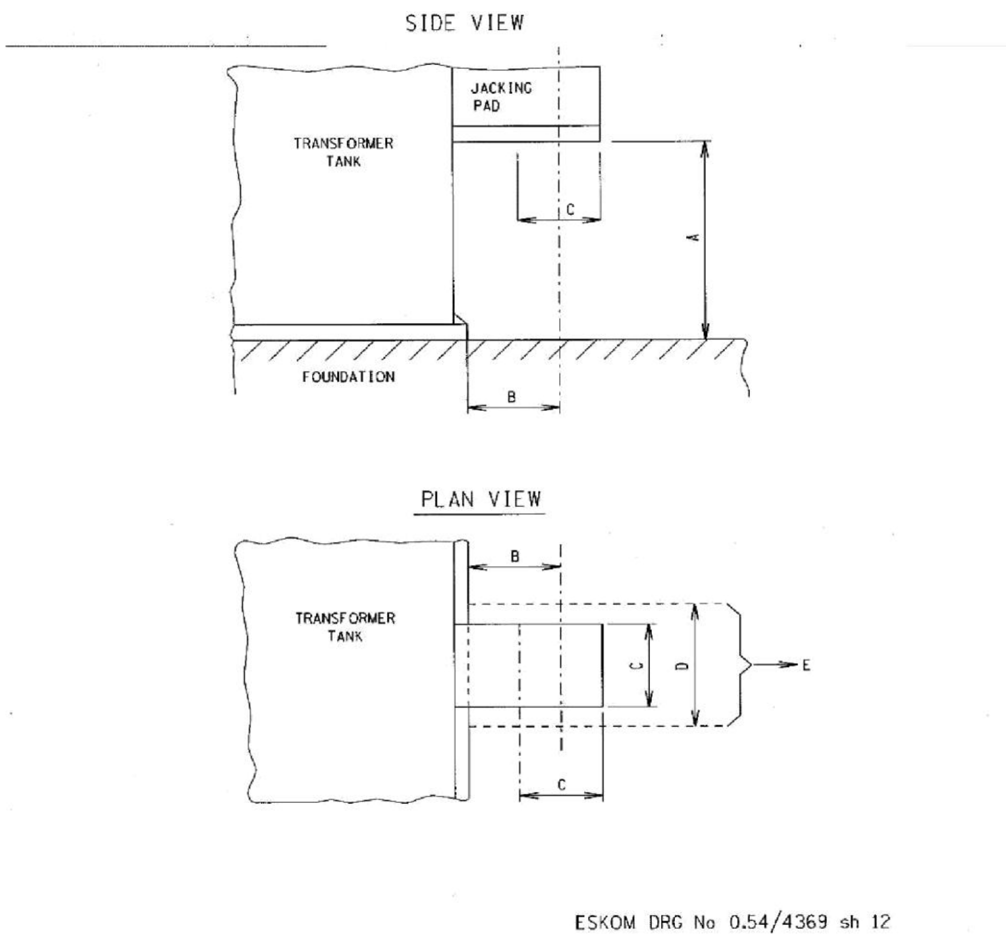


Figure 5: Arrangement of jacking pads

3.18.9 Lifting Lugs

Four symmetrically placed lifting lugs are provided so that it will be possible to lift the complete transformer when filled with oil without structural damage to any part of the transformer. The factor of safety at any one point is not less than 2.

The lifting lugs are so arranged and located as to be accessible for use when the transformer is loaded on the transport vehicle, and so as not to cause fouling of any of the transformer fittings and accessories.

3.18.10 Pressure Relief Devices

Transformers rated below 100 MVA are equipped with one spring operated pressure relief device. Transformers rated at 220 kV and above, or 100 MVA and above are equipped with two of these devices.

Each device must:

a. maintain its oil tightness under a static oil pressure equal to the static operating head of oil plus 20 kPa;

b. attain its full opening in not more than 2,5 ms when subjected to an internal pressure impulse equal to the static operating head of oil plus 50 kPa;

c. be capable of withstanding full internal vacuum at sea level;

d. be fitted with a visual operation indicator plainly visible from ground level, and arranged for manual resetting;

e. be equipped with normally open contacts which may be used to give electrical indication that the device has operated; and

f. has an opening diameter of at least 100 mm.

Pressure relief devices are mounted so as not to entrap gasses which may be generated or released inside the transformer. These devices are fitted directly to the side walls of the transformer tank at a level as near as possible to the top of the windings. Where one device is fitted it is positioned as close as possible to the centre phase. Where there are two devices they are arranged on opposite sides of the transformer, i.e. between 'A' and 'B' phases on one side and between 'b' and 'c' phases on the other. Alternative mounting positions such as on the tank cover may be considered if adequate mechanical protection can be provided to avoid inadvertent damage by erecting personnel. This is subject to approval by the *Employer*.

A combined weather guard and oil deflector is fitted to ensure free deflection of the oil towards the ground.

Because pressure relief devices are recognised to have a limited action for severe internal faults, alternative well proven devices to only detect pressure waves resulting from internal faults but not giving any pressure relief, may be submitted for consideration by the *Employer.*

Despite any testing requirements in this Specification the overpressure device is not influenced to generate invalid trip signals by tank vibrations and the magnetic fields generated during normal operation and through faults.

3.18.11 Provisions for Earthing

Provision is made for earthing the transformer tank and associated apparatus as follows:

at a height not less than 300 mm from the base of the transformer tank, and near each end of each of the two major sides of the tank (i.e. in four positions).

These take the form of earthing pads integral with the tank walls; where the pads are attached by welding, such welding being continuous around the perimeter of the pads. The contact surfaces of the pads are protected from corrosion by means of heavy duty galvanising.

Provision is made for connection to the earthing pads of four copper earthing straps each 50 mm x 3 mm laid one upon another, and clamped in position by means of a heavy clamping plate fastened by means of not less than two M16 studs or set screws having hexagonal heads and fitted with lock washers, spanning the width of the copper straps.

The conductivity of such connections is not less than that of the connection provided at the neutral terminal of the transformer.

At intervals not greater than 700 mm on a line from a point adjacent to the neutral terminal of the transformer to the nearest earthing pad at the bottom of the tank, cleats are provided for securing two 50 mm x 3 mm copper earth straps laid one upon the other, in such a manner as to eliminate vibration against the tank wall. This line approaches the earthing pad vertically. Cleats are also provided on the tank for securing 50 mm x 3 mm copper straps to the tertiary surge arresters (see 3.1.17.11.d below.).

a. All tank attached apparatus, including cable marshalling boxes, tap changer operating gear and mechanism boxes, and fan and pump motors are bonded to their supporting structures.

b. Earthing pads, as specified in 3.1.17.11.a), are also provided on either end of the supporting structures for all separately mounted cooler banks and oil conservators, and on all free-standing cubicles.

c. Where surge arrester mounting brackets are provided, suitably spaced cleats must be provided on the tank side for securing the copper earth leads between the arresters and the nearest earthing pad.

3.18.12 Main Tank Covers

3.18.12.1 Shape

The main cover of the transformer tank may be flat, domed or of the "bell type".

Positive provision is made to guide any gas that may develop towards the Buchholz relay.

This provision takes into account the possible slopes of the plinth on which the transformer will be mounted.

The effectiveness of guiding gas in the transformer is tested by injection of a known quantity of gas into bottom drain valve furthest away from the Buchholz relay.

In order to avoid the undesirable and possible dangerous entrapment of gas in the transformer, this test is carried out prior to the final vacuum treatment of the transformer oil.

3.18.12.2 Lifting

Lifting lugs or eyes are provided, and the cover so arranged that it might be lifted and handled without permanent distortion.

3.18.12.3 Support

The cover may be supported from, but must not support, the core and winding assembly. (See 3.1.10.4.2).

3.18.12.4 Gas venting

The transformer cover and generally the internal spaces of the transformer and all relevant oil connections are designed so as to provide venting of any gas in any part of the transformer to the gas and oil actuated relay.

Covers are vented at least at both ends.

Attention is drawn to the foundation tolerances specified in 1.1 and the testing requirement in 3.1.17.12.1.

3.18.12.5 Cover identification

The main tank cover has indelibly stamped into its edge below the "C"-phase bushing, the maker's serial number, which also similarly appears in the adjacent position on the edge of the main tank flange.

3.18.12.6 Thermometer pockets

In addition to the pockets required to house the detecting elements of the dial-type, top oil temperature indicators specified in 3.1.23.4, a similar thermometer pocket fitted with a captive flanged screw plug is provided and suitably positioned for use with a mercury-in-glass type check thermometer to verify top-oil temperatures.

Thermometer pockets are located such as to avoid errors in temperature indication due to the heating effects resulting from stray flux.

3.18.12.7 Currents flowing in tank cover and bushing turrets

To allow for the effect of induced loop currents and capacitive surge currents, the tank cover and bushing turrets are fixed to the transformer in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.

Special care is taken in the vicinity of high current terminals.

3.18.13 Welding of Cover

All joints, other than those, which may have to be separated during transport or for maintenance in service, are welded.

The main tank/cover joint is preferably welded, in which case a fire-proof gasket is included to prevent foreign matter entering the transformer during welding or un-welding.

The welded joint is designed to permit removal of the weld with minimum damage to the mating flanges, and to leave them suitable for re-welding.

Bolted covers are allowed, provided the *Contractor* illustrates that the sealing of the bolted covers are adequate. Where a bolted top cover is used, proper earth continuity is provided between the main tank and the top cover to prevent flashovers between the main tank and top cover during transient conditions

3.18.14 Gaskets: Types, material, re-tightening and welding

3.18.14.1 General

All gasketed joints are designed, manufactured and assembled to ensure long term leak and maintenance free operation.

Gasketed joints that do not need to be removed for normal maintenance or transport are welded in accordance with 3.1.17.13.

Seals and gaskets requiring re-tightening in order to avoid oil leaks as a result of shrinkage are retightened in the second 6 months of service by the Contractor at no extra cost to the Employer. Gaskets and seals are replaced each time they are disturbed by opening.

All gasketed joints are of the rectangular cord and groove type. The rectangular cord is of Nitrile rubber or better. The Nitrile rectangular cord may not be joined but passes twice around the perimeter with the loose ends at the bottom. Stoppers to prevent over compression are also provided.

Details of all gasketed joints are submitted for approval.

3.18.14.2 Attachments to the transformer tank

Attachments to the transformer tank are only fixed by means of bolting to the prepared flat surface of a flange facing, either integral with or welded to the tank and sealed by a gasket or O-ring to the mating flange of the attachment. Joints dependent on the sealing of screw threads, and direct welding of fittings to the tank are not acceptable.

3.18.14.3 Pipe joints

Oil pipes above 15 mm bore have flanged, gasketed and bolted joints. Flexible compression joints are not acceptable unless specifically approved. Joints dependent on the sealing of screw threads are not acceptable.

3.18.14.4 Drilling of pipe flanges

The drilling and bolting of pipe flanges and the mating flanges of fittings complies with BS 4504 or DIN EN 1092-1.

3.18.15 Access Openings and Covers

An appropriate number of suitably proportioned hand holes and manholes are provided for easy access to the upper portions of the core and windings assembly, the lower ends of bushings, internal current transformers and the oil side of the terminal boxes (see 3.1.11.4).

3.18.15.1 Handles

Manhole covers are provided with stout handles to facilitate their removal.

3.18.15.2 Lifting lugs

Covers with a mass above 25 kg are provided with symmetrically arranged lifting lugs.

3.19 VALVES AND OIL SAMPLING DEVICES

3.19.1 Isolating Valves

Suitably dimensioned isolating valves are provided at:

a. each point of connection to detachable cooling apparatus (oil pumps and radiators); and

b. each point of connection to tap changer compartments, cable disconnecting chambers and cable sealing boxes supplied from the transformer tank.

The use of Gate valves is preferred and is used where possible.

All valves are of the gland seal type or a type that is unlikely to leak in the long term. Where a non-gland seal type valve is used, the *Contractor* supplies the necessary information to the *Employer* for approval of the valves. The *Contractor* motivates why the type of valve is reliable and unlikely to leak in the long term.

3.19.2 Filtering and Drain Valves

Not less than two 50 mm double-flanged Gate-valves are provided. Where only two filtering valves are provided, one valve is located at the top of the tank adjacent to the oil conservator, and another at the bottom of the tank on the opposite end to give a cross current of oil during filtration. The lower valve is a combined drain and filtering valve and, as such, is installed such as to drain, as far as possible, all the oil from the transformer tank.

The tap changer diverter chambers are fitted with 25 mm drain valves for maintenance purposes. If inaccessible from ground level, they are piped down to 1,5 m above ground level.

3.19.3 Sampling Devices

Transformers shall have sampling devices only at routine sampling points, which are

- the Buchholz sampling point at the bottom of the main Buchholz relay sampling pipe,
- And at the bottom of the transformer tank bolted and gasketed to the free flange of the 50 mm drain valve specified in 3.1.18.2.

The Oil sampling devices supplied for the above two sample points is to be approved by the *Employer.*

3.19.4 Strength and Oil Tightness

Valves and oil sampling devices are of adequate strength to withstand the hydraulic and mechanical loads imposed upon them during testing, processing and transporting of the transformer and in service. Pewter and similar low strength materials are not acceptable.

Valve discs, wedges, wedge facing rings, seats and seat rings, stems and spindles are of approved non-corrodable material. Valves and oil sampling devices must withstand the tests prescribed in 3.1.25.17.

3.19.5 Valve Stem Seals

Valve stem seals are capable of adjustment in service without draining the transformer oil. In this connection, and generally, aluminium (or aluminium alloy) threads must not mate with threads of brass valve stems. Gland seals are preferred.

3.19.6 Locking and Padlocking

Suitable means for padlocking specific valves in both the open and closed positions are specified in Schedule AB when required. All valves have a mechanical locking facility in both the open and close positions to prevent accidental closing and opening due to vibration.

3.19.7 Blanking Plates

All valve entries communicating with the atmosphere are sealed by means of bolted and gasketed blanking plates, or captive screwed caps, or plugs as the case may be.

3.19.8 Valve Function Plate

A schematic diagram plate indicating all valves, vent plugs and sampling points is provided in the same manner as the rating and diagram plate (see 3.1.29 for requirements) indicating the position of each, the total number, the function and the required position during operation. This is only applicable for transformers rated 20 MVA and above.

3.19.9 Valve Position Indication

The position of each valve, i.e. fully open or fully closed, is clearly and unambiguously discernible on inspection. Where this is not possible, e.g. in the case of lever operated valves, the "open" and "closed" positions of the lever in relation to a clearly recognisable part of the transformer are depicted on the valve function plate prescribed in 3.1.18.8.

3.19.10 Labelling of Oil Sampling Devices

All the oil sampling points, as defined in 3.1.18.3, are numbered the same as on the valve function plate with exception of the two routine sampling points that are also labelled as follows:

SAMPLING POINT	LABEL
• Buchholz relay (Main 1)	TRANSFORMER OIL ROUTINE SAMPLING POINT
drain valve	ROUTINE SAMPLING POINT

When transformers without Buchholz relays are specified, the drain valve at the bottom of the main tank will be considered the routine oil sampling point and is labelled TRANSFORMER OIL ROUTINE SAMPLING POINT.

3.20 OIL CONSERVATOR TANK AND CONNECTIONS

3.20.1 Capacity

The capacity of the oil conservator is such that the oil level does not fall below the top of the feed pipe to the transformer for a top oil temperature of –10 °C and as a minimum, not overflow for a top oil temperature of 115 °C. Note also the requirements for the sump below.

