Eskom	Standard	Technology

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Executive Summary

This reactor specification was revised from the original document TSP41-143. This document details the requirements of both the series and shunt reactors used in Eskom. The requirements are applicable to the 3-phase and single phase units. The reactors, when in service and maintained as per the OEM requirements or better, shall be able to fulfil their intended purpose without stray gassing or any unexpected technical concerns or risks. Variable shunt reactors are not included in this specification.

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1. Introduction

The reactors specified in this document are intended for both the replacement and the extension of Eskom's network and may be used on a line or a bus-bar. All reactors must be robust enough to withstand 5 switching operations a day for the full expected life.

For the 765kV line reactors, in order to facilitate successful single-phase line fault-clearing Eskom will install reactors of approximately 1 Henry on the neutral of the three-phase reactor sets. The neutral-end of the reactors will thus not be solidly grounded but will assume some transient voltage during the single-phase fault clearing event.

The Alpha and Beta substations were built with GIS technology, all their transformers and reactors are interfaced with their GIS switchgear via intermediate 50m air insulated sections. However, instead of extending the existing 765 kV GIS switchgear, Eskom has used Air-insulated switchgear the other network extensions. The units must be usable in both systems with no limitations to the specified ratings. Eskom expects the new reactors, as per this specification, to perform harmoniously with any of the existing reactors. For this purpose it is necessary to take cognisance of the physical dimensions and situations of the existing units and installations.

Eskom expects the reactors to have a minimum life expectancy of at least 40years when operated **continuously at maximum voltage** under "normal" network conditions.

Note: Eskom requires any tenderer in response to this specification to take full cognisance of this requirment and to notify Eskom explicitly if the tenderer's design cannot fulfil Eskom's expectation.

Eskom also requires that a tenderer/supplier under this specification shall explicitly notify Eskom if any item in this specification or accompanying document would be causing the manufacturer to supply a product of lesser quality.

Eskom's written approval must be sought for any changes in design or specification.

2. Supporting clauses

2.1 Scope

This specification covers The Employer's requirements for oil immersed HV shunt reactors (Three phase and single phase application) for:

- line reactors where single-phase switching is used
- busbar reactors to be switched as 3-phase

The reactors are for outdoor use under system conditions and for the ratings specified below and in schedule A.

All items not specifically addressed in this specification shall be in accordance with the transformer specification,,,

2.1.1 Purpose

This document was produced in order to record the standardized requirements that shall be applied when procuring new reactors for Eskom to be used in the Eskom network. This covers both reactors procured directly by Eskom and those purchased under turn-key projects

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2.1.2 Applicability

This document shall apply throughout Eskom Holdings Limited Divisions. It is applicable to all the *Contractors* that shall be tendering to supply reactors to Eskom.

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] ISO 9001 Quality Management Systems.

[2] IEC 60076-1, Power transformers — Part 1 General.

[3] IEC 60076-2, Power transformers — Part 2 Temperature rise.

[4] IEC 60076-3, Power transformers — Part 3 Insulation levels and dielectric tests.

[5] IEC 60076-4, Power transformers — Guide to Lightning and Switching Impulse.

[6] IEC 60076-5, Power transformers — Part 5 Ability to withstand short circuit.

[7] IEC 60076-6, Power transformers Part 6: Reactors

[8] IEC 60076-7, Power transformers — Part 7 Loading guide for oil-immersed power transformers.

[9] IEC 60076-8, Power transformers — Part 8: Application guide.

[10] IEC 60076-10, Power transformers — Part 10 Determination of sound levels.

[11] IEC 60076-10-1, Power transformers Part 10-1: Determination of sound levels - Application guide

[12] IEC 60076-13, Power transformers Part 13: Self-protected liquid-filled transformers

[13] IEC 60076-14, Power transformers Part 14: Design and application of liquid- immersed power transformers using high-temperature insulation materials

[14] IEC 60076-18, Power transformers Part 18: Measurement of frequency response.

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

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

[17] IEC 60156, Insulating liquids – Determination of the breakdown voltage at power frequency.

[18] IEC 60185, Current transformers.

[19] IEC 60214, On-load tap-changers.

[20] IEC 60034, Rotating electrical machines.

[21] IEC 61850 (All parts) Communication network and systems in substations

[22] 32-9 Definition of Eskom documents.

[23] ESP32-644 Eskom documentation management standard

[24] 474-65 Operating Manual of the Steering Committee of Technologies (SCOT)

[25] 240-56063843 Winding and oil temperature specification

[26] 240-56063908 Oil and gas actuated (buchholz) relays fitted to transformers and reactors

[27] 240-56063886 Dehydrating breathers fitted on transformers, reactors, and on-load tap changers

[28] 240-56356191 Transformer and reactor oil level indicators

[29] 240-56063867 Rapid Pressure Rise Relay Specification

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[30] 240-56063871 Pressure Relief Devices (PRD) Fitted to Transformers and Reactors Specification

[31] 240-56356202 Bag Leak Detector Specification

[32] 240 – 56535946 Transformers and Reactors cooling fans standard

[33] 240 -64917195 Technical standard for dissolved gas analysers for application in power transformers for all Eskom divisions.

[34] 240-59083215 Permanent online oil drying system used on transformers and reactors.

[35] 240-56062799 Technical Specification for Capacitor Bushings for Application in Power Transformers and Shunt Reactors in Eskom

[36] 240-56030674 Corrosion Protection of new and in-service power & station auxiliary transformers

[37] 240 - 75661431 Mineral insulating oils (uninhibited and inhibited) part 1: purchase, management, maintenance and testing

[38] 240-56062726 Standard for Intrusive work and Oil filling, under vacuum of transformers and reactors on site

[39] QM 58 Eskom Quality Procedure

[40] D-DT-3202 Eskom Drawing MV and LV cable box

[41] EST32-136: Contractor Health and Safety Requirements

[42] Eskom 10TB-018: Technical Bulletin for Loss Evaluation

[43] TPC 41-246: Management of manufacturers and suppliers equipment drawings

[44] 240 – 53902530 Substation automation – data concentrator for data retrieval and remote access

[45] 240 – 64038621 Remote device communication standard for data retrieval and remote access

[46] 240 – 46264031 Fibre optic design standards – Part 2 – Substations

[47] 240-56062720 Oil Sample point labelling standard

[48] TB 204 Cigre Publication, Guidelines for transformer design reviews

[49] South African National OHS act

[50] Eskom ORHVS

[51] TPC 41-246 Management of manufacturers and suppliers equipment drawings

2.2.2 Informative

[52] TSP 41-143

2.3 Definitions

2.3.1 General

Definition	Description
Appointed bodies	Refers to persons, beside Eskom employees, appointed by Eskom to provide professional services to Eskom.
Contractor	This refers to the party that received a purchase order from Eskom
Employer / Purchaser	These refer to Eskom and it is interchangeably used to refer to the customer

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Definition	Description
Partial Drain	The phrase refers to draining the transformer or reactor is such a way that the HV insulation and the active part remains fully immersed in oil and vacuuming will not be necessary after completion of work
Service Life	This refers to the expected lifetime of the reactor operating incident free.

2.3.2 Disclosure classification

Controlled disclosure: controlled disclosure to external parties (either enforced by law, or discretionary).

2.4 Abbreviations

Abbreviation	Description
A	Amperes
CT	Current Transformer
DGA	Dissolved Gas Analysis
HV	Highest Voltage / High Voltage
kW	Kilo Watt
MW	Mega Watt
MVAr	Mega Volt Ampere (reactive)
ONAN	Oil Natural Air Natural
PRD/V	Pressure Relief Device / Valve
SFRA	Sweep Frequency Response Analyses
SW	Series Winding
TOV	Temporary Over Voltages
UV	Ultra Violet

2.5 Roles and responsibilities

All the Eskom employees and/or appointed bodies involved in the procurement of reactors and/or the associated accessories shall ensure that the product meets the requirements of this specification. Any deviation from these requirements shall constitute a non-conformance, unless it was agreed to in advance by a delegated Eskom transformer specialist in writing and is based on sound engineering judgement.

All the Contractors supplying reactors to Eskom must be conversant with the requirements of this specification, and shall comply with the requirements. All the deviations shall be clearly listed in the deviation schedule as part of the tender deliverables.

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No deviations will be accepted unless approved by Eskom in writing. The Contractor shall ensure that he gets clarity where required and that he has all the supporting information or documents necessary for the contractor to comply with this document.

The Eskom Transformer Corporate Specialist shall be responsible for ensuring the validity of this document.

2.6 Process for monitoring

This document and its relevance will be annually evaluated by the relevant SCOT Care Group.

2.7 Related/supporting documents

The schedule A of the relevant AB schedules shall form part of this specification and they shall take precedence over this specification in case the two documents are conflicting.

3. Specification Minimum Requirements

This specification defines the minimum requirements for the site survey and assessment, design, design-review, manufacturing, factory testing, transporting, delivery to site, off-loading, assembly, installation, in-transit and on-site testing, and commissioning, and performance of the said reactors. The reactor shall as a minimum be designed for the environment where it will be utilised. The reactor manufacturer shall apply the best internationally benchmarked engineering and manufacturing practices to produce a reactor, including accessories, which in conjunction with minimal maintenance, will result in a safe and reliable service throughout the expected lifespan under the rigors of service in the Eskom power system. The reactor, when in service, shall not exhibit unsafe or any uncertain condition e.g. stray excessive gassing, partial discharge, etc. Engineering practices or techniques that have no measurable quality control shall not be accepted for correction of deviations.

The reactor and the associated accessories shall be risk free to Eskom.

3.1 Design Reviews

A design review shall be done on the first reactor of each type. 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.

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

- Ensure there is a clear and mutual understanding of the technical requirements.
- Verify the system and project requirements and to indicate areas where special attention may be required.
- Verify that the design complies with the technical requirements.
- Identify any prototype features and evaluate their reliability and risks.

A design review meeting is required before the procurement of any materials or manufacturing proceeds. The purpose of the design review is to allow Eskom to understand the basic design, construction and installation of the reactor and to make sure that interchangeability requirements are met. Eskom shall not be obliged to accept components and/or materials procured prior to the design review and without a written agreement from Engineering. The design review shall follow an internationally benchmarked process.

The manufacturer shall design the reactor in order that it performs satisfactory under all service conditions specified in this document.

The manufacturer has to demonstrate that all the decisive design parameters are well within the manufacturer's design limits based on proven research, or relevant limits specified in standards or internationally benchmarked criteria.

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Eskom reserves the right to reject the design when the manufacturer fails to demonstrate the capability for design and manufacturing of the reactor under review. This can happen when the presented design does not meet internationally and Eskom's accepted criteria and the manufacturer cannot prove his design by previously tested reactors of the same concept and voltage class.

The manufacturer shall inform Eskom twelve (12) weeks prior to the design review. All the discussions and final decisions taken during the design review must be recorded, signed by all the parties, and submitted to Eskom.

Eskom participation in the design review will in no way relieve the manufacturer of any of their duties in terms of any contract.

Preliminary design review details must be supplied to Eskom one week before the design review meeting.

3.2 Site Conditions

The *Contractor* shall take note that the equipment shall operate under the following site conditions

- Outdoor installation
- Altitude above sea level – 1800m
- Ambient temperatures
  - Maximum + 40°C
  - Monthly average +28°C
  - Yearly average + 25°C
  - Minimum - 10°C
- Average humidity of 90%.
- Solar radiation 2500kWh/m^2
- Atmospheric UV radiation = High
- Seismic conditions at a minimum of 0.3g, this requirement must be proved by calculation.
- Symmetrical three phase network supply voltages, negative and zero phase sequence voltages up to 2%.
- Pollution level: Very Heavy

In special cases the site conditions, when different from these, it shall be indicated in the AB schedules.

NOTE: The yearly average for South Africa is 23°C according to the SA Weather Services website, which is 3K higher than that in IEC 60076-7. A further 2K was added for climate change reasons and hence the yearly average is considered 25°C.

3.3 Ratings

3.3.1 Rated Power

The values of rated power specified in Schedule A of the enquiry document are the continuous ratings at rated voltage, in MVAr, at which the reactor can operate without exceeding the temperature rise limits specified in this specification.

3.3.2 Reactance

The tolerance on rated reactance at maximum operating voltage (U_m) and frequency shall be ± 5%.

In the case of three-phase shunt reactors or banks of three single-phase reactors, the reactance in the three-phases when connected to a system of symmetrical voltages (U_m) shall not deviate from the average by more than ± 2%, but always remain within the above mentioned ± 5% reactance.

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3.3.3 Mutual Reactance

For the purpose of single phase switching duty, the mutual reactance between phases as measured in IEC 289, clause 8.10 shall not exceed the value specified in schedule A.

3.3.4 Rated Voltage

The rated voltage of each of the reactor shall be specified in Schedule A, unless otherwise stated, it corresponds to the system nominal voltage, U_n.

3.3.5 Maximum Continuous Rated Voltage

The reactor shall be able to operate in this voltage continuously and without any limitation. No excessive gassing, excessive vibrations, or any other uncertain condition shall arise because of this voltage.

3.3.6 Maximum Temporary Overvoltages

Under switching conditions, the power frequency voltage may exceed the maximum system voltage (U_m). The reactors must be designed to withstand the following over-voltages without harm:

1.05 U_n continuously for 400kV and above, and below 400kV – 1.1 U_n continuously (this is $U_{m)}$.

1.05 U_m for 10 minutes

1.25 U_m for 1 minute

1.5 U_m for 5 second: and

1.75 U_m for 1 second

Also see the additional requirement to comply with IEC 60076-3.

3.3.7 Cooling plant

Unless otherwise specified, the reactor shall be naturally cooled (ONAN).