The transformer is nevertheless able to carry the overloads specified without overflowing.

3.20.2 Strength and Colour

The conservator is designed and tested to meet the requirements of 3.1.17.5.

The finished colour of the conservator external plate is white enamel, unless otherwise stated in Schedule AB.

3.20.3 Mounting

Oil conservators may be mounted on the transformer tank, on a separately mounted cooler bank, or separately on a floor mounted supporting structure provided by the Contractor.

Tank mounted conservators are bolted on brackets to facilitate the complete removal of the conservator for whatever purpose.

The oil conservator inclines in the direction of its main compartment drain valve by not less than 25 mm over the length of the conservator.

3.20.4 Sump

The connection to the transformer is arranged such that a level of oil of not less than 10 % of the internal vertical dimension of the conservator with a minimum of 50 mm in the case of transformers having a rating of up to and including 20 MVA and 75 mm for larger units, remains in the conservator after it has been drained to the transformer.

The conservator does not contain pockets which are undrained by the drain valve.

3.20.5 Removable End Cover

The end plate of the conservator adjacent to the drain valve is attached by means of a bolted and gasketed external flange to facilitate internal cleaning of the conservator. In the case of a conservator partitioned to supply also the tap changer switch compartment(s), both ends are removable.

These covers are provided with integral lifting lugs. The removal of these covers when the transformer is completely erected as in service is not obstructed by other pipework or fittings.

3.20.6 Filling Aperture

A filling aperture not less than 65 mm diameter, fitted with an air tight gasketed cover is provided at the top of each conservator. An appropriate pipeline is installed that enables on load topping up and draining of the Generator transformer conservator tank from ground level using a hand pump.

3.20.7 Isolating/Drain Valves

A suitably dimensioned isolating valve is attached direct to the outlet of each oil conservator by means of a bolted and gasketed flange.

A 50 mm double-flanged valve is provided to fully drain each main tank conservator. This valve is mounted, on an extension pipe where necessary approximately 1,5 metres above ground level.

A 25 mm double-flanged drain valve is provided to fully drain each tap changer oil conservator. Valves, flanges and flange facings comply with the relevant requirements of 4.18.

3.20.8 Pipework Connections

Pipework connections are of ample size for their duty and as short and direct as possible. Only radiused elbows must be used. Pipework does not obstruct the removal of tap changers for maintenance.

The feed pipe to the transformer tank enters the transformer cover plate at its highest point and is straight for a distance not less than five times its internal diameter on the transformer side of the Buchholz relay, and straight for not less than three times that diameter on the conservator side of the relay. This pipe rises towards the oil conservator, through the relay, at an angle of not less than five degrees.

For transformers containing up to 10 000 litres of oil, the feed pipe diameter is not less than 50 mm, and for larger transformers, not less than 75 mm.

Gas-venting pipes, as referred to in 3.1.17.12.4, are connected to the final rising pipe to the Buchholz relay as nearly as possible in an axial direction, and preferably not less than five pipe diameters from the relay, on the transformer side of the relay.

3.20.9 Sealed Oil Preservation System

When a bagged main conservator is specified in Schedule AB the materials, design and construction are subject to approval by the Employer.

Note that the design and materials take the long life expectancy of the transformer into account. The following is considered:

a. High and low oil level alarm contacts are provided together with the oil level indication.

b. The bag allows expansion without increasing the pressure or creating a partial vacuum. The bag or system does not prevent or restrict the normal draining of the conservator or the flow of oil to the transformer.

c. To prevent oil filling into the bag, the oil filling aperture is clearly marked.

d. The system is air tight.

e. Dehydrating breathers are fitted even when bags are specified.

f. The bag allows expansion without increasing the pressure or creating a partial vacuum over the full specified temperature range.

The rating and diagram plate bears a warning statement that the conservator is fitted with a bag.

The transformer manual contains clear instructions on the operation, maintenance, testing and replacement of the bag.

3.21 GAS AND OIL ACTUATED RELAYS (BUCHHOLZ)

An approved gas and oil actuated relay suitable for operation in transformer oil as specified over the temperature range from 115 °C to –10 °C is installed in the connecting pipe between the oil conservator and the transformer tank in such a manner that all gas from the tank must pass through the relay as it rises to the oil conservator.

For the purpose of redundant protection, transformers having a voltage rating of 220 kV and above or a rating of 100 MVA and above, are provided with two Buchholz relays located in series in the connecting pipe between the oil conservator and the transformer tank, with at least a distance of five pipe diameters between them.

Alternatively, one device with dual contacts for both the alarm and tripping functions is acceptable.

Contacts as specified in 0 are provided to close as follows:

a. the gas alarm signalling contacts are closed by the falling of the oil level to a predetermined point in the relay due, either to the deficiency of oil, or to the presence of gas in the relay;

b. the gas tripping contacts close on a further lowering of the oil to a point before the gas escapes to the conservator.

If this cannot be achieved, the gas alarm signal is used for a gas trip signal in which case this arrangement is subject to approval by the Employer; and

c. the surge tripping contact closes when there is a surge of oil through the relay towards the conservator with a rate of flow not less than that stated in Table 7.

Table 7:Gas and oil actuated relays oil flow rates for closure of surge contacts

Transformer total oil content (l)	Relay nominal size (mm)	Limits of minimum steady oil flow rate (mm/s)
Up to 1 000	25	Between 700 and 1 300
1 001 to 10 000	50	Between 750 and 1 400
10 001 to 50 000	75	Between 900 and 1 600
Above 50 000	75	Between 1 500 and 2 500

The performance of the relay is demonstrated as specified in 3.25.

3.21.2 Relay Stability

In addition to the tests specified in 3.25, the relay withstands the contact tests prescribed in 4.25.

No maloperation of the relay results from starting or stopping of the transformer oil circulating pumps under any oil temperature conditions. Stability, in this regard, is not achieved by the use of pipe or relay aperture baffles to the impairment of sensitivity to oil surges as specified.

No maloperation of the relay results from any seismic activity. The use of mercury type switches for the alarm- and trip functions are therefore not acceptable.

3.21.3 Magnetic Influence

Despite the testing requirements below, the relay does not operate for through fault conditions or influenced by the magnetic fields around the transformer under normal or external fault conditions.

3.21.4 Mounting and Marking of Relays

Pipe mounting flanges and relay lengths between flange facings comply, unless otherwise approved, with Figure 10. Preference is given to relays which are, in these respects, interchangeable. Each relay bears clear indication as to which end is connected to the conservator. .

3.21.5 Windows

Unless otherwise approved, two graduated windows are provided in opposing sides of the relay and so arranged that the oil level in the relay may be clearly gauged. The internal surfaces of the relay are finished in glossy white, oil resistant enamel.

3.21.6 Gas Release and Oil Sampling Cock

An oil-tight gas release cock, terminated in a threaded (6 mm) air connection fitted with a captive screw cap, and communicating by a small bore non-ferrous tube to the top of the relay body, is located approximately 1,5 m above ground level. The tubing is protected against physical damage by appropriate routing, fastening and or protective conduit.

3.21.7 Testing

Each Buchholz relay has an internal test nozzle for simulating the gas alarm, gas trip and surge trip signals by injecting gas into this nozzle. The nozzle is piped down to a height of 1,5 m above ground level in the same manner as the gas release cock specified in 3.1.20.5 above.

Alternatively, an approved mechanical device that operates the float mechanism and not only the switch contacts may be provided.

3.21.8 Oil Tightness and Strength

The relay withstands the internal pressure and vacuum conditions specified in 3.18.6 without damage and without leakage of oil, either externally or into its terminal box, and, in the case of the application of vacuum, without ingress of air.

3.21.9 Electrical Connections, Terminals and Terminal box

In general, these comply with the requirements of 3.17. The gauze covered drain and vent hole in the terminal box on the relay (see 3.17.2) is not required.

The terminal box cover gasket is confined to the perimeter of the cover where sealing is required, i.e. the central area of gasket material over the terminals is removed.

A suitable water-tight and weather resistant electrical conduit threaded cable entry is provided.

The alarm signalling and the tripping contacts are electrically separate and independent, and are externally connected as specified in 3.17.4 (c).

3.21.10 Devices for the Protection of Relay Contacts

Where the Contractor deems it necessary to protect the relay contacts from the effects of cable capacitance or electromagnetic relay inductance by means of inductors or diodes, he provides and fit these items, preferably in the relay terminal box, or alternatively in the marshalling box on the transformer. Such designs are approved by the Employer.

3.21.11 Type and Routine Testing

The Buchholz relays meet the requirements of the tests prescribed in 3.26.18.

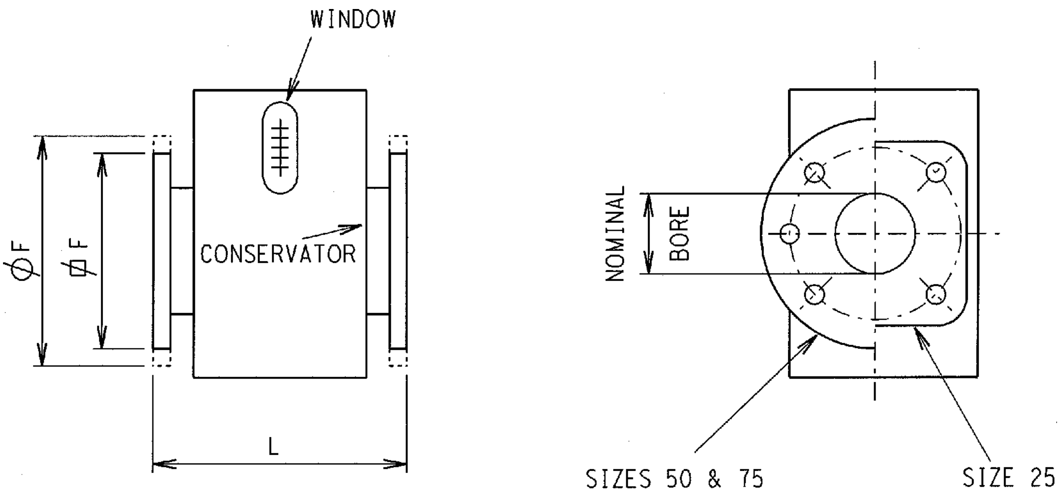
A standard test card bearing the manufacturer's serial number of the relay is included with each of the operating instruction manuals required for the transformer.

3.21.12 Assembly, Operating and Maintenance Instructions

Original and fully detailed instructions for assembly, operation and maintenance of the relay are included with each of the operating instruction manuals for the transformer.

3.21.13 Floats

The buoyancy of the floating elements is due to their specific gravity and is not dependent on the sealing of a hollow float. The materials are not affected by hot transformer oil.



RELAY SIZE & NOM. BORE	LENGTH L	FLANGE SIZE-F	BOLT HOLES		
			No	SIZE	PCD
25	127	ϕ 75	4	TAPPED M 10	72
50	185	ϕ 140	6	12	110
75	185	ϕ 160	6	12	130

NOTES:
1. FLANGES TO BE DRILLED OFF-CENTRE TO THE VERTICAL.
2. ALL DIMENSIONS IN MILLIMETRES.

Figure 6: Buchholz relay outline drawing and sizes

3.22 DEHYDRATING BREATHERS

3.22.1 General

Direct contact between oil and the air is prohibited. Conservator tanks are fitted with a conservator bag to avoid contact between the oil and the atmosphere. The air in contact with the conservator bag passes via a dehydrating breather as described below.

No single breather carries a silica gel charge in excess of 12,5 kg. Where the required quantity exceeds this mass, it is subdivided into a sufficient number of individual compartments arranged in series. A single atmospheric oil seal is provided to serve the entire breather group. The breather is carefully designed for easy and frequent changing of the silica gel charge by non-specialist maintenance personnel.

3.22.2 Type of Breather

Unless otherwise approved, a desiccating breather employing cobalt impregnated silica gel, complying with BS 3523, is required.

3.22.3 Breather Proportions

The silica gel charges contained in the dehydrating breathers is not less than 0.3 kilograms per 1 000 litres of total oil content, with a minimum of 2 kg.

3.22.4 Diffusion of Air through the Desiccant

The silica gel charge is so supported and arranged that the air passing through the charge is diffused throughout the charge so as to contact all gel particles in the charge, and in particular those observable from the outside or through the window provided for this purpose.

3.22.5 Air Intake during Starting of Oil Circulating Pumps

The arrangement and proportions of the dehydrating breather is such that air inhaled during starting of the oil circulating pumps receives adequate dehydration, and also such that the oil in the atmospheric seal is not drawn into the breather unit(s) during this operation, nor blown out of the oil seal during the stopping of the oil circulating pumps.

3.22.6 Containing of the Silica Gel Charge

The silica gel charge is preferably contained in a transparent and independent container of weather proof, UV and heat resistant (up to 115 °C) material, which may be simply and easily removed and replaced without the use of special tools.

In the case of multi-unit breathers, each separate charge is independently retained upon removal of the oil seal.

3.22.7 Visual Inspection of the Desiccant

Unless the container for the silica gel charge is of transparent material an inspection window, at least 50 mm wide, is provided for inspection of the colour and condition of the silica gel. The inspection window is positioned to make the desiccant visible at both ends and for the full length of each cartridge.

Windows or containers of heat resistant glass or other fragile material are protected by means of metal grids.

3.22.8 Seals

The breather's desiccant is not in contact with the atmosphere unless the transformer is breathing, but is sealed by a device containing a quantity of transformer oil.

The designed oil level in this device is clearly marked. The seal is preferably constructed of heat-resistant glass.

All other seals on the breather are effected by oil proof and air tight gaskets that are effectively retained on dismantling of the breather for the purpose of changing the desiccant charge.

3.22.9 Castings

Where cast components are used they are made of high quality and non-porous castings.

3.22.10 Corrosion Proofing

Corrosion is eliminated by the use, wherever possible, of non-corrodable materials, and by avoiding the contact of dissimilar metals.

The corrosion proofing is in accordance with 3.18.3.

3.22.11 Mounting and Pipework Connections

Dehydrating breathers are mounted approximately 1.5 m above ground level.

Connection is made to a point in the oil conservator not less than 50 mm above the maximum working oil level (i.e. with a top oil temperature of 115 °C), by means of a pipe with a minimum diameter of 20 mm in the case of breathers less than 10 kg in total mass, and a minimum diameter of 25 mm for units of 10 kg and above.

Breathers having a mass less than 10 kg may be supported by the connecting pipe, whereas units of 10 kg and above are supported independently of the connecting pipe.

Connecting pipes are securely cleated to the transformer, or other structure supplied by the Contractor, in such a manner as to eliminate undesirable vibration and noise. In the case where a breather of less than 10 kg is supported by the pipe, there is a cleat directly above the breather flange.

Pipe connections comply with 3.20.8 unless otherwise approved.

3.23 OIL LEVEL INDICATORS, ALARM AND SIGNALLING DEVICES

3.23.1 General

The oil level in conservators and oil-filled chambers having a free oil level, is clearly indicated when viewed from ground level by approved weatherproof oil level indicators. The indicators are suitable for the design, i.e. free breathing or bag type conservators.

3.23.2 Range of Indication

The oil level indication is continuous over the range of top oil temperature from -10 °C to +115 °C.

The level of oil in the conservator corresponding with the –10 °C index is not less than 25 mm above the transformer feed pipe entry.

3.23.3 Graduation of Indicator

The oil level indicator on the oil conservator connected to the transformer tank bears the following markings:

If the dial indicator type, the words “FULL” and “EMPTY”, appropriately placed. (Dial-type indicator pointers move from empty to full in the clockwise direction).