When specified in schedule A, additional cooling plant shall be offered as an alternative to ONAN.

The following types of additional cooling are acceptable:

3.3.7.1 **Combination of radiator and fan cooling (ONAF)**

When this type of cooling is used, the reactor shall be capable of operating at the specified maximum ambient temperature without exceeding the temperature rise limits specified in this specification.

All fans shall be of equal rating.

3.3.7.2 **Forced air and forced oil cooling (OFAF)**

When this type of cooling is used, it shall be possible to permit any one heat exchanger unit (consisting of fans and oil pumps) to be out of service without causing the temperature rise of the reactor to exceed the limits specified in this specification.

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3.4 Core

3.4.1 Design

For the 3 phase reactors, the core shall be a 5 limb type. These requirements shall be specified in schedule A of the enquiry.

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The maximum temperature rise of the core surface in contact with oil and cellulose insulation above the average ambient temperature of 25°C should not exceed 80K for all possible rated in service conditions. The core surface temperature must be limited to the temperature capability of the material in contact with the core using average ambient specified. The material used in core cooling ducts, and between the core and frames, and between the core and the tie plates shall have a continuous temperature rating of 150°C minimum.

3.4.2 Materials

The core shall be manufactured of high permeability; non-ageing cold rolled grain oriented steel sheet laminations having smooth, insulated surfaces. The maximum allowable size of burrs on the slit or cut edge of the electromagnetic steel shall not be capable of causing damage to the insulation between sheets. For all reactors core shall be of mitred construction. The core sheets shall be properly stacked in the step-lap configuration and all the insulation designed in a way that no detrimental changes in physical or electrical properties will occur during the lifetime.

3.4.3 Clamping

For the core clamping no bolts through the limbs and yokes shall be used. The limbs should be fastened by non-metallic bands/belts. Non continuous steel straps or rods used around the yokes must be insulated from the yokes to prevent shorts to the core and circulating currents. The pressure of the yokes shall be adequate to prevent movement of the lamination during shipping accelerations. All the return limbs shall be vanished to improve the mechanical stability during shipment/ transportation.

3.4.4 Earthing

The main magnetic core shall be directly grounded via a bushing on top of the cover with a removable external ground connection. The core shall be bonded to the core clamping structure at one point only, which is easily accessible, and protected to allow testing after installation of the reactor.

No core earthing connection shall have a cross-sectional area smaller 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.

The core earth grounding point shall be clearly marked with a permanent label. The factory core insulation resistance value(s) shall be permanently marked at the core earth grounding point together with **"CORE EARTH MUST ALWAYS BE CONNECTED WHEN EQUIPMENT IS ENERGISED"** and indicating the terminal identification.

3.4.5 Stack-stack Resistance

The resistance between the core stacks shall be such that no dangerous or detrimental voltages arise. The control of the stack to stack resistance shall be done using engineering techniques where quality control is measureable and adjusting is possible. Scratching of the core laminations to reduce the inter-stack resistance is not allowed.

3.4.6 Temperature Rise

Hotspot rise above ambient of metal parts in contact with oil shall not exceed 80K under the most extreme operating circumstance. Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or other thermally non-conducting material should not exceed the safe operating temperature of that material. Adequate safety margins should be included when determining these criteria.

3.4.7 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 shall be inserted to maintain electrical continuity between sections.

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3.5 Coils/Windings

3.5.1 Design

Core form windings shall be of circular concentric type. All the conductor joints within the winding must be minimised and are only permissible at locations on the outer surface of windings. Multiple strand joints shall only be applied in areas of low stray flux density. Shell form windings are not preferred and can only be considered in special circumstances and when approved by Eskom in writing.

3.5.2 Materials

All windings shall be constructed with copper conductors only. Continuously Transposed Conductors (CTC) shall be free from inter-strand shorts after the winding has been completed. For all the reactors the windings shall be vanished/enamelled conductor to prevent corrosive sulphur effects between the insulation and the conductor. Where the varnish is removed to make joints in the conductor, special arrangements must be made to ensure no corrosive sulphur damage can take place. The shear or tear strength of the bond and base of enamel/ epoxy shall not be less than 40% of the room temperature strength when heated to 125°C after curing.

3.5.3 Hot Spot Calculations

The calculated hot spot shall be based on the maximum calculated localised losses in the windings, the insulation on the points with maximum losses, and the oil rise in the windings. If the designer is not able to determine the oil rise in the windings, an added 5K will be made at the design review to allow for the difference between the oil rise in the windings and bulk top oil in the tank.

The maximum hot spot in the leads shall not be more than 1K above the maximum calculated hot spot in the windings.

Winding hot spot shall be measured directly during a heat run test at the factory before release.

3.5.4 Insulation

When determining the equivalent power frequency for impulse voltages i.e. Design Insulation Level (DIL) for analysis of insulation stresses, the ratio of full wave impulse voltage to the power frequency shall not exceed 2.5. The minimum acceptable margin in oil spaces shall be 20% based on the Weidemann® oil strength data.

All conductor insulation shall be thermally upgraded paper, except when it is otherwise stated.

The expected life of the paper insulation is 35 to 40 years and the processes implemented in the factory during the manufacturing of the reactor shall not reduce the paper life to less than 950 DP value. The *Contractor* shall demonstrate this for each reactor using a direct DP measurement method. The test must be done using an adequate paper sample. The *Employer* may from time to time request a physical paper sample for verification purposes by an independent or internal laboratory. This must be catered for during the production activities. DP values below the indicated value will entitle the *Employer* to a compensation event.

3.5.5 Joints and Internal Connections

Copper conductor shall be used throughout, for the windings and for the leads.

There shall be no soldered joints or terminals in the reactor. All internal lead connections shall be brazed, welded, or compression type. If compression type is used, then the method employed must be approved by the *Purchaser*.

No joints are permitted internal to the windings unless it involves a single strand of a multiple strand (5 or more strands) conductor. Joints shall be permitted at crossovers and leads external to the windings. The manufacturer shall have an established quality assurance program to detect, prevent and repair nicks, dents, burrs and other imperfections in the conductor material. The manufacturer shall have an established quality assurance program to ensure that all joints comply with the requirements.

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All internal connections shall be designed so that bushings can be removed or installed without exposing the paper/ winding block to the atmosphere i.e. with partial drain. Inspection covers must be available to enable verification of tightness of connections. Where there are joints in adjacent leads they may not overlap but must be staggered. All leads must be securely supported and braced. Sizing and Compressing

The winding shall be compacted with a minimum pressure of 7.5N/ mm² on the spacers, for helical and disc windings. It is expected that the windings will be dried under constant pressure. All windings shall be sized using a maximum tolerance of -0 + 2mm. The sizing pressure after final vapour phase drying shall not be less than 5N/ mm² on the reactor board spacers.

The manufacturer will be responsible for proposing methods for checking the pressure on the windings after the final assembly is completed to ensure that it is not less than 5N/mm^2 on all spacers.

The *Contractor* shall fully demonstrate the adequate clamping of the windings as required at all stages of manufacturing. The clamping pressure shall be sufficient even for the maximum forces assumed occurring during the coldest conditions of the unit.

3.5.6 Termination on bushings

Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions without jeopardising the in-service integrity of the reactor.

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

Allowances shall be made for accommodating up to 100 mm tolerances on bushing axial dimensions and the fact that bushings may have to be rotated to get oil level inspection gauges to face in a direction that allow easy inspection from ground level. In particular, rotation or straining of insulated connections shall be 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 be provided to minimize the possibility of creating faults during the installation of bushings.

3.5.7 Clamping

The *Contractor* shall fully demonstrate that adequate clamping of the windings as required at all stages of manufacturing is controlled.

3.5.8 Drying

The *Contractor* shall fully demonstrate that adequate drying and moisture ingress into the winding as required in all stages of manufacturing is controlled.

3.6 Bushings

The bushings used shall be of technology that provides safe operation of the reactor, maintenance free or at most minimum maintenance, environmentally friendly, and as far practically as possible does not add fire risk. Only dry technology of bushings is acceptable except in exceptional cases which shall be agreed with Eskom during a tender stage and shall be indicated in Schedules AB. One of such a case is when such a technology does not exist at all or is not matured enough in the category of the required bushings.

The bushings shall comply with the requirements of the bushings specification 240-56062799 and as stipulated in schedules AB of a given purchase order. For units going to long-term storage (spares) the bushings shall be provided with an oil storage vessel.

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3.7 Tank and Parts

3.7.1 Tank Design

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

The tank and cover shall be designed so that local heating due to stray flux in any structural part shall not exceed the top oil temperature limit specified for the reactor, by more than 10 °C.

Heating, due to stray flux, shall also not cause local temperature elevations of more than 15 °C relative to the oil temperature at that level.

Thermometer pockets shall be located so as to avoid errors in temperature indication due to the heating effects resulting from stray flux. Thermometer pockets shall be located in a position where the least traffic is during activities such as OLTC maintenance and bushing replacements.

3.7.2 Tank Base

The underbase shall be suitable for the movement of the reactor in any direction, by sliding on greased rails.

Unless otherwise approved, reactor underbase shall be of a thickness not less than that specified in this document. Fabricated bases shall not retain water. Skid bases are not accepted, except in special cases where they may be needed, it shall be so indicated by the *Employer.* The position of the axial and transverse centre lines as shown on the dimension and foundation drawings shall be 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.

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Table 1: Minimum thickness of reactor tank base plates — mild steel

Length of tank (m)	**Minimum plate thickness** (mm)
Fabricated bases,	
not exceeding 2,5	10
exceeding 2,5	12
Flat bases,	
not exceeding 2,5	12
over 2,5m but less than 5	20
over 5m but less than 7,5	26
exceeding 7,5	32

3.7.3 Tank Main Top Cover

The top cover of the tank shall be the welded type unless stated otherwise in the schedule AB or during the mechanical design review. The positioning of the auxiliary components and pipes on the top cover must take into considerations the need to walk on the top of the tank during the maintenance activities. Preferably the conservator tank should not be on the top cover as it makes movement extremely difficult to almost impossible during inspection and maintenance activities. The top cover shall be painted with a non-slippery paint to enhance safety of personnel.

3.7.4 Tank Strength and Oil Tightness

3.7.4.1 **Rigidity**

Reactor tanks and their associated components shall have adequate mechanical strength and rigidity to permit the complete reactor, 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 reactor, and without the necessity for the special positioning of sliding rails in relation to the tank. Tank stiffeners shall not cover welded seams, to enable the repair of possible oil leaks. The tank and reactor as a whole shall be suitable for transport by low-bed or beam wagon.

3.7.4.2 **Internal Pressure and Vacuum**

Reactor tanks, complete with all fittings and attachments normally in contact with the insulating oil, and filled with oil of the specified viscosity, shall withstand the pressure and the leakage tests. When empty of oil they shall withstand the full vacuum test. In the case of type tests for strength and oil tightness the fittings (e.g. pressure relief devices and bushing stems) may be tested separately. The ability of the tank to withstand overpressure shall be co-ordinated with the pressure relief valves.

The tank shall be designed to withstand full vacuum for vacuum filling. If barrier boards are installed between the main tank and any other tank (selector tank) the barrier board shall be designed to withstand full pressure of the main tank filled with oil on the one side of the barrier board with full vacuum on the on the other side of the board

3.7.4.3 **Joints**

a) All gasketed joints shall be designed, manufactured and assembled to ensure long term leak-free and maintenance free operations.

b) Joints that need not be removed for normal maintenance or transport shall be welded.

c) Details of all gasketed joints shall be submitted for approval during the mechanical design review meeting.

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3.7.4.4 **Gasket Types**

a) Subject to clause b), all gasketed joints shall be of the O-ring and groove type. The O-ring shall be manufactured from nitrile rubber or better.

b) Bolt-on type tap-changers and selector tanks that have to be removed for transport or maintenance are specifically excluded for the use of O-ring type gasket joints. In these applications rectangular cord and groove joints where the nitrile rubber cord is not joined but passed twice around the perimeter with the loose ends at the bottom, are acceptable. Alternatively a flat nitrile rubber gasket with stoppers to prevent over compression will be acceptable.

c) Approved non O-ring gaskets that need re-tightening in order to avoid oil leaks as a result of shrinkage, shall be retightened in the second 6 months of service by the *Contractor* at no extra cost to the *Purchaser*. All costs to maintain the system leak free shall be for the *Contractor*'s account during the guarantee period.

3.7.4.5 **Attachments to the reactor tank**

Attachments to the reactor tank shall only be fixed by bolting them 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 will not be accepted.

3.7.4.6 **Pipe joints**

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

3.7.4.7 **Drilling of pipe flanges**

Except where otherwise stated, the drilling and bolting of pipe flanges and the mating flanges of fittings shall comply with BS 4504 or DIN 2631.

3.7.5 Access openings and covers

An appropriate number of suitably proportioned handholes and manholes shall be 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 their terminal boxes (see 3.6.3). Manholes for the purpose of internal inspection are preferred to be as close as to ground level as necessary to eliminate the need of climbing.

The following minimum inspection covers shall be provided on the main tank:

- At each bushing terminal where the bushing is connected to the winding
- On the tank wall, a minimum of one accessible from ground level to allow access for active part inspection at least 600 mm in diameter. The inspection cover shall be located to allow for maximum access to the active part and the tap changer. Where this is not possible more than one inspection cover shall be provided.
- On the top cover, a minimum of one to allow access for active part inspection at least 600 mm in diameter.

3.7.6 Handles

Manhole covers shall be provided with stout handles to facilitate their removal.

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3.7.7 Lifting lugs

Covers with a mass greater than 25 kg shall be provided with symmetrically arranged lifting lugs.