Graduations indicating the normal oil levels at 15 °C, 25 °C, 35 °C, 60 °C, 75 °C and 90 °C, or alternatively, decade graduations between 0 and 1,0.

The actual temperature values should, preferably, not appear on the oil level indicator, which should bear only clear index marks at the specified points.

A table or curve correlating the index marks with their corresponding temperature values appears on the rating and diagram plate, or on a similar plate affixed adjacent to it.

3.23.4 Direct Reading Indicator

Direct reading type oil level indicators are only acceptable when approved by the Employer for specific applications.

3.23.5 Dial-type Indicator

These are of the magnetically operated type in which breaking of the glass will not expose the oil to the atmosphere.

The buoyancy of the floating element is due to its specific gravity and is not dependent on the sealing of a hollow float. The materials used are unaffected by the hot transformer oil in the long term.

The vibration of the transformer does not produce wear and damage to the mechanism of the indicator.

3.23.6 Gaskets

Gaskets are as specified in 3.18.14.

3.23.7 Mounting

Oil level indicators are arranged for front-end mounting without the necessity of access to the inside of the oil conservator or chamber.

3.23.8 Low and High Level Alarms

A pair of circuit-closing, potential free low oil level alarm signalling contacts is provided in each oil conservator. These contacts are set to close at the −10 °C point.

A pair of circuit-closing, potential free, high oil level alarm signalling contacts is provided in each oil conservator. These contacts are set to close before the oil is pushed into the breather pipe (see 3.22.11).

The electrical contacts comply with the requirements of 3.16.3

3.24 COOLING ARRANGEMENTS

3.24.1 Type of cooling required

Transformers shall be either is ONAF or ONAN cooled as specified in Schedule AB.

3.24.2 Oil Temperature Measurement and Settings

A dial-type thermometer, graduated in degrees Celsius over the specified temperature range, and unless otherwise approved, fully compensated for the effects of ambient temperature, is provided for registering the temperature of the transformer "top-oil".

The instrument is fitted with a maximum temperature indicator, arranged for manual resetting, and with alarm signalling and tripping contacts, which can be manually set to close at predetermined temperatures which, unless otherwise specified, are:

Alarm — 95 °C

Trip — 105 °C

The instrument is preferably mounted in a separate control cabinet, where this is provided, or otherwise by means of an approved anti-vibration mounting on the transformer tank.

The Employer requires low maintenance, reliable instrumentation with fixed settings. Analogue temperature indication as well as maximum temperature indication may be waived if alternative proposals are found acceptable. Manufacturers are invited to submit such proposals.

3.24.3 Winding Temperature Measurement and Settings (where applicable)

Winding temperature thermometers are of the dial-type, unless otherwise approved, fully compensated for changes in ambient temperature, and have a load-temperature characteristic approximately the same as the hottest part of the windings. The current transformers for operating the thermometers are built into the main transformer tank and are located such as to reflect the maximum hot-spot temperature of the respective windings. For delta-connected windings, the current transformer is located electrically inside the delta connection.

For each loaded winding a separate winding temperature thermometer is provided, except in the case of two-winding transformers (which only have HV and LV windings) which are provided with a single winding temperature thermometer arranged to provide a thermal image of the maximum overall winding hottest-spot.

Thermometers are provided with dials indicating the temperature in degrees Celsius and fitted with a resetable maximum temperature indicator. A pair of adjustable alarm contacts, which can be set to close at predetermined temperatures, is provided and, in addition, a pair of contacts for tripping purposes. Alarm and tripping contacts comply with the requirements of 0. The alarm contact circuits of these indicators are paralleled, and the trip contact circuits paralleled and each brought out to a pair of terminals.

The alarm signalling and the tripping contacts are electrically separate and independent, and are externally connected as specified in 3.1.16.3.6 (c).

Unless otherwise specified, the alarm and trip settings must be:

Alarm — 110°C

Trip 1 — 115 °C

Trip 2 — 120 °C

Unless otherwise approved, the operation of the winding temperature thermometer does not require any external electrical power supply.

The instrument is preferably mounted in a separate control cabinet, where this is provided, otherwise, by means of an approved anti-vibration mounting on the transformer tank.

Where supplementary forced cooling is provided, an additional pair of contacts, or an additional thermal or auxiliary relay is provided to automatically start the oil pump and/or fans for cooling the transformer. These contacts are self-resetting. Alternatively, the start signalling is derived from a current relay with suitable hysteresis characteristics to avoid hunting.

Terminals and links are provided in the marshalling box or, where provided, the cooler controller cabinet for checking the output of the current transformer and/or the functioning of the heater coil by means of an external supply.

See also the last paragraph in 3.24.4 for alternative proposals.

3.24.4 Constructional Details

The requirements of 3.18 also apply to the cooling apparatus provided for the transformer, wherever they are relevant.

Pipework and coolers are arranged to permit free access to oil conservators, tapping mechanism boxes, terminal and marshalling boxes and any items requiring inspection or maintenance in service.

In order to facilitate painting of non-detachable (non-galvanised) cooler tubes on site a minimum of 80 mm is allowed between adjacent tubes, and between these and the transformer tank.

For all tubular radiators, the joints between tubes and the header are welded outside and not inside the header in order to reduce the possibility of corrosion in the seams.

3.24.5 Detachable Radiators

Detachable radiators are provided with:

a. lifting lugs;

b. drain valves or plugs, at their lowest points;

c. vent plugs, at their highest points;

d. flanged and bolted isolating valves at both points of attachment to the transformer tank or cooler bank;

e. individual serial numbers indelibly stamped on the mounting flanges for quality control purposes.

NOTE – The radiators must be individually pressure tested.

3.24.6 Galvanised Radiators

Radiators are of suitable material and designed to permit successful galvanising.

3.24.7 Air Forced Cooling (where applicable)

3.24.7.1 Forced Air Coooling Control and settings

Forced cooling equipment is designed for automatic operation by means of winding temperature thermometer or current level contacts set at predetermined temperatures/currents. Generally the manufacturer’s standard settings for the starting of fans and pumps are used, otherwise a setting of 65 °C or 0,6 p.u current applies.

The cooler arrangement is to be such that a spare group is always available to cut in when a running fan group fails.

All required coolers are started by a single external circuit closing contact supplied by the Employer. Staggered time delayed starting is required under these conditions. If any one group is out of service and isolated, this does not affect the automatic starting of the remaining groups.

Fan groups are capable of individual manual on/off control. In the event of the failure of any component of a selected group of coolers, tripping of the defective group closes a set of potential free contacts which the Employer will use to initiate suitable remote warning alarms.

3.24.7.2 Cooler control equipment

In designing and building the control equipment the Contractor must comply with the requirements of IEC 60947

All the necessary automatic control, motor contactors, protective devices, and switches for the forced cooling equipment are assembled in a rustproof, weatherproof and vermin-proof cabinet. This cabinet is arranged either for separate floor mounting in the proximity of the transformer or, alternatively, by means of approved anti-vibration mountings on the transformer tank. Hinged door(s), handle(s), locking facilities, a separately fused 230 V single-phase heater and switch, and a separately fused lamp with door switch are provided.

The heater rated and located such that none of the apparatus in the cabinet will suffer damage due to prolonged operation of the heater at high ambient temperatures.

Tap changer control equipment may also be housed in this cabinet, as well as the Oil- and Winding Temperature Instruments.

The cooler control equipment includes:

a. an isolating switch rated to carry and break full-load current for each group of fan motors. These switches are padlockable in the OFF position for maintenance isolation purposes.

b. a "manual"/"auto" change-over switch;

c. a magnetic contactor for each group of fan motors. Contactor coil leads are wired to the terminal board. A set of normally open contacts is provided to initiate an alarm circuit if the contactor is tripped by its overload element. All such contacts of the various groups are paralleled and wired to a pair of terminals in the control cabinet.

d. Magnetic contactors maintain supply to motors at supply voltage down to 0,85 p.u of the rated supply voltage at their terminals. Tripping only occurs on a controlled basis and automatic restarting in the staggered mode is required if the voltage recovers while the transformer is in service; and

e. Provision for disconnection of all fans on the closure of a pair of contacts provided by the Employer on the master tripping relay controlling the isolation of the transformer on the occurrence of a fault.

The ratings of these contacts will be:

(i) Make and carry continuously : 1 250 W at maxima of 5 A and 660 V.

(ii) Make and carry for 0,5 s : 7 500 W at maxima of 30 A and 660 V.

(iii) Break : 100 W resistive

(iv) 50 W inductive as defined in BS 142 : Table 13, i.e. L/R = 40 ms. The arrangement for disconnection the fans are not self-resetting.

A change over relay is provided in the control scheme. A contact of the trip relay, on the *Employe*r protection panels will energise the operating coil of this change over relay which in turn isolates the contactor control circuits. A reset push button is provided in the marshalling kiosk for resetting the above change over relay. The operating coil of the relay is continuously rated, or a make contact of it is wired in series with the operating coil and a break contact in series with the reset coil. Where a contactor is supplied for this purpose, the operating coil is suitable for operation by way of the above mentioned contacts and operates and resets correctly between 80 % and 120 % of the dc auxiliary supply voltage specified in **Schedule AB**. The contactor has two sets of normally closed contacts, one of which isolates the fan and/or oil pump motor control circuit(s), and the other inhibits the fail alarm.

The Cooler control cabinet makes provision for the following:

1. provisions for staggering the starting times of fans or of individual groups of fans if required;
2. overload and single-phasing relays;
3. winding temperature and oil-temperature indicators, which are visible through a window in the door of the cabinet if installed in the same cabinet;
4. links for testing winding temperature relay, and the interposing current transformer;
5. fuses, links and terminal boards (see 4.16) to make a complete assembly; and
6. labelling of all apparatus, which are inscribed indelibly in black lettering on a white background, and does not discolour during long term service.

3.24.7.3 Fans

Fans and fan-motors do not require concrete foundations.

Fan blades and fan ducting are of aluminium alloy, stainless steel, galvanised steel, or other corrosion- resistant material and are designed to keep noise and vibration to a minimum. All fans are provided with galvanised wire-mesh guards. The rotation and air flow directions are clearly and indelibly indicated by appropriate arrows.

3.24.7.4 Motors

All motors are suitable for direct starting and continuous running from the supply voltage specified in **Schedule AB**. Three-phase motors are preferred but single-phase motors of 0,5 kW and less are acceptable

All motors comply at least with IEC 60034 and are of the totally enclosed weather-proof type. Three-phase motors are of the single-cage squirrel cage type. Bearings of all motors are of the ball or roller bearing type. With the exception of oil-pump motors, the bearings are grease lubricated.

Each motor is equipped with a terminal box arranged to accommodate incoming cable provided by the Contractor (see 3.1.16.4). If necessary, a suitable cable box is provided to terminate the cable.

Motors are provided with starters, overload protection (three-phase where applicable) and, in the case of three-phase motors, single-phasing protection. All motors are labelled indicating kW and A rating.

3.24.7.5 Maintenance

Fans/motors are installed such to facilitate easy removal in event of failure. Although very low maintenance is desired, lubrication and servicing instructions, if required, are indicated clearly in the transformer manual. Labelling are provided at each pump and fan.

3.25 QUALITY AND DESIGN REVIEW REQUIREMENTS

3.25.1 Quality

The *Employer* reserves the right to inspect the *Contractor's*- and sub-contractor's *Works* and processes at any stage after receiving tenders in order to assess the manufacturing capabilities and the quality of their products and processes. In addition, the overall quality assurance requirements of ISO 9000 apply as appropriate.

3.25.2 Design Review

A design review in a planned exercise is envisaged to ensure that there is a common understanding of the applicable standards and specification requirements, and to provide an opportunity to scrutinise the design to ensure the requirements meet the Employer's requirements.

3.25.2.1 Objectives

The objective is to review specific aspects of the electrical, mechanical and thermal design is to:

a. Ensure there is a clear and mutual understanding of the technical requirements.

b. Verify the system and project requirements and to indicate areas where special attention may be required.

c. Verify that the design complies with the technical requirements.

d. Identify any prototype features and evaluate their reliability and risks.

3.25.2.2 Reviews

The review meetings are held in several phases with hold point release at the end of each phase. The Contractor compiles a quality plan illustrating all the design review phases including the applicable procedures and standards to be used.

The sequence of the design review is:

a. Tender evaluation closure

b. Tenders / specification clarification review meeting
c. Contract award
d. Contractor performs high level design
e. High level design review meeting. This review is ended by the release of a hold point approving go-ahead to order major components such as copper and core materials.
f. Contractor performs detail design of active part, tank and auxiliaries.
g. Detail design review meeting. This review is ended by the release of a hold point approving go-ahead to order other materials and to start with manufacturing process.

The following design review meetings are held:

3.25.2.2 (a) Tender / Specification Clarification Review

The tender clarification review serves as the first stage after tender closure before the *Contract* is awarded. The information stated in **Schedule AB** and requested in **Schedule AB** is reviewed. Visits to the *Contractor's Works* to inspect the design, manufacture and test facilities may also take place. During this stage the Contractor has the opportunity to ensure that the specification has been interpreted correctly.

The *Contractor* identifies and states the major sub-contractors and the *Employer* describes the intended inspection program during this meeting.

3.25.2.2 (b).i System conditions

The system conditions under which the transformer will be required to operate is reviewed and the *Contractor* confirms the healthy operation of the transformer under these conditions: These include the:

a. AC system voltage variations. Where a load tapchanger is specified, the usage of the tapchanger is examined and how it is operated. That is, will be used as a constant flux unit, or a variable flux unit, or both.
b. AC system frequency variation.
c. DC or harmonic system components.
d. System short circuit capacity including system operating data.
e. System switching and transformer protection.
f. The type of transformer protective switching. Review location, type and rating of switching devices. Review the type and application of over-voltage protection.
g. System earthing conditions.
h. The system connections to the transformer are discussed noting that the surge impedance is less for cable and bus connections. This may affect the terminal impedance used during impulse tests.
i. High frequency transients. Some system operations such as switching of large capacitor banks, GIS or cable are known to produce fast transients (FTs), or very fast transients (VFTs). These and other possible sources of FTs and VTs may result in excessive voltages within the transformer.

3.25.2.2 (a).ii Environmental

The environmental conditions under which the transformer is required to operate are reviewed. Any conditions, which result in a variation in the design or material from the manufacturer's standards, is highlighted and examined. Environmental data reviewed are:

a. Ambient temperature range.

b. Site altitude.

c. Humidity.

d. Pollution.

e. Seismic zone and response spectra.

f. Geomagnetic currents.

g. Isoceraunic level.

3.25.2.2 (a).iii Ratings

a. MVA rating

In addition to the fundamental nameplate rating, any requirements for planned or unplanned overloads are reviewed.

b. Terminal voltages

- No load
- Winding connections and vector relationships.
- Tap changer requirements.

c. Insulation levels

d. Winding impedances

The winding impedances are reviewed including tolerances and anticipated differences between design values and test results. The variation in impedance across the tapping range and any special requirements for paralleling with existing transformers is considered.

e. Cooling provisions

f. Temperature limits

g. Sound levels

i. No load, including any specific requirements for levels above 1.0 p.u. voltage.

ii. Full load.

iii. Variation with tap position.

iv. Variation with tertiary loading (if applicable).

h. No-load and Full Load Losses

3.25.2.2 (a).iv Testing

The inspection and Test Plan is made available for review. The testing requirements of the Contract and standards are discussed and clarified in relation to each aspect of the design.

Special attention is given where the requirements and information required varies from the standards or normal practice of the Contractor.