3.7.8 Valves and oil sampling devices

3.7.8.1 **Isolating valves**

Suitably dimensioned isolating valves shall be provided:

a) at each point of connection to detachable cooling apparatus; and

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

c) Isolating valves shall provide effective sealing at 100 kPa pressure and full vacuum at sea level.

d) Radiator isolating valves shall be freely accessible for opening and closing with the reactor fully assembled.

e) No special tools or tools shall be required to open or close radiator valves.

f) Radiator valves shall be fitted to allow replacement of individual radiators.

3.7.8.2 **Filtering and drain valves**

Two 50 mm double-flange valves shall be provided for filtering purposes. At least one valve shall be 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 shall be a combined drain and filtering valve and, as such, shall be positioned so that it drains, as far as possible, all the oil from the reactor tank.

The top filtration valve shall be routed inside the transformer tank and be brought out on ground level, and shall be clearly marked externally**.** The intake of the pipe for the top filtration valve shall be positioned at the allowable partial drain level.

All valves shall be painted with the same colour as the reactor tank.

No valves shall be fitted by means of stud welding or welding to the main tank.

All drain valves shall be protected against mechanical damage. The means of mechanical protection shall be indicated on the general arrangement drawing.

3.7.8.3 **Oil sampling devices**

If specified in AB schedule, an oil sampling device consisting of a flange and drain plug as per the Oil sampling specification 240-56062720 or other approved device shall be provided in the following locations where applicable:

a) at the bottom of the reactor tank, bolted and fitted with O-rings to the free flange of the 50 mm drain valve specified in 3.7.8.2;

b) at the end of the main Buchholz relay sample pipe. A ¼" needle valve shall be provided on the Buchholz pipe for oil sampling.

These points shall all be numbered on the sampling point with the number corresponding to the same point on the valve function plate (see 3.7.8.7).

The sample pipes shall be copper tubing with an ID of at least 7 mm (3/8" or 10 mm copper tubing). All fittings used shall be 3/8" brass or stainless steel. Only SAE 45-degree flares must be used on the copper tubing - compression fittings are not acceptable. The tubing shall be protected against physical damage by appropriate routing, fastening and / or protective conduit. Provision shall be made to secure oil sample copper tubing with rails welded to the tank and structures. At no point shall the copper tubing make contact with any steel surfaces.

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A sample valve shall be provided and located approximately 1.5 m above ground level and be easily accessible from the reactor plinth. The sample valve shall be a needle type valve of 3/8" or 10 mm size – ball valves may not be used. Only brass or stainless steel needle valves shall be used. A stopper plug shall be provided to seal the open end of the sample valve.

All oil sampling devices to be accessible from ground level.

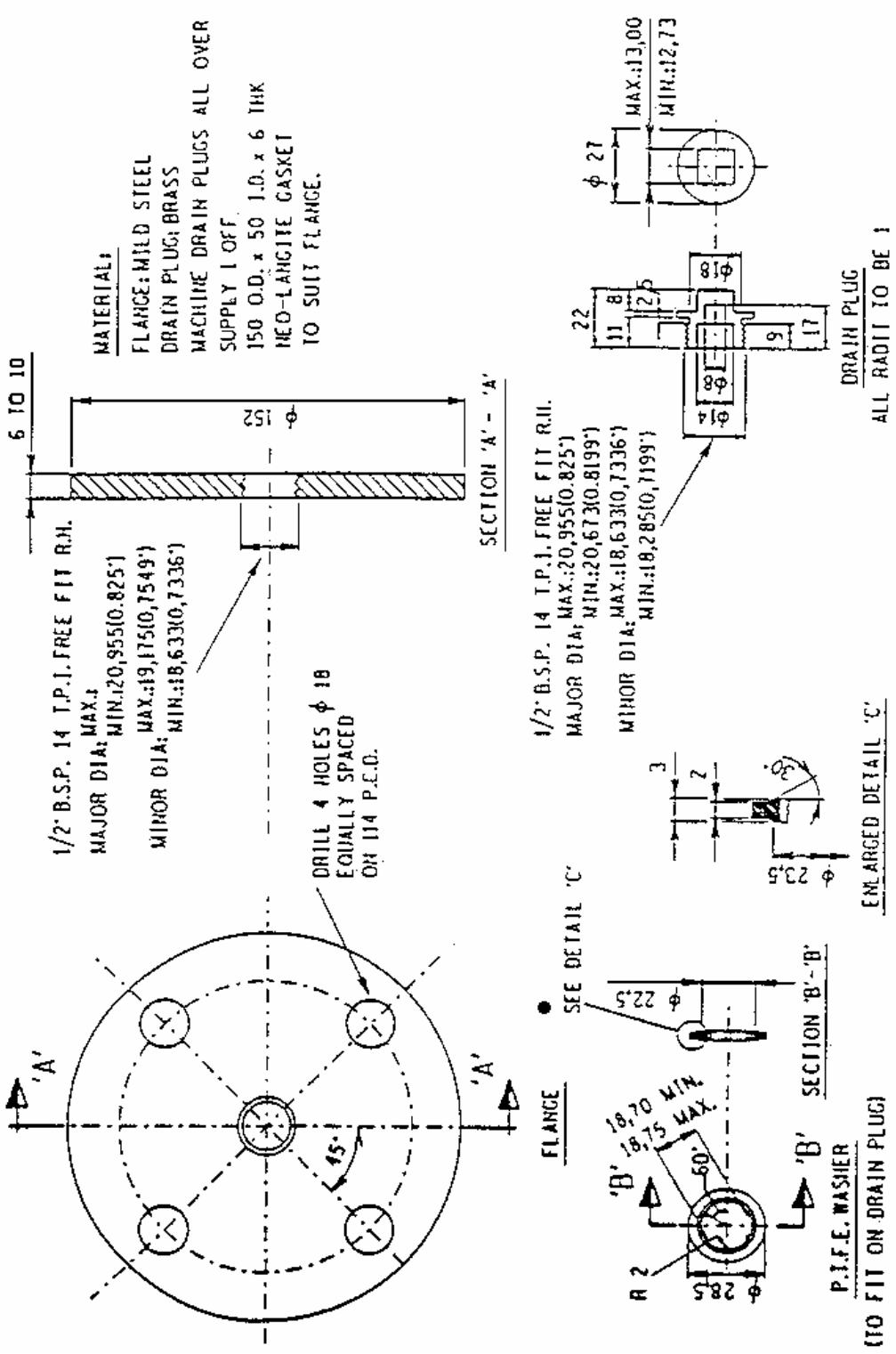

Figure 1: Oil sampling flange interfaces

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3.7.8.4 **Strength and oil tightness**

Valves and oil sampling devices shall be of adequate strength to withstand the hydraulic and mechanical loads imposed upon them during testing, processing and transporting of the reactor and in service. Pewter and similar low strength materials will not be accepted.

Valve discs, wedges, wedge facing rings, seats and seat rings, stems and spindles shall be of approved non-corrodible material. Valves and oil sampling devices shall withstand the 3.18 test requirements,

3.7.8.5 **Valve stem seals**

Valve stem seals shall be capable of adjustment in service without draining the reactor oil. In this connection, and generally, aluminium (or aluminium alloy) threads shall not mate with threads of brass valve stems.

3.7.8.6 **Blanking plates**

All valve entries communicating with the atmosphere shall be sealed using bolted and gasketed (“O” rings accepted) blanking plates, or captive screwed caps, or plugs as the case may be.

3.7.8.7 **Valve function plate**

A schematic diagram plate indicating all valves, vent plugs and sampling points shall be provided in the same manner as the rating and diagram plate. This plate shall also indicate the position of all valves in operation, and out of operation.

3.7.8.8 **Valve position indication**

The position of each valve, i.e. either fully open or fully closed, shall be clearly and unambiguously visible on inspection. Where this is not so, e.g. in the case of lever operated valves, the “open” and “closed” positions of the lever in relation to a clearly recognizable part of the reactor shall be depicted on the valve function plate specified in 3.7.8.7.

3.7.8.9 **Labelling of oil sampling devices**

All the oil sampling points shall be numbered the same as on the valve function plate with exception of the two routine sampling points that shall also be labelled. The labels shall comply with the requirements of the labelling specification 240-56062720

3.7.9 Jacking Pads

Four suitably and symmetrically placed jacking pads shall be provided in positions that shall be accessible when the reactor is loaded on to the transport vehicle, except where jacking pads are used as transport pads on vehicles with built-in jacking.

The position of the jacking pads shall be such that they do not restrict the direction in which the reactor could be moved (forward, backward and sideways) once off-loaded on site.

Each jacking pad shall be designed to support, with an adequate factor of safety at least half of the total mass of the reactor 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 reactor base, and the unimpeded working surface of the jacking pads shall be as in **Table 2** (read in conjunction with **Figure 2**).

Table 2: Jacking pad dimensions

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Reactor 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 direction 'E' shall be unrestricted.				

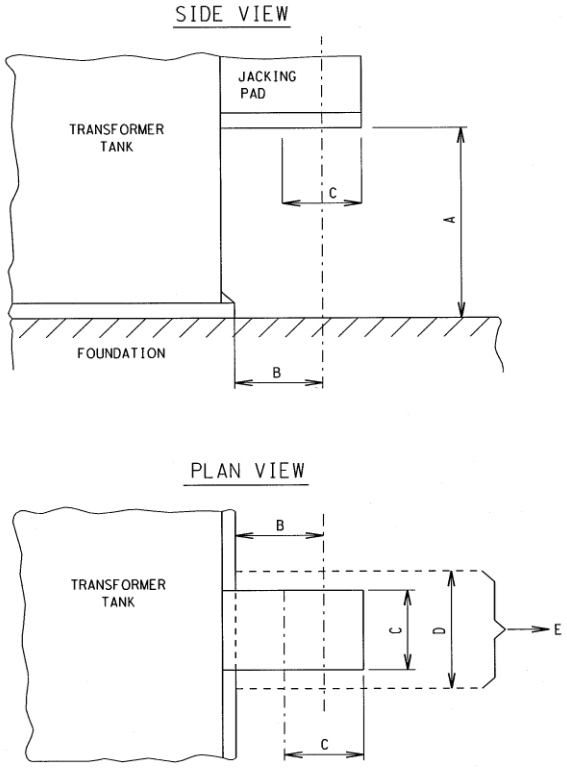

Figure 2: Arrangement of jacking pads

3.7.10 Lifting Lugs

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

The lifting lugs shall be so arranged and located as to be accessible for use when the reactor is loaded on the transport vehicle, and so as not to cause fouling of any of the reactor fittings and accessories. These should create water packets

3.7.11 Centre of Gravity

Centre of gravity shall be clearly visible and indicated on all sides of the reactor tank.

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3.7.12 Manholes and Handholes

At least one manhole shall be provided on the sidewall, to allow access for internal inspections not higher than 500 mm from the base of the tank. Manholes shall be round with a diameter of not be less than 600 mm.

Hand holes shall be provided to facilitate the removal and installation of bushings.

3.7.13 Provisions for earthing

Provision shall be made for earthing the reactor and associated apparatus as follows:

3.7.13.1 **Reactor tank earthing**

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

These provisions shall take the form of earthing pads integral with the tank walls; where the pads are attached by welding, such welding shall be continuous around the perimeter of the pads. Earthing pads shall be stainless steel and allow installation of 50 x 3 mm flat copper straps.

3.7.13.2 **Reactor neutral(s) earthing (direct)**

A stainless steel pad having the same clamping arrangement as the reactor earthing pads and integral to the reactor tank shall be provided for each reactor neutral terminal for earthing.

This pad shall be mounted as near as possible to its corresponding neutral terminal in order to ensure a short and steady connection to earth. The pads shall be mounted on the side of the tank from the top to ground at 800 mm intervals.

3.7.13.3 **Reactor surge arrester earthing (line and neutral surge arresters)**

The surge arrester mounting brackets shall be used as the earth path for surge arrester discharging to earth via the reactor tank (i.e. copper earth tails shall not be used for surge arresters).

Where brackets for phase and neutral surge arresters are to be fixed to the tank using tank mounted bolts, stainless steel pads (similar to the reactor tank earthing pads that form an integral part of the tank) shall be used. When these pads are attached by welding such welding shall be continuous around the perimeter of the pads.

Where brackets are not directly mounted onto the tank (on radiators) a separate suitably rated corrosion protected connection shall be provided to the earthing pad on the tank.

Note: Bolted down surface contact areas of reactor surge arrester support brackets and earthing pads shall be free of any paint or metal spray coatings.

- All tank attached apparatus, including cable marshalling boxes, tap-changer operating gear and mechanism boxes, pipes, fan and pump motors shall be bonded to their supporting structures.
- Earthing pads, as specified in 3.7.13, shall also be provided on each end of the supporting structures for all separately mounted cooler banks and oil conservators and on all free-standing cubicles.
- No copper shall be used as connections for the purpose of earthing.

NOTE: Integral pads to suit the fault levels specified.