The following is specifically clarified:

a. Impulse testing: tap position(s), connections grounded terminals, ability to generate the waveshape, detection traces required, number and polarity of impulses.

b. Induced voltage test(s): connection(s), tap position(s), frequency used, duration, percentage of nominal induction, which terminals are grounded.

c. Partial discharge measurement: connections, tap position, required voltage profile, maximum background level, measurement units being microvolt or picoCoulomb, and acceptance criteria.

d. Heat run test(s): tap positions(s), required power available, procedure for oil forced cooling when switching off, any special overload test, required Dissolved Gas Analysis.

e. Heat run tests with auto-transformers: are tests on more then on tap position required.

f. Measurement of No-load and Full-load losses as well as the acceptance criteria for each.

g. Order of tests.

h. Any extra tests required, e.g. during fabrication.

i. Required details in the test report.

3.25.2.2 (a).v Bushings

a. Manufacturer.

b. Tests performed by the manufacturer, including the availability of test certificates.

c. Type and general construction of the bushing.

d. Use of lower terminals shields or insulation assembly.

e. Sensitivity of matching the shields and bushings.

f. Interchange ability.

3.25.2.2 (a).vi Current Transformers

a. Manufacturer.

b. Ratio and accuracy.

c. Overload characteristics

d. Tests performed by the manufacturer, including the availability of test certificates.

3.25.2.2 (a).vii Tap changers

a. Manufacturer.

b. Type and ratings.

c. Overload capabilities

d. Dielectric capabilities.

e. Tests performed by the manufacturer, including the availability of test certificates.

3.25.2.2 (a).viii Internal Surge Arresters

The *Contractor* provides details of any internally connected arresters or non-linear resistors or other means of voltage control installed. The location and mounting arrangement is reviewed.

3.25.2.2 (b) High level Design Review

A high level design review, initiated and chaired by the *Employer* is held for the purpose of conducting an in-depth review of the transformer and to allow the *Employer* to have a clear understanding of the overall design. This review is preferably held after the completion of the electrical design, the preliminary outline drawing, and the rating plate drawing and before the start of any manufacturing activities.

The *Contractor* demonstrates how the design will function reliably within the operating requirements and meet the performance guarantees. Sufficient information is provided for each basic element to review the design for functionality and for future reference, e.g. maintenance considerations.

Any prototype features in the design or fabrication, are highlighted and assessed for risk and reliability. Changes made to the design from that offered and/or discussed in detail during the tender clarification review is presented and described by the *Contractor.*

The *Contractor* highlights and indicates the limits used for current densities, flux densities mechanical Short Circuit forces etc. during the design review. The reasoning behind the specific limits are also discussed during the design review.

The Contractor must provide the following calculations and information for review during the High Level Design Review:

- Overall cooling system performance calculations ,
- Leakage magnetic flux analyses, tank shields, shunts, frame protection. The *Contractor* must outline the availability of 2D and 3D field programs. The field's magnitude in all parts, resultant heating and temperature rises in all parts must be supplied in the design review documents.
- Busbars and wire harnessing layout, balancing, image currents, knee forces, cooling, eddy current in crease by stray flux, clearances support and strength,
- Exit lead arrangements and effects by leakage flux, short circuit capability pitch forces , and image currents in adjacent frames , cooling including eddy current loss by stray flux effects, clearances, knee forces, bending radius and impact on conductors, fixing structures support, connections type and methods
- Coil design and buckling forces, clamping pressures and sizing, cooling at all parts including crossovers, classical hot spot, pitch force management, arrangement conductors, wire details.
- Electrical stress analysis criteria for insulation design. Coil voltage distribution, main insulation design, shield designs. The stress in the insulation must be determined by electrostatic field plots. The design is to show that it has sufficient margin above the industry accepted values (i.e. Weidmann oil curves)

- Transient voltage analysis requirements. The Contractor demonstrates the transient voltages in all parts of the windings which includes part winding resonances
- *Contractor's* acceptance criteria for short circuit design and how this is applied to the design. Details are to be given of supported and unsupported inner winding buckling, axial ending and stress applied to spacers.
- Thermal criteria for hot spot temperatures in various parts of the transformer
- Core cooling, type clamping support, insulation, Material flux distribution and densities, division and earhting, hot spot temp calculations. The Hot spot calculations are based on the maximum localised losses, insulation of the components and oil flow patterns.

3.25.2.2 (b).i Fabrication General Construction

The Contractor provides the following Cover, Base and Tank Construction data:

a. Arrangement of stiffeners / bracing for distortion.

b. Details of gaskets and stops for all flanged joints on the main tank.

c. Fit of interfaces between cover, tank body and flanges. Ensure that all flange surfaces cannot trap water against the gaskets.

d. Location and details on lifting, jacking devices.

e. Tank draining location.

f. Base structure: design and mechanical strength considerations and fitness for the intended foundation.

g. Leakage and deflection tests.

h. Provision and location of the required valves. Any required access during transformer operation is identified.

i. External insulation distances between phases and phase to earth.

3.25.2.2 (b).ii Core

The *Contractor* describes the design for the core, explaining how it performs within the operating parameters. Specific items are reviewed, including the following:

a. A general description of the core

- cross sectional areas
- operating flux density
- weight
- type or grade material
- method used for joints

b. Losses

c. Thermal aspects

- limits

- control
- core asymmetry of the yoke

d. Over-excitation limits

3.25.2.2 (b).iii Winding General arrangement

The *Contractor* describes each of the windings in sufficient detail to provide a clear understanding of the physical arrangements. The description includes the following:

- Number of turns.
- Winding type and dimensions, including axial and radial spacer details.
- Type of conductor or cable, including number of strands and conductor insulation.
- Conductor arrangement.
- Current densities.

3.25.2.2 (b).iv Insulation design

The *Contractor* provides an insulation layout sketch. Each major region of the insulation structure (i.e. main gap between windings, shielding and/or ground insulation at winding ends, inner winding to core, outer winding to tank, axially along windings) is identified with the test or operating condition which is most critical to its dimensioning and design. A brief summary of the stresses in the critical regions for each test or operating condition is reviewed.

The *Contractor* demonstrates how the insulation is designed to withstand the imposed stresses, i.e. indicated insulation structure, corresponding stress and resultant dielectric strength:

a. Turn to turn.

b. Section to section.

c. Winding to winding.

d. Winding to ground.

e. Phase to phase.

f. Location of electrostatic plates and shields.

g. Other winding stresses due to:

- Winding nodes,
- Leads
- Transferred voltages from other windings

Nodes are coil interconnections and changes in winding construction that cause a change in the series capacitance of the winding.

3.25.2.2 (b).v Thermal design

i. Losses

The *Contractor* provides the calculated losses for I^2R and eddy losses. He indicates these losses for the self-cooled and maximum ratings of the transformer

ii. Cooling

The *Contractor* describes how the windings are adequately cooled. This description includes details on:

- Oil ducts and dimensions.
- Oil flow system.
- Location of winding hottest spot temperature.
- Oil velocities, including any concerns about static electrification.

Any special cooling or operating condition specified, such as loss of one cooler or other special cooling considerations are reviewed.

iii. Temperature

The *Contractor* provides a description of the thermal model of the windings and a summary of the calculated temperatures for the various ratings and cooling conditions. This includes:

- Average winding temperature rises
- Hot spot temperature rises; the Contractor describes how the hot spot rises are calculated with pumps on and off if applicable
- Oil temperatures in the windings.

This includes consideration of temperatures over the tapping range where applicable, and for different loading combinations.

Where direct winding temperature measuring probes are required, the locations of the probes are reviewed.

3.25.2.2 (b).vi Overload

Where defined overloads are specified (See Schedule AB, Item AB.17.8), the Contractor describes the following:

i. Top oil and hot spot maximum temperatures.

ii. Anticipated temperatures and capabilities of accessories such as bushings, cable connections, tap changers, leads and busbars.

iii. Provision for oil expansion.

3.25.2.2 (b).vii Mechanical Strength

The Contractor provides a description of the capability of the windings to withstand the mechanical forces due to the specified external short circuits.

This description includes the following:

i. Calculation of fault currents, including impedance, pre-fault voltage,

ii. presentation on how the windings are designed and manufactured to withstand the stresses of each of the failure modes, all as described in the CIGRE W.G.12.19 report

iii. coil clamping provisions,

iv. Supportive evidence or experience.

3.25.2.2 (b).viii Core and Coil Assembly

The Contractor describes the general assembly and mechanical features for the following:

a. Core manufacturer.

b. Core clamping.

c. Core insulation system

- Laminations
- Bonding
- Earthing.

d. Coil clamping, including the clamping pressure used, and why.

e. Provision for withstanding shipping stresses and the design values.

f. Dry-out and processing.

The Contractor describes their methods for moisture removal for the insulation ensuring the design dimensions of the coils are achieved. The acceptance criteria are included.

3.25.2.2 (b).ix Lead and Cleats

The *Contractor* describes the arrangements used for the winding leads and interconnections. This includes details of the following:

a. Methods used for joining interconnections

b. Insulation design

- shielding
- dielectric stresses and strengths.

c. Hotspots and provisions for cooling critical areas. The *Contractor* indicates what and where the critical areas are.

d. Providing mechanical support.

3.25.2.2 (b).x Sound Level

A mutual and clear understanding for the requirements for the sound level is agreed upon with the *Employer*. That is, what is the guarantee, what is it based on and how will it be measured.

The *Contractor* provides a description of the design provisions that are used to meet the specified sound level.

It is generally considered that the core is the primary source of transformer noise; however other sources may also contribute to the operating sound levels. These sources may include:

a. cooling fans,
b. oil pumps,
c. leakage flux shunts,
d. load current in the windings,
e. varying flux design for voltage regulation,
f. internal reactors in the tertiary winding circuit.

While these sources may not contribute to the sound level measured according to IEC 60076-10, the *Employer* may have an interest in knowing the effects for operational considerations.

3.25.2.2 (b).xi Seismic

Generally the seismic activity stresses on the core and coil assembly are much less than the stresses which occur during shipping or system faults. However other structures are reviewed.

i. Structural analysis

The *Contractor* presents a summary of the structural analysis of the transformer due to seismic loading. It includes the method of analysis and the design criteria for the following:

- Welding design and loading
- Flexible expansion / contraction requirements of piping etc.
- Adequacy of provision for anchoring to the foundation
- Stresses and strengths of the
  - Radiator assembly.
  - Conservator.
  - Bushings.
  - Jacking pads and Lifting lugs
  - Other ancillary components as appropriate.

3.25.2.2 (b).xii External Cooling Equipment

i. Fit of interfaces; flanges.

ii. Pressure leakage pre-test details.
iii. Internal cleaning details.
iv. Shut-off valves, review design and material.
v. Pumps.

3.25.2.2 (b).xiii Conservators / Preservation System

i. Fit of interfaces; flanges.
ii. Volume considerations.
iii. Details of conservator bag and level indication instruments
iv. Pressure / vacuum capabilities.
v. Moisture controlling devices.

3.25.2.2 (b).xiv Tank

i. Conforms to the requirements with regards to welding and NDT.
ii. Details to show all weld and NDT processes complete with symbols.
iii. Location and identification of welds to receive NDT.

3.25.2.2 (b)xv Gas Collection System

Review cover design to ensure all gas is directed to a collection point (or points).

Ensure non-gas pipe connections project below the cover.

Ensure all pockets are piped or blocked.

Cover supports or bracing has separate holes or slots to avoid trapping gas.

Slopes are adequate.

3.25.2.2 (b).xvi Surface Preparation and Painting

The Contractor details the following data and processes for Tanks, Radiators, and Conservator etc.

a. Blast material.
b. Checking of blast profile.
c. Paint system.
d. Calibration of dry film thickness gauges.
e. Adhesion testing.

3.25.2.3 (b).xvii Ancillary Equipment

The Contractor provides details and data for the following major accessories, or ancillary equipment.

Bushings

a. Manufacturer.
b. Tests performed by the manufacturer.
c. Type and general construction of the bushing.
d. Use of lower terminals shields or insulation assembly.
e. Sensitivity of matching the shields and bushings.
f. Interchangeability.

Current Transformers

g. Manufacturer.
h. Ratio and accuracy.
i. Overload characteristics

Tap Chargers

j. Manufacturer.
k. Type and ratings.
l. Overload capabilities.
m. Dielectric capabilities.

Internal Surge Arresters

The *Contractor* provides descriptions for any internally connected arresters or non-linear resistors or other means of voltage control. The location and mounting arrangement is reviewed.

Control Cabinet and External Cabling

The following items are reviewed to ensure that the requirements are met:

n. Ensure the cabinet size is adequate and can accommodate the Purchaser’s cables and connections.
o. Wiring standards are correct.
p. Adequate heating and ventilation is provided.
q. Cables from transformer accessories are suitable for the climate and protected mechanically.

On-line Monitoring Equipment

The intended use of specified equipment and sensors for on-line monitoring is reviewed. Fitness for the site conditions in view ambient, EMC and any mechanical stresses is considered.

3.25.2.2 (b).xviii Transportation and Installation

The intended shipping process is reviewed. This includes consideration of the:

a. Routing.
b. Dimensional clearance limitations.
c. Shipping weight limitations.
d. Use of impact recorders.
e. Site handling procedures and requirements.
f. Erection sub-Contractors and warranty considerations.
g. Oil supply

3.26 TESTING

3.26.1 Manufacturers' Testing Capabilities

The *Contractor* is fully equipped to perform all the required tests as specified. Tenderers confirm their manufacturing capabilities in this regard when submitting tenders. Any limitations are clearly stated. The *Contractor* bears all additional costs related to not being able to do the required test at their *Works*, as tendered.

3.26.2 Witnessing of Tests

The *Employer* reserves the right to be present at any of the tests specified.

The *Contractor* ascertains the sequence of tests required in each particular case and whether witnessing of tests is required. After completion of all the preliminary tests in their *Works*, gives the *Employer* not less than 14 days notice of the firm date when the transformer(s) and associated apparatus will be ready for witnessing of the actual testing. As many tests as possible are arranged to take place on the same day.

No transformer are despatched from the *Contractor's Works* without the *Employer's* approval of its testing and overall quality.

Any costs incurred by the *Contractor* as a result of abortive or protracted visits by the *Employer* representatives, due to poor organisation on the part of the *Contractor* or test failures, are for the *Contractor*'s account.

The *Employer* is notified as soon as possible of all test failures and corrective measures. This takes the form of abbreviated reports which, upon request, are supported by more detailed reports. It is desirable that the *Employer* is notified of test failures to allow in situ inspection if desired.

3.26.3 Test Instruments and Apparatus

The testing apparatus are to the *Employer's* approval. All instrumentation and equipment possess a valid, as per manufacturer recommendations, calibration certificate. The calibration certificates of the test equipment and instrumentation reflect the manufacturer's recommended calibration interval. All apparatus are arranged and operated with due regard to the safety of personnel and so as to minimise damage to the test object in case of breakdown.

3.26.4 Test Certificates

Four copies of the test certificates are supplied to the *Employer* within 30 days of the completion of the tests in the *Works*. These test certificates are presented in English.

The certificates note the test equipment serial number, make and last calibration date of the equipment.

A copy of the test certificates is incorporated into each maintenance/operating manual provided for that transformer.

3.26.5 Tests on Site

High-voltage and short-circuit tests at site are not required unless specifically called for in Schedule AB

Refer to Schedule AB for a list of minimum site tests to perform.

The results of the all the site tests done during commissioning are documented and a copy included in the site manual.

3.26.6 Temperature Rise Tests

NOTE — THE TEMPERATURE RISE LIMITS DIFFER FROM IEC 60076 (SEE 4.1.1.).