3.7.14 Brackets for Surge Arrestors

For terminals of 132kV and below, the surge arrestor brackets used shall comply with the following requirements:

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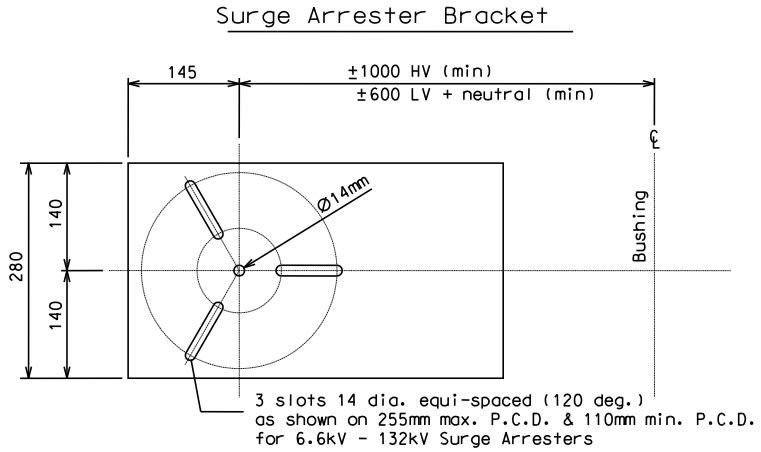
a) The surge arrester mounting brackets shall be provided to suit the dimension shown in **Figure 3: Surge arrester bracket dimensions** The outline and dimension drawings provided in terms of a contract, shall show the surge arresters mounted on the reactor with all necessary clearances and sizes dimensioned.

b) Universal surge arrester mounting details, fully dimensioned, shall be shown in an inset on these general arrangement drawings.

c) Refer to 3.7.13 for the earth continuity requirements of the surge arrester brackets.



Notes :

1. All steel work shall comply with SABS 1200H.
   All steel work shall be hot dip galvanised to SABS ISO 1461.
   no cutting, welding or drilling shall be done after
   the galvanising process is completed.
   Tolerance - on dimensions +/- 2
   - on hole centres +/- 1
2. Steel plate 10mm thick.

Voltage	No.off	Phase spacing	HV / MV
132 kV	3	*	HV
88 kV	3	*	HV
66 kV	3	*	HV
44 kV	3	*	HV
33 kV	3	700mm C/C	MV
22 kV	3	700mm C/C	MV
11 kV	3	700mm C/C	MV
6.6 kV	3	700mm C/C	MV

* = Centre phase inline outer phases, bushing centres + 450mm min.

Figure 3: Surge arrester bracket dimensions

The surge arrestor bracket arrangement must be finalised during the mechanical design review meeting.

3.7.15 Permanent Ladder

A permanent steel ladder shall be welded to the main tank in a position to provide unrestricted access to the top of the reactor with the unit fully assembled. The ladder shall not interfere with or restrict maintenance activities and routine inspections. It shall not cover or restrict access to inspection / manhole covers and interfere with fitting of monitoring and on-line drying equipment.

A safety harness securing point shall be positioned at the landing space immediately above the steel ladder on the top cover.

3.7.16 Partial Draining

To facilitate oil leak repairs on inspection covers and header pipes, reactors shall be designed to allow partial draining to a level of at least 150 mm below the top lid cover without exposing any cellulose insulation. Refilling of the reactor shall not trap air under inspection covers or top lid. Where necessary, bleeding points shall be provided to vent trapped air.

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The tank side wall shall be permanently marked by welded sign or labelling to indicate the minimum oil level allowed for partial draining without exposing any cellulose insulation. The labelling shall be submitted to the purchaser for approval. This mark shall be located on the side wall i.e. same face where the bottom drain valve is located.

3.8 Auxiliary Supplies, Terminal Boxes, Wiring and Cabling

3.8.1 Supply Voltage

The auxiliary power supply will be rated at 400/230 Vac, three phase, 4-wire, 50 Hz. The unearthed DC supply will be 110 V or 220 V nominally as specified in Schedule A.

3.8.2 Marshalling and Terminal Boxes

The Marshalling box shall be mounted on the reactor main tank. It shall be mounted in a position that it can remain fitted to the reactor tank during transport and installation. The Marshalling box shall be mounted on vibration reducing mountings to prevent damage or malfunction of internal accessories. The base of the Marshalling box shall not be lower than 300 mm form the base of the reactor but limited to 400 mm. All parts inside the marshalling box must be accessible from ground level.

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

Covers for terminal boxes may be of the slip-on type, and those for Marshalling boxes shall be hinged in a vertical plane. Marshalling kiosk access doors shall open to a minimum angle of 120 degrees and shall be provided with a door open retainer. The door retainers must be strong enough to hold the cover in the presence of wind stresses.

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

Marshalling boxes and terminal boxes, arranged in a vertical plane, shall be 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 shall be flush inside to permit total drainage.

3.8.3 Earthing terminal

An earthing terminal of M12 to M16 shall be provided in each terminal and marshalling box with a stud on both the inside and outside.

3.8.4 Spare terminals

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

3.8.5 Incoming auxiliary circuits

To prevent entry of water, the auxiliary wiring from the gas- and oil-actuated relay, current transformers and other auxiliary apparatus, shall be arranged for side or bottom entry into the marshalling or terminal box. If bottom entry is adopted, the gland plate used shall be independent of that provided for the *Purchaser*'s outgoing cables. If cables enter the terminal boxes or marshalling kiosk from the side, drip-loops shall be provided to prevent water from entering the cable gland.

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3.8.6 Provision for outgoing cables

The marshalling box shall be provided with a separate, removable, undrilled plate to take the *Purchaser*'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 or the *Purchaser*'s cables. The gland plate shall be of 6 mm thick brass sheet. Steel plates are not accepted

The gauze covered drain and vent hole may be fitted to this gland plate. The gauze covered drain hole must be in the lowest part of the kiosk and must not be on the gland plate.

3.8.7 Cabling and Wiring

Only UV stable, heat and oil resistant PVC SWA (steel wire armouring) cable shall be used on reactors. Only corrosion resistant cabel glands for armoured cables shall be used. Plastic compression type cable glands shall not be used on armoured cables. Heat, oil and UV restant cable shrouds shall be fitted to all cable glands.

All cable terminations shall be provided with cable numbers fitted to the cables on both ends. Only permanently engraved, non-corrodible, UV, oil and heat resistant material shall be used for cable numbering. These labels shall be permanently fixed to the cable ends just before the glands on the outside of the terminal box.

The cable armouring shall be earthed at least one side. Earthing shall be by means of the steel cable gland.

3.8.8 Insulation

Wiring insulation shall be oil- and moisture proof, and, where affected by temperatures above that of the ambient air, shall have thermal characteristics at least equal to class 'A' of IEC 85.

3.8.9 Insulation test voltage

All auxiliary circuits shall withstand a test voltage of 2 kV DC for 60 seconds to earth and to all other circuits.

3.8.10 Type of conductor

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

As far as possible, only cables with the correct number of strands shall be used. Where this is not possible the free stands shall not be cut, but effectively earthed on one side of the cable.

3.8.11 Supporting and securing of cables

All cables shall present a neat appearance and shall be supported on cable rails elevated 20 – 30 mm from the tank surface. The rails shall be welded to the reactor tank surface. Similar rails shall be provided to route and secure cables to auxiliary components, i.e. oil level indicators, Buchholz relays, cooling fans, etc.

Cables shall be secured to cable rails by means of stainless steel strapping with a minimum width of 6 mm and not exceeding 10 mm.

Routing of cables shall be done to eliminate the cable from touching sharp edges on the reactor tank structure.

No cables in steel conduit will be accepted.