3.26.6.1 Test conditions

The test is generally carried out in accordance to IEC 60076-2.

Note that the Employer regards the Heat Run test as a quality test on all transformers larger than 3.125 MVA and not a type test as per IEC. Thus where more than one transformer or consecutive transformers are ordered of the same design over 3.125 MVA Heat Run test must be done on all ordered transformers. This requirement can be waved depending on circumstances and as per the requirements as specified in Scheduel AB.

The Heat Run tests must be done on the centre phase of the transformer being tested and the Heat rise gradients of the centre phase measured and recorded.

System and other transformers:

A temperature rise type test is carried out on each of the transformers, if specified in **Schedule AB**. The test is carried out with the transformer connected on the tapping with the highest losses.

(a) The top oil temperature rise is that resulting from the circulation under the specified test conditions of sufficient current to produce the total losses, corresponding to those which would occur in service, when the transformer input winding carries rated power at rated voltage on the tapping giving the highest losses.

(b) In the case of transformers with more than two windings, it is assumed that the remaining windings will carry the specified loading combination which would result in maximum losses, assuming that the loads on these windings have the same power factor as the power supplied to the input winding.

(c) A dissolved gas analysis test is performed both before and after the heat run type test in order to detect possible hot spots. Note: that the permissible gas increases tabled in table 8 is to be used and not the values as tabled in table A-1 of IEC 61181.

Table 8:Permissible gases in oil increases during testing

Gas Symbol	Gas Name	Permissible increase (ppm)
CH4	Methane	2
C2H6	Ethane	2
C2H4	Ethylene	1
C2H2	Acetylene	No Increase (Not detectable)
H2	Hydrogen	10
CO	Carbon Monoxide	20
CO2	Carbon Dioxide	200

3.26.6.2 Test records

Full details of the test arrangements, procedures and conditions are supplied with the test certificates and include the following:

3.26.6.3 (a) General

1) The *Employers'* order number and transformer site designation.

2) Manufacturer's name and transformer serial number.

3) Ratings of transformer:

(a) MVA

(b) Voltages and tapping range

(c) Number of phases

(d) Frequency

(e) Rated currents for each winding

(f) Vector Group

4) Class of cooling.

5) Measured no-load losses and load losses at 75 °C .

6) Altitude of test bay.

7) Designation of terminals supplied and terminals strapped.

3.26.6.4 (b) Top oil temperature rise test

A log of the following quantities taken at half-hourly intervals:

i. time;
ii. volts between phases;
iii. current in each phase;
iv. power in each phase and total power;
v. ambient temperature, measured on not less than three thermometers (or water inlet and outlet temperatures);
vi. top oil temperature; and
vii. cooler inlet and outlet oil temperatures.

NOTE — When requested by the *Employer,* infra-red scanning is done, as agreed between the *Employer* and the *Contractor*.

3.26.6.5 (c)Winding temperature rise test (centre phase only)

1) Record the weight of conductor in each winding, and the losses in watts per kilogram, the 'cold' resistance of each winding and the simultaneous top oil and ambient air temperatures, together with the time required for the inductive effect to disappear.

2) Record the thermal time constant of the winding.

3) Log the half-hourly readings of the quantities as for the top oil temperature rise test.

4) Provide a table of readings, after shut-down of power, giving the following information:

i) time after shut-down;

ii) time increment;

iii) winding resistance;

iv) resistance increment;

v) x, where x is the time after shut-down divided by the thermal time constant of the winding; and

vi) y, where y = 100 (1-e⁻x)

(Any graphical/computer method used to determine the temperature of a winding by extrapolation to the instant of power shut-down must produce a linear curve.)

5) Provide a record of all calculations, corrections and curves leading to the determination of the winding temperatures at the instant of shut-down of power.

6) Record any action taken to remedy instability of the oil surge device during initiation of the oil circulating pumps.

Where two or more coils are used to make up a winding, consideration is given to the fact that the time constant for the coils might not be the same. Thus using a simple model of one exponential curve to fit the resistance (or temperature) as a function of time curve will not be sufficient. An equation consisting of two or more exponential constants is required for the curve fitting process.

NOTE — The possible measurement of winding temperature by using probes during this test is agreed upon by the *Employer* at the *Contract* placing stage.

3.26.6.2 (d) Untanked Current test

If specified in **Schedule AB** an Untanked Current test must be performed.

During the test current is injected into the transformer once the active part is complete and all leads and coil paper have been impregnated with oil. Thermo vision scanning equipment is used to look for Hot Spots. Another method is to look for any smoke generation by Hot Spots.

An alternative test achieving the same objective is acceptable.

3.26.7 Short-circuit Tests

3.26.7.1 Transformers to be tested

One transformer of any batch may be selected by the Employer for short-circuit testing to prove its ability to withstand the expected short-circuit currents, specified in Schedule AB. The Employer, prior to carrying out any such tests will communicate this fact, complete with the serial number of the transformer, to the Contractor.

Calculations may be submitted in lieu of short circuit tests.

3.26.7.2 Reference data, diagnostic tests and inspection

Short-circuit tests are generally be carried out as specified in IEC 60076-5.

The transformer is able to withstand a short-circuit with the source voltage at U_m.

The details of all reference data and oscillograms are recorded before the tests and used as a basis of reference for the determination of the effects of the short-circuits on the transformer. The testing techniques and procedures to be used to diagnose such effects, are subject to agreement between the *Contractor* and the *Employer*.

Fast transient analysis of the transformer impedance may be applied to identify any damage.

3.26.7.3 Tests circuit arrangement and currents

The test circuit is arranged to apply the short-circuit currents to the transformer having one winding previously short-circuited by means of bolted connections.

The transformer is disconnected from the supply by means of a circuit breaker. The fault current and the minimum and maximum time settings are subject to agreement between the *Contractor* and the *Employer*.

3.26.7.4 Application of currents

The short-circuit test consists of three applications, spaced at suitable intervals to avoid excessive temperature in any part of the transformer.

The tapping and point-of-wave switching positions are selected by the Employer. 3.1.25.7.5 Test results and conclusions

The transformers are considered to have passed the tests if it is agreed that no damage or distortion has resulted from the application of the short-circuit currents.

3.26.8 Impedance and Load Loss Measurement

3.26.8.1 Impedance

The impedance of every transformer is measured on the principal tapping position and on the two extreme tapping positions, in accordance with the requirements of IEC 60076.

Details of the terminals short-circuited and the terminals supplied with power, the tapping positions, the current, voltage and frequency readings, the winding resistance and the corresponding temperature of the windings under tests, together with the impedance corrected to 75 °C winding temperature, are recorded on the test certificate.

3.26.8.2 Load losses

NOTE — The *Employer* does not allow any tolerances on load losses above that stated in IEC60076-1, table1.

3.26.8.2 (a) Load losses on principal tapping

The load losses on every transformer on the principal tapping position, and when referred to the rated current on the tapping, are measured and corrected to 75 °C.

3.26.8.3 (b) Load losses on other tapping positions (system transformers)

The load losses are also measured on the tapping position(s) giving maximum losses. These losses are referred to the principle tapping

3.26.8.2 (c) Records required

In addition to the details in 3.1.25.8.2(a) the following details must be recorded under the heading of load losses on the test certificate:

1) voltage measured across the phases;
2) currents measured in the phases;
3) total losses measured;
4) total losses corrected to 75 °C winding temperature.

3.26.9 Acoustic Noise Level Measurement

3.26.9.1 Method

Where, in Schedule AB measurement of the acoustic noise level produced by the transformer is specified, the method to be used is in accordance with IEC 60076-10.

3.26.9.2 Records

Full details of the arrangements and conditions of the tests and of the readings and corrections made are recorded on the test certificates. When the measured values exceed the values specified in Nema T-R-1, the transformer is regarded as having failed the test (see 3.1.25.2).

3.26.10 Magnetising Harmonic Current Measurement

3.26.10.1 Transformers to be tested

The harmonics of the no-load currents in the three phases are measured and the harmonics expressed as a percentage of the fundamental. The measurement is done at 0,9 U_n, U_n and 1,1 U_n.

3.26.10.2 Records

The magnitude of the harmonics, expressed as a percentage of the fundamental component, is recorded on the test certificates for each of the test voltages.

3.26.11 No-load Loss and Current Measurements

3.26.11.1 Method

The no-load losses and the no-load current of every transformer are measured as specified in IEC 60076, unless specified differently in Schedule AB. The guaranteed value of no-load losses, as called for in Schedule AB, is that incurred by the application of rated voltage to the principal tapping. Measurements are also made on that tapping which produces maximum flux conditions in the magnetic circuit. In each case the measurements are made at 0,90 Ut, 1,00 Ut and 1,10 Ut, where Ut is the particular tapping voltage.

3.26.11.2 Records

The following details are recorded and submitted with the test certificates:

a. the terminal markings of the terminals supplied with power;

b. the voltage readings taken on each voltmeter on each phase;

c. the mode of response and scaling of the voltmeters;

d. the current readings taken on each phase;

e. the power readings taken on each phase;

f. the frequency reading;

g. the instrument constants and corrections;

h. corrections made to power and current results, due to non-sinusoidal wave forms of voltage and current;

i. the magnetization curve of the transformer.

NOTE — The *Employer* does not allow any tolerances on no-load losses above that stated in IEC60076-1, table 1.

3.26.12 Core Assembly Dielectric and Earthing Continuity Tests

3.26.12.1 Method

The insulation of the magnetic circuit, and between the magnetic circuit and the core clamping structure, including core-bolts, bands and/or buckles withstand the application of a test voltage of either 2 kVac or 3 kVdc for 60 seconds. The continuity of the single-point earthing is verified before despatch.

For transformers operating at voltages at and higher than 275kV the test voltage is 8KV r.m.s in the dry state, prior to oil filling and 16kV after oil filling.
This test is to be done at the factory and is to be verified again on site after installation.

3.26.12.2 Records

The results of the *Works* tests are recorded on the test certificate, and include the resistance reading obtained from a measurement made between the core and core clamping structure by means of at least 1,5 kVac or 2 kVdc. Where erection is included, the *Contractor* repeats this measurement on arrival at site. The records of the results of these tests are included in the transformer manual.

3.26.13 Power Frequency Voltage Withstand Tests

3.26.13.1 Separate source voltage withstand tests

3.26.13.1 (a) Test requirements

These tests are performed as specified in IEC 60076-3.

3.26.13.1 (b) Applied power frequency withstand voltages

The power frequency withstand voltages are given in **Schedule AB**.

3.26.13.2 Induced AC voltage tests

The ACSD (Short-duration AC withstand voltage test) shall be performed as stipulated in IEC60076-3. This test shall be without PD (Partial Discharge) measurement except where indicated differently in the **Schedules AB**.

3.26.13.2 (a) Acceptance criteria

Acceptance criteria as per IEC60073-3

3.26.14 Lightning Impulse Voltage Withstand Tests

3.26.14.1 Methods and procedures

These tests are carried out as recommended in IEC 60060 and IEC 60076-3, except when otherwise agreed to in writing, between the *Contractor* and *Employer*. The gas and oil actuated relay is in operation during the tests and is checked for gas content before and after the tests.

3.26.14.2 Tests required

Lightning impulse tests, comprising full wave tests, are carried out as a routine test on all transformers at values specified in Schedule AB.

The specified voltage impulses are applied to each terminal in turn, including, for transformer windings having partially graded insulation, the neutral terminal, all other terminals being earthed.

Alternatively, for partially graded insulation, the specified test voltage may be produced at the neutral terminal by earthing this through a suitable resistor when applying an impulse voltage through the line terminals.

Chopped wave impulse tests on neutral terminals are not required.

3.26.14.3 Test apparatus

The test apparatus and circuits, including all earthing and measuring arrangements and circuits, are free of any cause of high frequency or spurious oscillations, and are to the approval of the *Employer*.

3.26.14.4 Choice of tapping position

The tapping position, on which the transformer windings are connected for the purpose of the impulse tests, is agreed upon by the Employer after examination of recurring low voltage impulse measurements or other valid studies for all tap positions.

3.26.14.5 Impulse voltage levels

The minimum peak value of the applied impulse voltage for any test is that specified in Schedule AB.

3.26.14.6 Application of voltage impulses

Apart from the voltage impulses required for calibration of apparatus, the normal sequence of voltage impulses applied to the transformer is:

- one full-wave at reduced voltage for the purpose of reference;
- one full-wave at the specified test voltage;

* NOTE — Accurate control of the chopping time is preferred.

3.26.14.7 Records

The report of the test gives full details of the test circuits, the measuring apparatus and its calibration for determination of the crest values of the voltage impulses.

Oscillograms requiring comparison have the same amplitudes and sweep times and are affixed to the same sheet and where possible, adjacent to one another. The details necessary for the analysis of the oscillograms, including voltage amplitude and time calibration, are given on the sheet to which they are affixed or on which they appear.

Each oscillogram is properly identified, and is of such size and so produced and reproduced as to give throughout clear resolution of the traces, which are continuous and free from spurious oscillations.

The oscillograms provided clearly show:

(a) for recording the voltage wave-shapes:

the wave front,

the wave-tail down to at least half-value.

(b) for recording test results:

the voltage wave trace from its inception back down to at least the half-value, but in any case as far as may be required for fault location,

in the case of chopped wave impulses, the voltage wave trace from its inception to at least 10 ìs after the instant of chopping, but in any case as far as may be required for the location of faults occurring in the transformer after chopping of the voltage wave; and

(c) for recording the current trace shapes and test results

the oscillations of the neutral current trace, including the higher frequency components near the front of the wave,

enough of the current trace to permit detection of any discrepancies occurring at the tail end.

These requirements may demand more than one current trace and the respective sweep times are chosen so as to give clear identification of the later parts of the traces produced by the shorter sweep times with the corresponding parts of the traces produced by the longer sweep time(s).

3.26.15 Bushing Tests

3.26.15.1 Tests and records

Bushings are tested in accordance with the recommendations of IEC 60137.

The withstand voltage test levels for the transformer are given in Schedule AB, items **AB.22.5**, **AB.22.6** and **AB.22.7**. Wherever any test is to be carried out to prove the efficiency of any bushing seal, that test is preceded by the application of the cantilever load specified in 3.1.25.15.2, and those leakage tests, in turn, precede the dielectric tests to be made on the particular bushing.

The bushing test certificates include adequate details of the conditions of the test, bushing temperatures, the test methods, procedures, apparatus and connections, instrument calibration, test readings and oscillograms, corrections and results, including plots of curves where relevant.

3.26.15.2 Cantilever loads for leak tests

Immediately prior to the commencement of any test to prove the effectiveness of any bushing seal, a steady cantilever load is applied to the external bushing terminal in any direction normal to the axis of the bushing for 60 seconds.

The value of this cantilever force is not less than that given in Table 9 of this Specification for the corresponding bushing voltage rating.

Table 9: Maximum cantilever forces on bushing terminals

In <800	Up to 1 600
1 000	1 250

3.26.15.3 Type tests

The type tests included in IEC 60137, and those listed below are carried out on one bushing of each design, type and rating, which is fully representative of the bushings being supplied with the transformer. The results of these tests are included in each transformer manual.

The tests for the efficiency of the seals are specified in IEC 60137.

A test for leakage under vacuum at the conductor seals of all bushings.

The bushings, mounted on a test tank, are subjected to a full vacuum drawn on the empty tank. The tank is then sealed off from the means used to evacuate it.

The bushing conductor is deemed to be effective if, after 15 minutes, the original vacuum is maintained.

All other type tests prescribed by IEC 60137.

3.26.15.4 Routine tests

The required routine tests are those prescribed in IEC 60137.

A dielectric loss angle measurement is required to be made at 10 kV in addition to that specified in the above mentioned document. The bushing temperature is recorded.

Measurement of partial discharge, in accordance with the recommendations in IEC 60270, is made at ambient temperature on all the bushings for operation at a dielectric stress above 1,5 kV/mm across major insulation of organic material. The bushing temperature is recorded.

3.26.16 Testing of Current Transformers

3.26.16.1 General

The type and routine tests called for in IEC 60044-1 are carried out as specified, except where modified in this subsection.

3.26.16.2 Insulation test levels

The power frequency and impulse withstand voltages to be applied are those applicable to the power transformer as specified in Schedule AB.

3.26.16.3 Type tests

3.26.16.3 (a) Type tests previously performed

If evidence is available of type tests previously performed on identical current transformers that meet the Employer's requirements, this may be acceptable instead of these tests.

3.26.16.3 (b) Impulse tests on transformer

The current transformer is in position and connected as in service during the impulse tests carried out on the power transformer with which they are associated. All current transformers are short-circuited and earthed during the test.

3.26.16.3 (c) Additional type tests

The following are required as additional type tests for protection current transformers:

1. a magnetization curve which includes the kneepoint of the curve;
2. the secondary winding resistance referred to 75 °C; and

the secondary leakage reactance in the case of high-reactance current transformers.

3.26.16.4 Routine tests

3.26.16.4 (a) Secondary insulation and polarity tests

In addition to the specified tests, a final check on the secondary circuit insulation and the polarity of each current transformer, in relation to the power transformer connections, is required before despatch.

A test voltage of 2 kV rms. is applied for 1 minute between the external terminals of each secondary winding, or section thereof and earth; any other winding, core, frame and case (if any) all being connected together and to earth.

3.26.16.4 (b) Accuracy of protection current transformers

The following measurements are recorded:

In the case of Class X current transformers, the excitation current is measured with the secondary voltage specified in Schedule AB, item AB.22 applied to the secondary winding.

Secondary winding resistance referred to 75 °C.

The secondary leads of all current transformers are short-circuited in the factory prior to dispatch.

3.26.16.5 Test certificates

The records of all tests and measurements required by IEC 60044-1 including previous type tests and the corresponding current transformer serial numbers, are attached to the test records required for the power transformer(s) with which the current transformers are associated.

3.26.17 Transformer Tanks Tests

3.26.17.1 Routine oil leakage test

3.26.17.1 (a) Tank and fittings

Each transformer tank complete with all the fittings and attachments normally in contact with the transformer oil, and filled with oil with a viscosity not greater than that specified in IEC 60296, withstands for twenty four hours at room temperature, without leakage, a hydraulic pressure which is not less than 35 kPa above the maximum working pressure at every point in the transformer.

3.26.17.1 (b) Pressure relief valve

One pressure relief valve of each make and type, and set to open at the specified pressure, withstand for twenty four hours, at room temperature, an internal pressure of oil of 20 kPa above the maximum working pressure at the position of the valve, without leakage.

3.26.17.2 Strength tests

3.26.17.2 (a) Internal hydraulic pressure withstand

One tank and oil conservator of each type and size are subjected for 1 minute, to an internal hydraulic pressure equal to 70 kPa or the maximum operating pressure plus 35 kPa whichever is the greater, without suffering permanent deflection, measured after a first application greater than the amounts specified in Table 12 of this Specification. The application point of the hydraulic pressure is such that the maximum pressure measured at the point of Pressure Relieve Valve installation in the tank is not higher than the values stated above

3.26.17.2 (b) Vacuum withstand

One tank and oil conservator of each type and size, both empty of oil, are subjected for 1 minute, to an absolute internal pressure of 1,5 kPa, against atmospheric pressure at sea level on the outside, without suffering permanent deflection, measured after a first application greater than the amounts specified in Table 10 of this Specification. After a second application no further permanent deflection must be measurable.

NOTE — The above two tests may, by agreement, be combined.

Table 10: Maximum permanent deflection of steel tank panels between

Maximum permanent deflection (mm)	Major dimension of fabricated assembly (mm)
16	> 3 000
14	> 2 700 > 3 000
12	> 2 300 > 2 700
10	> 2 000 > 2 300
8	> 1 650 > 2 000
6	> 1 300 > 1 650
4	> 950 > 1 300
3	> 750 > 950
2	> 600 > 750
1	> 450 > 600
0	< 450

3.26.17.2 (c) Dye-penetrant

To avoid leaks dye-penetrant testing is done prior to corrosion proofing of the tank and other manufactured fittings after any welding.

3.26.18 Gas and Oil Actuated Relay Tests

3.26.18.1 Routine tests

These tests are carried out on each relay completely assembled as in service.

3.26.18.1 (a) Oil tightness

The relay is subjected to an internal hydraulic pressure of oil of 70 kPa for twenty four hours, at room temperature, without leakage.

3.26.18.1 (b) Insulation

The relay circuits withstand for 60 seconds an applied voltage of 2 kV rms. applied in turn between each electrically independent circuit and the casing of the relay and between the separate and independent electrical circuits.

3.26.18.1 (c) Alarm signalling

Air is introduced into the relay mounted as specified in 3.1.20, and at a minimum angle of 5 degrees rising towards the oil conservator but at the same angle as it would be in service, until the alarm signalling contacts close. This takes place before the air escapes freely from the relay towards the oil conservator, but not before a minimum quantity of air has been collected in the relay housing. This minimum is, in the case of a 25 mm relay, approximately 0,2 ℓ, and in case of 50 mm and 75 mm relays 0,3 ℓ and 0,4 ℓ respectively.

The quantity of air in the relay at the point of closure of the alarm signalling contacts is recorded on a relay test card.

3.26.18.1 (d) Tripping

With the relay mounted as in 3.26.18.1(c)) of this subsection, the tripping functions are verified by tests to prove that the tripping contacts will close as follows:

with steady rates of oil flow through the relay within the limits given in Table of this Specification, at room temperature;

with an oil surge through the relay, produced by the rapid opening of a lever operated valve, preferably also within the limits given in Table of this Specification.

In both (1) and (2), the closure of the relay contacts are unaffected by the presence in the relay of sufficient gas to escape freely through the oil conservator pipe connection; and

with further accumulation of gas in the relay but before gas escapes to the conservator.

The results of these tests, together with the flow rates producing contact closure at a 5 degree rising angle are recorded on the standard relay test card specified in 3.1.20.10.

The quantity of gas in the relay at the point of closure of the trip contacts is recorded on the relay test card specified in 3.1.20.10.

3.26.18.2 Type tests

One relay of each make, size and type is, after routine testing, subjected to the following tests (unless acceptable certificates of previous tests on identical relays are available):

3.26.18.2 (a) Vacuum

The empty relay is subjected to an internal pressure of 1,5 kPa against atmospheric pressure at sea level without damage.

3.26.18.2 (b) Contact life, vibration and shock

The alarm signalling and tripping contacts are tested as specified in 4.26.19. After these tests the routine testing of the relay is repeated.

3.26.19 Tests Applied to Devices with Alarm and Tripping Contacts

3.26.19.1 Routine tests

The manufacturer's routine tests are performed to confirm that individual protection instruments or relays were correctly manufactured and set up

3.26.19.2 Type tests

The following type tests are carried out on one complete instrument or relay of each design and rating and equipped with alarm and tripping contacts and mounted as in service.

3.26.19.2 (a) Contact life test

With the contacts loaded as in service and monitored by electrically operated counters, the device is operated over 2 500 complete cycles during each of which the making and breaking capabilities of the alarm and tripping contacts are demonstrated without sign of distress or failure.

3.26.19.2 (b) Power frequency (100 Hz) vibrations

A test is carried out on one complete device of each type and size, fitted with alarm and tripping contacts, as follows:

The device, having its contacts electrically monitored by means of an instrument capable of registering and recording a contact closure of 1 ms duration, is subjected to a sinusoidal vibration having a frequency of 100 Hz and an amplitude of 0,25 mm + 0,05 mm peak to peak and thus a maximum acceleration of 6 g in the plane of movement of the contact making arrangement for a period of 1 000 hours, during which there is no maloperation of the contacts.

Upon examination after the test there is no evidence of undue wear of any part of the movement, contact mechanism or connections of the device.

3.26.19.2 (c) Vibration, earth tremors and blasting

The equipment must comply with IEC 60255-21-3.

3.26.19.2 (d) Magnetic fields

It is demonstrated that the relay contacts are immune to magnetic fields which may be present around the transformer during inrush or through-fault conditions. Design features to achieve this are elaborated upon.

3.26.20 Overload Test

If so specified in Schedule AB, Item AB.28.1 an Overload test is performed. Refer to Schedule AB, Item AB.28.1.6 for the overload percentage and time duration of the test. The overload time duration as specified in Schedule AB, Item AB.28.1.6 commences as soon as the transformer reaches normal working temperature.

The test is done at each extreme tap position so as to induce maximum stray flux deviation.

During the test; tank, cable boxes, heavy current boxes and, bushing pocket temperatures are measured and recorded. A Thermal Camera is used for this purpose.

3.27 DRAWINGS AND MANUALS

3.27.1 Contract drawings

The Contractor guarantees in Schedule AB, to supply the drawings within the specified time. When microfilms or velos of the Contractor's standard drawings are supplied, the microfilms or velos also bear the Employer's drawing number and the Employer's order or Contract number.

The following drawings supplied:

a. preliminary outline and general arrangement drawing, including foundation details (A2);

b. details of underbase and jacking points to permit the design of plinth and off-loading facilities (A3);

c. schematic and, if applicable, wiring diagrams for on-load tap changer circuits, including a diagram of the complete timing cycle for the tap changer giving (A2):

1. **Time in seconds for normal tap changer operation stepping in:**
   i. raise direction after previous raise; and
   ii. lower direction after previous raise.
2. **Time in seconds for tap changer operation where a transition step is involved when stepping in**:
   i. raise direction after previous raise; and
   ii. lower direction after previous raise.

The schematic drawing includes:

1. motor power and control circuits;
2. tap position indicator circuit: and
3. location of each item of equipment either by means of suitable terminal marking or legend.

d. schematic and, if applicable, wiring, drawings for cooler control circuits (A2);

e. final outline and general arrangement (A2);

f. shipping and transport drawings (A2);

g. rating and diagram plates (A3);

outline, mounting and constructional details of marshalling boxes and control cubicles (A2);

h. cabling drawings for fan motor, pump motor and on-load tap changer control circuits (A2); and

i. manufacturing drawings for all transport blanking plates.

j. High Voltage and Low Voltage bushing drawings. The drawings show both internal and external dimensions.

k. Drawings showing Flexible (Low Voltage connection) arrangement detail. All dimensions and sizes are shown.

The same device references are used on schematic, wiring and cabling drawings.

3.27.2 Instruction manuals

The number of copies of approved instruction manuals for each transformer is as specified in Schedule AB. The manuals are complete with all approved drawings that are adequate to enable the equipment to be assembled, checked and overhauled.

Only original documentation, especially from sub suppliers, is provided. Photocopies are not acceptable due to the loss of colour information.

A complete set of all drawings submitted during the contracting stage is also included in the manual (i.e. a) to l) of 3.27.1.).

Each manual bears on the front cover the:

a. power station name;

b. order number;

c. manufacturer's serial number; and

d. rating and ratio.

Information is included on the following:

a. a completed copy of the Employers' Order Specification (Schedules A and B);

b. checking and erection procedures at site;

c. mechanical operation of tap changers and cooling apparatus;

d. electrical control of tap changers, fan motors, pump motors etc.;

e. assembly, adjustment and routine maintenance procedures for on-load tap changers and cooling apparatus;

f. drawings of tap changer circuit diagrams;

g. drawings of oil-filled bushings and outlines of HV, MV, LV and neutral bushings;

h. details for the calibration of winding temperature thermometers;

i. a set of A-5 size colour photographs of the specific transformer completely assembled showing all details, sides and top;

j. setting and testing of winding temperature and oil temperature, thermometers and gas and oil actuated relays;

k. serial number of the transformer unit;

l. details of permissible vacuum and site processing (drying-out procedures);

m. a copy of the certificates of all tests carried out by the *Contractor*, including the results of winding and core insulation resistance tests,

n. internal arrangement of the core and windings, showing lead supports and winding clamping arrangements;

o. details of core and core clamping; and

p. sectional arrangement drawing of the windings showing sufficient details of the conductors and insulation for local maintenance purposes.

q. long-term storage procedures for the transformer as well as for any spares supplied with the transformer to ensure these are adequately stored.

r. Loading diagram in table or graphical form showing permissible loading and time duration of the transformer with one to all cooler banks in operation.

The manual is designed from a user's point of view. It is organised in a logical sequence and all maintenance instructions are additionally collected from the relevant subsections and presented in a simplified/summarised format for the transformer as a complete unit, while maintaining reference to subsections which may contain more details.

These instructions refer to specific maintenance time periods, e.g. 3, 6, 12 months, 3 years, 6 years, etc., for the life of the unit. Specific attention is paid to bushing installation, transport, tap changer maintenance, processing and site tests.

For all projects an extra copy of the manual accompanies the transformer to site and is handed over to the *Project Manager*.

3.28 COMPONENT APPROVALS

The components and fittings associated with transformers are subjected to the Employer's approval. Technical literature, drawings, tests reports and lists of the names of the principal users, with the experience gained, is supplied on request.

Where the Employer deems it necessary the Contractor supplies sample components for approval by the Employer at the Employers cost.

The Employer has a preference for standardised and approved components already in use by himself in order to minimise spares.

3.29 CONDITION MONITORING / ASSESSMENT EQUIPMENT

3.29.1 Provision for Installation

The transformer is designed to accommodate the installation or retrofitting of modern on-line condition monitoring equipment. Unless specified the transformer Contractor proposes monitoring equipment and detailed constructional designs for approval suitable for his design of transformer and he provides for the facilities and fittings for optimum interfacing, installation or retrofitting of such monitors.

On line gas monitoring connected into remote indication or alarm facilities, is provided if specified in Schedule AB.

If specified in Schedule AB a fibre optic temperature sensor is installed in the windings of the Generator transformer.

3.30 RATING AND DIAGRAM PLATES

3.30.1 General

Rating and diagram plates comply with the requirements of IEC 60076 except where otherwise stated in this section of this Specification.

3.30.2 Materials and Methods of Marking

Rating and diagram plates are of stainless steel not less than 1,2 mm in thickness.

The required information is engraved on the plate and the engravure filled with glossy black, baked enamel.

The *Contractor* submits other arrangements for approval by the *Employer*.

3.30.3 Mounting

The rating and diagram plates are mounted on a purpose made backing plate, finished in accordance with 4.17.3.3, situated in an accessible position not more than 1,5 m above ground level, by means of stainless steel screws.

3.30.4 Information to be Displayed

The information displayed on the rating and diagram plate is in accordance with the requirements of IEC 60076 with addition of the following:

a. Tapping current values are shown for HV, MV and LV terminals for the principal tapping positions, and for the extreme tapping positions. Tapping values of current are also shown for those tapping position where the current will not exceed 1,05 times the rated current on the principal tapping.
b. the capability of the transformer (including bushings and tap changers) to carry overloads in accordance with the emergency duties detailed in IEC 60354 is shown; the system fault levels in kA for which the transformer is designed (as specified in Schedule AB, items AB.9);
c. zero sequence impedances in the case of three-winding auto transformers;
d. the current transformer data detailed in 4.14.8 must be shown;
e. a statement that the *Contractor* deems it necessary for the transformer to be oil-filled under vacuum appears;
f. a statement that the transformer will withstand full vacuum at sea level appears;
g. the *Employer's* Reference Number appears on the rating and diagram plate;
h. a blank space for the *Employer's* Asset Number is provided;
i. type, make and designation numbers of all bushings, to enable full identification (relating to stock spares) while the transformer is energised;
j. valve and oil sampling point functions and positions; and
k. a warning statement that the conservator contains a bag or other sealing systems if it is the case.

Whilst a single plate is preferred, separate plates mounted adjacent to the main plate are acceptable for the information required by items (f), (g), (h), (j), (k), and (l).

3.31 ADJUDICATION OF TENDERS

3.31.1 Failure Rates, Reliability and Manufacturing Experience of *Contractor*

The failure rate, reliability and manufacturing experience of the transformers, reactors and phase-shifters supplied from the transformer factory from which the Employer's transformer(s) will be sourced during the past 10 years are provided in Schedule AB. The statistical data of failure rates and manufacturing experience reflects the experience of the factory from which the Employer's transformer will be sourced and not the company group.

The factory failure rate, in service failure rate, manufacturing and testing experience statistical data is used during the tender evaluation.

3.31.1.1 Population

The population of transformers to be considered in the calculations of the in failure rates is transformers with a rating above that specified in Schedule AB that was manufactured at the factory over the past 5 years

3.31.1.2 Factory Failure

A failure in the factory is defined as a situation arising where major opening/dismantling of the transformer is required to correct a failure caused during factory testing. Thus having to drop the oil, untank or remove the top yoke in order to repair a failure or defect caused during testing is defined as a factory failure.

3.31.1.3 Factory failure rate

The factory failure rate (one-year) is defined as the ratio of the number of factory failures to the population of transformers, reactors and phase-shifters manufactured over a one-year period. A minimum of 5 years data is provided in the tender documentation. The factory failure rate (five-year) is the rolling average of the factory failure rates (one year) taken over a five year period Failures during testing of special transformers or new developments may be excluded from this statistics.

3.31.1.4 In service failure

An in-service failure is defined as a forced outage failure plus a scheduled outage failure as defined in IEEE 57.117.1986. Further to the definition in IEEE 57.117.1986 the

regarded as an in-service failure if the transformer had to be removed from its bay for the defect to be repaired

3.31.1.5 In service failure rate

The in-service failure rate (one-year) is defined as the ratio of the number of in-service failures to the population of transformers, reactors and phase-shifters accumulated service time over a one-year period. A minimum of 5 year's data is provided in the tender documentation. The in-service failure rate (five-year) is the rolling average of the in-service failure rate (one year) taken over a five year period.

3.31.2 No-load and Full-load Loss Evaluation

Depending on the size of the transformer the Full-Load and No-Load losses of the transformer will be evaluated by either method a or b described below:

For transformers larger than 3.125 MVA the no-load and full-load losses are evaluated by means of the Present Value Life Cycle Cost formula, given below:

$$PVLCC = CC + VateA \times AF \times NLL) + (RateB \times FLL \times LF^{2}) + RateC \times AF \times AUX \sim$$

Where:

CC	=	First capital cost of one unit delivered and erected.
NLL	=	Losses at no load conditions in MW
FLL	=	Losses at full load conditions (unit at 75 °C and at maximum rating) in MW
AUX	=	Auxiliary energy utilised (Pumps, Fans etc.). Spare cooler bank not engaged.
PVLCC	=	Present Value Life Cycle Cost of transformer
Rate A	=	Base Generation cost (R / [MW])
Rate B	=	Peak Generation costs (R / [MW])
Rate C	=	Auxiliary energy used cost (R / [MW])
AF	=	Availability Factor

LF = Load Factor

Refer to Schedule AB for the values of Rates A to C, AF and LF that will be used in the loss evaluation formula during the tender evaluation.

NOTE — the Employer does not allow any tolerance above that stated in, IEC 60076-1 table 1, on individual loss figures. Penalties will be applied where the guaranteed losses in Schedule AB exceed the tolerances as allowed for in the in the contract.

For transformers smaller and equal to 3.150 MVA the losses as tabulated in table 7 of SANS 780 applies.

3.31.3 Other Tender Returnables

To assist in the evaluation of the tenders, the following typical tender drawings and descriptive data as specified in Schedule AB and as deemed applicable by the Tenderers are required to be submitted with the tenders:

i. outline drawing showing the position of terminals, conservator and gauge glasses and control cubicle;
ii. diagrammatic arrangement of windings and tappings; and
iii. Sectional drawings of core and windings;
iv. Tender information is submitted related to the pre-treatment and sizing of windings and the assumptions made for the calculation of short-circuit strength;
v. drawings of the on-load tap changers or off-circuit tapping switches;
vi. type test certificates of identical units if available; and
vii. outline drawings of bushings
viii. Schedule AB, duly completed by the Tenderers
ix. Tenders include descriptive data and illustrations in sufficient detail to enable the equipment offered to be fully considered in respect of materials, design and construction of the individual parts. This information is furnished before the closing date of tenders.

3.31.4 Special too Active part Design Items to be Reviewed During the Tender Evaluation

The design of the transformer active part is accessed as described below.

3.31.4.1 General Coil Layout

The general layout of the coils must be kept as simple as possible without adding unnecessary complicated or high risk items that will induce risk of failure.

3.31.4.2 Losses

The energy loss due the losses in the transformer for the life cycle of the transformer is calculated and added to the overall tender price.

3.31.4.3 Core Design

It is preferred that the cross section from main limb yoke to return limb area must be 57 / 57 % of the main limb avoiding over-fluxing in these areas. Lower values will be given lower ratings. Consideration will also be given to issues such as the tie plate type and size, core material type and core clamping methods. Complex design features introducing risk will be looked at.

3.31.4.4 LV Winding/s Design

It is preferred that proper current sharing mitigations are implemented in the design. In general paper covered CTC has the drawback that the paper bulges and reduces the

effective radial oil gap and hence cooling. One mitigation method that can be used is an oversized oil gap of 5 mm. Consideration should also be given to the fact the radial gap will

reduce as the transformer ages. Netting CTC has the disadvantage that the additional paper insulation is lost. Consideration is given to avoid complex windings that will introduce unnecessary risks.

The *Tenderer* submits with the tender a description as to how the LV exit leads will be arranged. Key features to be addressed are:

- the support of the leads and how this will be taken into consideration in the final design.
- Taking the eddy current heat generated and the control of the temperature in the exit lead and how this will be taken into account in the final design.
- The type of connection that will be made. Brazing is seen as a risk particularly if large lugs are brazed, provided adequate evidence on how the quality will be controlled and the engineering that has been put into the brazing process. Also what tests / inspection that will be carried out.

The *Tenderer* should submit information with the Tender indicating how these factors have been taken into consideration.

3.31.4.5 HV Winding/s Design

It is preferred that complex designs that introduce unnecessary risks are eliminated. For 275 kV and above, centre entry HV coils are preferred. Where alternative designs are proposed, a motivation indicating the reasons that what risk mitigations will be implemented.

The type of impulse stress control applied must be stated. Simple and reliable techniques will be given preference.

Consideration should be given to design coils that will be simple and not introduce unnecessary complex manufacturing and associated risks.

3.31.4.6 Tapping Winding Design

Inner Tap Winding arrangement with Multi –start winding normally has a large pitch with an insulation requirement resulting in a soft winding. This type of winding is seen as a risk. The *Tenderer* offering such coils must submit mitigation measures.

3.31.4.7 Main Insulation Design

The gap of the main insulation is used to assess the risk associated with the main insulation area.

Well designed gaps will be considered a low risk. Lower gaps will be given lower ratings. Where lower gaps are specified the *Tenderer* may add a note indicating the mitigation measures.

3.31.4.8 Electromagnetic Forces During Short Circuit Conditions

The *Tenderer* carries out a short electromagnetic force study for a full short circuit on the transformer not taking any grid impedances into account (self protected transformer) and then completes the Table at the end of Schedule A & B. Safety factors of 50% are seen as good.

It is essential that the *Contractor* presents his design criteria documentation to the *Employee* during the design review meeting showing how the design basis was derived by study and/ or testing and the criteria used in the design.

3.31.4.9 Winding Hot Spot Gradient

The winding hot spot should be kept low. High gradients of 1.7 and more will need special motivation.

3.32 SPECIAL TOOLS AND EQUIPMENT

The Contractor provides as part of the Contract, free of charge, all the special tools and equipment which are required for the normal maintenance of the transformer. The Contractor provides a complete listing of such equipment and tools with their specific characteristics, including type, manufacturer, and purpose, at the tendering stage and hands these over with the transformer. Tools and equipment may be used for the erection of the transformer but is essentially in as good as new condition when handed over. The Employer has the right to demand new equipment and tools of good quality if they are not in satisfactory condition.

3.33 TRAINING OF EMPLOYER'S STAFF

The Contractor proposes an appropriate training program for the Operating, Maintenance- and Engineering staff of the Employer. This includes the nomination of an appropriate venue and duration of the training period.

If the proposed training involves travelling and accommodation and subsistence away from the Employers home country, the Employer is responsible for all the direct travelling and subsistence expenses involved for a maximum number of four (4) of the Employer's staff.

The Employer has the option, at his own expense, to add further two (2) staff members.

The Contractor provides a complete and detailed broken down schedule of the training events but it is not expected that formal training should last less than 5 consecutive working days nor more than 10 consecutive working days.

The Contractor advises the Employer of the minimum pre-requisite level of education required for the employees to successfully participate in the training programme.

Over and above any formal training, the program includes as a minimum, on-site component training, covering:

a. on site preparation for transportation;

b. loading and off-loading procedures and precautions

c. fitting of accessories like tap changers, bushings and their testing;

d. fitting of sensors and protective devices and their testing;

e. vacuum treatment, drying filtering and impregnation; and

f. All testing procedures and requirements of the complete system to ensure that it is ready for service.

Special emphasis is placed on quality control processes and the maintenance of the oil and insulation system in the best possible condition to ensure maximum life for the transformer, as well the underlying theoretical aspects.

3.34 GUARANTEE REQUIREMENTS

The *Contractor* Guarantees the transformer(s) and all ancillary equipment of the transformer for a period of 18 months for commercial units and 60 months for spare units unless otherwise stated in the contract.

During the contract award period the *Employer* and *Contractor* agree upon the condition monitoring that is done during the guarantee period.

The following minimum online condition monitoring tests are done:

a. DGA (Dissolved Gas Analysis) testing of the transformer oil according to IEC 60599,

b. Water in transformer insulation system,

c. Measurement of Furanic content in oil according to BS 148,

d. Oil Particle analysis,

e. Oil age related tests which include but are not limited to:

    i. Neutralisation value (SABS 555)

    ii. Tan Delta (IEC 60247)

    iii. Sludge (Doble)

    iv. Colour (ASTM 1500)

    v. Breakdown Voltage (IEC 60156)

    vi. Interfacial Tension (ISO6295)

    vii. Accelerated Aging (ASTM D2440)

f. Thermo image scanning of transformer tank and bushings.

g. And external visual inspections of the transformer.

The *Employer* performs the relevant tests according to the relevant test methods as approved by the *Contractor.* These tests will be done at 6 monthly intervals during the guarantee period. The *Employer* however reserves the right to increase the interval period. The results will be sent to the *Contractor* for his perusal after which the *Contractor* submits a report for the *Employer's* approval. The report states the condition of the transformer and any problems or premature aging that might be taking place.

The *Employer* reserves the right to take the transformer out of service during the guarantee period and perform the following minimum tests:

a. Tan-Delta tests on High Voltage and low Voltage bushings,

b. FRA testing,

c. RVM testing,

d. DP (Degree of Polymerisation) testing of the actual transformer paper,

e. Water content of transformer insulation paper,

f. And an internal visual inspection of the transformer.

The tests will be done by the *Employer* according to the relevant test methods as approved by the *Contractor.* The tests must be witnessed by the Contractor after which a report is submitted for the *Employer's* approval*.* The report states the condition of the transformer and any problems or premature aging that might be taking place.

4. AUTHORISATION

This document has been seen and accepted by:

Name	Designation
	Document Approved by TDAC ROD 16 July 2013
L.P. Malaza	Electrical Plant Engineering Manager
R.P. Madiba	Electrical and C&I Senior Engineering Manager

5. REVISIONS

Date	Rev.	Compiler	Remarks
November 2012	0.1	HWG Venter	**Draft Document for review created from 474-083**
November 2013	1.0	G.M. Mungwe	Final Document Authorised for Publication

6. DEVELOPMENT TEAM

E.J. Mbokodo

G.M. Mungwe

7. ACKNOWLEDGEMENTS

Acknowledge that the superseded standard content remains unchanged and only the document template with the new doc number is affected.

APPENDIX A : DETAIL PAINT COATING SPECIFICATIONS (SECTION 4.17)

SPECIFICATION DS460.1

**Corrosion Protection of Newly Fabricated Power and Station Auxiliary Transformers
(Applicable to Non-corrosive to High Corrosive Environments)**

METHOD	REFERENCES
SURFACE PREPARATION: Abrasive blast cleaning to Grade Sa 2.5. **COATING SYSTEM:** FIRST COAT: Apply by brush, roller or spray one coat Twin Pack, Zinc Rich or General Purpose Epoxy Primer. Dry film thickness 80 to 100 micrometers. STRIPE COATING After allowing sufficient time for the primer coat to cure, all edges, weld seams, bolts and nuts, and other crucial areas is given an additional stripe coat with the same material as the primer but of a different colour. SECOND COAT: Allowing sufficient time for the primer coat to cure, the manufacturer's recommendations are to be adhered to in this regard, apply one coat, Twin Pack, High Build (≥50% volume solids content) Micaceous Iron Oxide Pigmented Recoatable Epoxy Coating. Dry film thickness 80 to 100 micrometres. FINAL COAT: Allowing sufficient time for the second coat to cure, the manufacturer's recommendations are to be adhered to in this regard, apply one coat Twin Pack Aliphatic Acrylic Polyurethane Enamel Dry film thickness 40 to 50 micrometres. TOTAL THICKNESS OF FULL SYSTEM: Dry film thickness 200 to 250 micrometres. **SAFETY NOTE:** The manufacturer's recommendations regarding the safe handling and use of these materials are to be adhered to. **PREFERRED/RECOMMENDED SUPPLIERS:** Sigma Coatings, Stoncor, Jotun, Ameron, Barloworld Plascon and Varcol : **ADDITIONAL NOTES:** The colour of each coat is different to the previous coat. The colour of the Polyurethane topcoat is as stipulated by the *Employer* in schedule AB, item AB.6.2. The colour of the conservator tanks is White unless otherwise stated in Schedule AB, item AB.30.2	Section 4.6.2.3 ISO 8501-1 or SIS055900 SABS SM 772 SABS SM 769 ASTM E376 or SABS ISO 2808 Section 5 Sections 4.1.and 4.2 SABS 1091

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SPECIFICATION DS460.2

Zinc Metal-Spraying of Power Transformer Components
(Applicable to Very High Corrosive Environments)

METHOD	REFERENCES
SURFACE PREPARATION: Abrasive blastclean to Grade Sa 3 (ISO 8501-1 / SIS 055900). **METAL SPRAYING:** All metal spraying is carried out by Plasma Arc or the hot wire spraying process. Maximum atomisation of wire is attained, at all times, to obtain a fine-grained, dense sprayed film. **METAL SPRAY TYPES:** Zinc sprayed coatings is carried out in accordance with BS EN 22063. The wire analysis is: -Zinc 99,995% minimum. **COATING THICKNESS:** Unless otherwise agreed to by the *Employer*, the minimum coating thickness is 125 micrometres (ASTM E376 / SABS ISO 2808). **GENERAL:** The final metal-sprayed surface is free of all lumps, atomised wire and other surface irregularities When a further paint system is to be applied over the zinc metal-sprayed coatings, the *Contractor* obtains the *Employer's* approval of the metal-sprayed coating prior to the commencement of painting. Prior to the application of a paint system, the surface is brushed down to remove all loose oxidation deposits and blown off with clean, dry compressed air.	See Section 4.6.2.3 ISO 8501-1 or SIS055900 SABS SM 772 SABS SM 769 See BS EN 22063. See ASTM E376 or SABS ISO 2808

SPECIFICATION DS460.3

Hot Dip Galvanising of Power and Station Auxiliary Transformer Radiators (Applicable to Non-Corrosive to Very High Corrosive Environments)

METHOD	REFERENCES
SURFACE PREPARATION: All weld areas are abrasively blast cleaned to Grade Sa 2,5 (ISO 8501-1 / SIS 055900). Following blast cleaning of the welds, all items are suitably pickled, rinsed, dried and fluxed. **GALVANISING:** All items are hot dip galvanised in accordance with SABS ISO 1461 to a minimum coating thickness as laid down in the appropriate tables of SABS ISO 1461. All nuts, bolts, clips and other items, including High Strength Friction Grip and High Tensile Bolts up to M10 size required for the fixing of galvanised articles are hot dip galvanised to this Standard. Hot dip galvanising of higher strength bolts greater than M10 size is not allowed (due to the possibility of hydrogen embrittlement) and these are Electro-plated in accordance with BS 3382. **TOLERANCES:** Tolerances on all threaded articles are according to SABS ISO 1461. Threaded items are spun in a Centrifuge during the galvanising process. **NOTE:** In addition to the requirements of SABS ISO 1461 the following criteria with respect to white rust and passivating treatments applies. (1) White rust: All material is free from white rust and black staining when it is handed over to the *Employer*. To assist in meeting this requirement, close attention is paid to the manner in which the material is stacked and stored at the galvaniser's works and also during its subsequent handling until such time as it is handed over to the *Employer*. Material, which has been inspected at the galvaniser's or manufacturer's works and passed by the *Employer*'s appointed inspectors will still be liable to rejection if it has been found that white rust has developed between the date of inspection and the date when the material is handed over to the *Employer*. If the material is affected by white rust the *Contractor* may clean it (using non-metallic brushes) before handing over and if the weight of zinc coating still meets the requirements specified in the appropriate tables of SABS ISO 1461, the material will be accepted. (2) Passivation: Unless galvanised items are to be subsequently painted, all items are passivated. The passivating coating is applied to the material immediately after galvanising to afford temporary protection to the galvanised surfaces. This coating is even, and is sufficiently transparent to enable the *Employer's* appointed inspectors to examine the underlying surfaces for any defects.	Section 4.6.2.3 ISO 8501-1 or SIS055900 SABS SM 772 SABS SM 769 SABS ISO 1461 BS 3382

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SPECIFICATION DS460.4

Painting of Newly Fabricated Galvanised or Zinc Metal-Sprayed Power and Station Auxiliary Transformer Components
(Applicable to Very High Corrosive Environments)

METHOD	REFERENCES
SURFACE PREPARATION: Galvanised or zinc metal-sprayed surfaces are cleaned prior to painting to provide a water break-free surface, using a solvent detergent degreaser specifically formulated by the supplier of the paint system, for cleaning new galvanising or zinc metal-sprayed surfaces. Water rinsing after cleaning is essential to remove all traces of the cleaner. This is best achieved by hosing with a high-pressure water spray. Allow drying. **COATING SYSTEM:** FIRST COAT: Apply by brush, roller or spray one coat Twin Pack, General Purpose, Epoxy Primer (Specially formulated for zinc metal surfaces). Dry film thickness to 50 to 80 micrometers. SECOND COAT: Allowing sufficient time for the primer coat to cure, the manufacturer's recommendations are adhered to in this regard, apply one coat Twin Pack, High Build (≥ 50% volume solids content) Micaceous Iron Oxide Pigmented Recoatable Epoxy Coating. Dry film thickness 80 to 100 micrometres. FINAL COAT: Allowing sufficient time for the second coat to cure, the manufacturer's recommendations are Adhered to in this regard, apply one coat Twin Pack Aliphatic Acrylic Polyurethane Enamel. Dry film thickness 40 to 50 micrometres. TOTAL THICKNESS OF FULL SYSTEM: Dry film thickness 170 to 230 micrometres. **SAFETY NOTE:** The manufacturer's recommendations regarding the safe handling and use of these materials are adhered to. **RECOMMENDED SUPPLIERS:** Sigma Coatings, Stoncor, Jotun, Ameron, Barloworld Plascon and Varcol **ADDITIONAL NOTES:** The colour of each coat is different to the previous coat. The colour of the Polyurethane topcoat is as stipulated by the *Employer* in schedule AB, item AB.6.2. The colour of the conservator tanks is White unless otherwise stated in Schedule AB, item AB.30.2.	ASTM E376 or SABS ISO 2808 Section 5 Sections 4.1.and 4.2 SABS 1091

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SPECIFICATION DS460.5

Flow coating - This specification only applies to those galvanised components, which due to their complicated geometry, cannot be adequately painted by normal coating techniques i.e. in accordance with DS460.4
(Applicable to Very High Corrosive Environments)

METHOD	REFERENCES
SURFACE PREPARATION: Galvanised surfaces are cleaned prior to painting to provide a water break-free surface, using a solvent detergent degreaser specifically formulated by the supplier of the paint system, for cleaning new galvanising surfaces. Water rinsing after cleaning is essential to remove all traces of the cleaner. This is best achieved by hosing with a high-pressure water spray. Allow drying. **COATING SYSTEM:** FIRST COAT: Apply by flow coating technique, one coat Phenolated Alkyd Primer to a dry film thickness of 50 to 55 micrometres SECOND COAT: Apply by flow coating technique, one coat Quick Dry Alkyd Gloss Enamel to a dry film thickness of 50 to 55 micromtres. FINAL COAT: Upon completion of assembly, apply by airless spray a second coat Quick Dry Alkyd Gloss Enamel to a dry film thickness of 25 to 35 micrometres TOTAL THICKNESS OF FULL SYSTEM: Dry film thickness 125 to 145 micrometres. **SAFETY NOTE:** The manufacturer's recommendations regarding the safe handling and use of these materials are adhered to. **RECOMMENDED SUPPLIERS:** Any SABS approved supplier. **ADDITIONAL NOTES:** The colour of each coat is different to the previous coat. The colour of the Polyurethane topcoat is as stipulated by the *Employer* in schedule AB, item AB.6.2. The colour of the conservator tanks is White unless otherwise stated in Schedule AB, item AB.30.2	ASTM E376 or SABS ISO 2808 Section 5 Sections 4.1.and 4.2 SABS 1091

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SPECIFICATION DS480.8

Spot Repair and over coating of Previously Coated Power and Station Auxiliary Transformers

METHOD	REFERENCES
INSPECTION: A detailed visual inspection is carried out to identify all areas where corrosion is taking place or damage to the original coating is evident.	Section 4.6.2.4
SURFACE PREPARATION: Remove all loose corrosion products, salt, paint and other contaminants that may be present on the surfaces to be painted by means of spot blasting, scrapers, grinders and wire brushes, etc. Note that irrespective of which cleaning tool is being used, the required surface preparation for the damaged areas is to Grade St. 2. Following mechanical cleaning, the affected area is cleaned down to a smooth surface and feathered back to a hard edge, using abrasive paper. All surfaces to be overcoated are abraded with sandpaper and washed with a detergent solution using bristle brushes and/or "Scotch-Brite" pads. It is important that all harmful deposits be removed i.e. grease, chalking compounds etc. Following the detergent wash, the surfaces are rinsed with clean potable water and allowed to dry. **It is imperative that all surface dirt and contaminants are completely removed before over-coating or the adhesion between the existing and new coats will be impaired. No more than 4 hours elapses between cleaning and the application of the primer coat to avoid recontamination of the surface.**	ISO 8501-1 or SIS055900 ASTM E376 or SABS ISO 2808 Section 5 Sections 4.1.and 4.2 SABS 1091
SPOT REPAIR: Patch prime those areas where the metal substrate is exposed with one coat Twin Pack, High Build (≥85% volume solids content), Aluminium Pigmented Surface Tolerant Epoxy. **Work coating into all irregularities.** Dry film thickness to 80 to 100 micrometres. After allowing sufficient time for the patch areas to cure, the manufacturer's recommendations are adhered to in this regard, the following system is applied.	
COMPATIBILITY TESTING: Compatibility between the existing coating and the epoxy coating to be used for overcoating is checked by the application of one coat Twin Pack, High Build (≥ 50 volume solids content), Micaceous Iron Oxide Pigmented Recoatable Epoxy Coating to a small test area. If no softening of the existing coating occurs the following system can be applied. Where softening of the coating occurs, these components should be dealt with on a individual basis.	
OVERCOATING SYSTEM: FIRST COAT: All surfaces are overcoated by brush, roller or spray, with one coat Twin Pack, High Build (≥50% volume solids content) Micaceous Iron Oxide Recoatable Epoxy Coating. **Work coating into all irregularities.** Dry film thickness to 80 to 100 micrometers. FINAL COAT: Allowing sufficient time for the patch and first coats to cure, the manufacturer's recommendations are adhered to in this regard, apply one coat Twin Pack Aliphatic Acrylic Polyurethane Enamel. Dry film thickness 40 to 50 micrometres. TOTAL THICKNESS OF FULL SYSTEM: Dry film thickness 120 to 150 micrometres.	
SAFETY NOTE: The manufacturer's recommendations regarding the safe handling and use of these materials are adhered to.	

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RECOMMENDED SUPPLIERS: Sigma Coatings, Stoncor, Jotun, Ameron, Barloworld Plascon and Varcol **ADDITIONAL NOTES:** The colour of each coat is different to the previous coat. The colour of the Polyurethane topcoat is as stipulated by the *Employer* in schedule AB, item AB.6.2. The colour of the conservator tanks is White unless otherwise stated in Schedule AB, item AB.30.2	

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SPECIFICATION D8480.7

Painting of Previously Galvanised Power and Station Auxiliary Transformer Components

METHOD	REFERENCES
PRE-TREATMENT: Remove all grease, oil, salts and other surface deposits by means of washing with a detergent solution and rinsing with clean potable water. **SURFACE PREPARATION FOR WEATHERED GALVANISED STEEL:** Abrade all galvanised surfaces with sandpaper to remove white rust and other loose deposits. Where the zinc is totally depleted and rusting of the steel substrate has occurred, remove all rust and other contaminants by means of spot blasting, scrapers, grinders and wire brushes, etc. Note that irrespective of which cleaning tool is being used, the required surface preparation for the damaged areas is to Grade St. 2. After surface preparation, wash surfaces with copious quantities of fresh potable water and allow drying. **No more than 4 hours elapses between cleaning and the application of the coating system. Steelwork will have to be re-washed if left overnight.** The cleaned surfaces are then examined. Should any pitting be observed in areas where total zinc depletion has occurred; the depth of the pits are measured by means of a profile gauge. Where pitting exceeds 200 micrometers, these areas are "patch primed" prior to overcoating the entire component. **PATCH PRIMING:** Where pitting exceeds 200 micrometers and the metal substrate is exposed, patch prime with one coat Twin Pack, High Build (≥85% volume solids content), Aluminium Pigmented Surface Tolerant Epoxy. **Work coating into all irregularities.** Dry film thickness to 80 to 100 micrometres. After allowing sufficient time for the patch primed areas to cure, the manufacturer's recommendations are adhered to in this regard; the following system is applied to the entire component. **OVERCOATING SYSTEM:** FIRST COAT: Apply by brush, roller or spray, one coat Twin Pack, High Build (≥ 85 volume solids content), Aluminium Pigmented Surface Tolerant Epoxy. **Work coating into all irregularities.** Dry film thickness to 80 to 100 micrometers. FINAL COAT: Allowing sufficient time for the first coat to cure, the manufacturer's recommendations are adhered to in this regard, apply one coat Twin Pack Aliphatic Acrylic Polyurethane Enamel. Dry film thickness 40 to 50 micrometres. TOTAL THICKNESS OF FULL SYSTEM: Dry film thickness 120 to 150 micrometres. **SAFETY NOTE:** The manufacturer's recommendations regarding the safe handling and use of these materials are adhered to. **RECOMMENDED SUPPLIERS:** Sigma Coatings, Stoncor, Jotun, Ameron, Barloworld Plascon and Varcol. **ADDITIONAL NOTES:** The colour of each coat is different to the previous coat.	Section 4.6.2.4 ISO 8501-1 or SIS055900 ASTM E376 or SABS ISO 2808 Section 5 Sections 4.1.and 4.2 SABS 1091

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The colour of the Polyurethane topcoat is as stipulated by the *Employer* in schedule AB, item AB.6.2. The colour of the conservator tanks is White unless otherwise stated in Schedule AB, item AB.30.2	

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SPECIFICATION DS460.8

New Hot-dip Galvanised Nuts and Bolts

Hot-dip galvanised fasteners is purchased from an SABS approved bolt manufacturer to SABS ISO 1461. If this is not stipulated there is likelihood that zinc or cadmium electroplated fasteners will be supplied. **BOLT AND NUT ASSEMBLIES:** Galvanised bolts and nuts should be supplied in the nutted-up condition. This ensures that bolts and nuts have been matched and supplied by the same manufacturer. **WASHERS:** Washers required for use with high strength fasteners is through hardened prior to hot-dip galvanising. **REPACKING:** When repacking is necessary at premises other than those of the galvanisers, bolts and nuts are repacked in the assembled state, with the repacker ensuring a proper fit between bolt and nut. **CONTAINERS:** Galvanised articles and assemblies are packed in closed containers capable of withstanding wear and tear during transport and do not cause deterioration or damage to the articles during transportation. **DEFECTS:** Defective articles found during further processing or replacing is rejected. **MARKING:** Where the SABS Mark applies, this Mark appears on every container or on a label securely attached to the container. **COATING:** After installation, all hot dip galvanised nuts and bolts are degreased with a solvent degreaser and overcoated with the complete system as applicable for the rest of the transformer.	**REFERENCES** SABS ISO 1461

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SPECIFICATION DS460.9

On Site Patch Repairs of New Organic Coatings

INSPECTION:	REFERENCES
After installation a detailed visual inspection is carried out to identify all areas where damage to the coating is evident.	Section 4.6.2.4
SURFACE PREPARATION:	
After identification of the defective areas, the cured material is removed back to substrate by means of angle grinding, needle gunning or vacublasting depending on size or surface area to be repaired.	
Following mechanical cleaning, the affected area is cleaned down to a smooth surface and feathered back to a hard edge, using abrasive paper. This cleaning is extended to a minimum distance of 25mm beyond the periphery of the affected area.	
It is vitally important that the sound, existing coating be abraded/ in order to provide a good "key" for the overlapping repair coating.	
After preparation, all dust, grid blasting medium or any other deleterious matter is removed by means of a soft brush or vacuum.	
It is imperative that all surface dirt and contaminants are completely removed before coating or the adhesion of the repair coating is impaired. No more than 4 hours elapses between cleaning and the application of the primer/first coat to avoid recontamination of the surface.	
COATING SYSTEM: The defective area is then repaired by full re-instatement of the specified coating system	