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3.8.12 Identification of wiring

All equipment boundary/interface terminals and the equipment wires connected to those terminals shall have a unique wire/terminal number in accordance with the manufacturer's drawings approved by the *Purchaser*'s. The wires shall be 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 *Purchaser*'s approval.

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

3.8.13 Cabling by the Purchaser

Multi-core cabling to the remote control point will be provided by the *Purchaser*. Where a separately mounted outdoor control cubicle is provided near the reactor and where the *Contractor* is responsible for erection, he shall provide and connect all cabling between this control cubicle, the reactor marshalling box and the auxiliary apparatus on the reactor together with all necessary cable fittings, attachments and identification of cables and cable cores.

3.8.14 Identification of fuses

All fuses shall be labelled indicating the rating and circuit.

3.8.15 Identification of equipment

All equipment identification labels in marshalling kiosks and control cubicles shall be fixed on permanent surfaces next to the equipment (above, underneath or next to) and not on removable covers or on the equipment itself.

3.9 Rating and Diagram Plates

3.9.1 General

Rating and diagram plates shall comply with the requirements of IEC 60076 except where otherwise stated in this specification.

3.9.2 Materials and methods of marking

Rating and diagram plates shall be of stainless steel not less than 1,2 mm in thickness.

The required information shall be engraved on the plate and the engraving filled with glossy black, baked enamel.

Other arrangements shall be specifically approved.

3.9.3 Mounting

The rating and diagram plates shall be mounted on the door of the marshalling interface box for all tank mounted boxes. If otherwise, the plates must be mounted on the tank. The plates must be finished in accordance with 240-56030674 situated in an accessible position not more than 1,5 m above ground level, and secured by stainless steel screws.

3.9.4 Information to be displayed

The minimum information to be displayed on the rating and diagram plate shall be in accordance with the requirements of IEC 60076 with addition of the following as detailed in **Figure 4**.

a) the current reactor data shall be shown;

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b) a statement that the manufacturer deems it necessary for the reactor to be oil-filled under vacuum;

c) a statement that the reactor will withstand full vacuum at sea level;

d) the *Purchaser*'s reference number shall appear on the rating and diagram plate;

e) values for all relevant parameters used by the digital temperature gauge for the winding hot-spot and reactor lifetime calculations as per IEC 60354 or IEC 60076-7

f) The temperature probe hole diameter/s and depths.

g) a blank space for the *Purchaser*'s asset number shall be provided;

h) the type, make and designation numbers of all bushings, to enable full identification (relating to stock spares) while the reactor is energised;

i) the valve and oil sampling point functions and positions;

j) a warning statement that the conservator contains a bag or other sealing systems if it is the case; and

k) the type of corrosion protection: Corrosive or low corrosive.

l) Initial DP value

m) Tie-in resistor schematic and value (if used).

n) Vector Group

o) Surge Arrestors on regulating winding

p) Tertiary Reactor

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), (m), (n), and (o).

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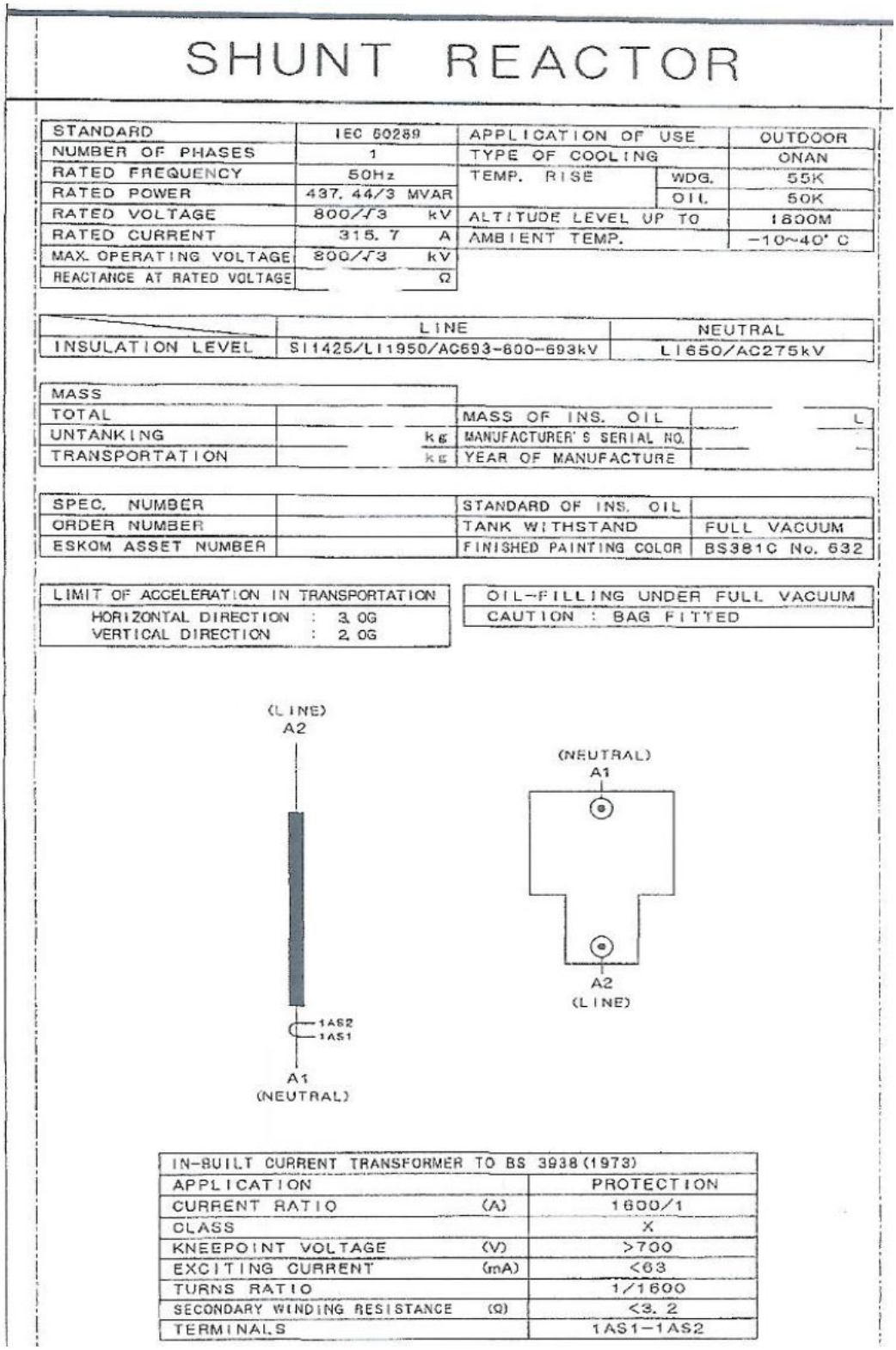

SHUNT REACTOR

STANDARD	IEC 60289	APPLICATION OF USE		OUTDOOR
NUMBER OF PHASES	1	TYPE OF COOLING		ONAN
RATED FREQUENCY	50Hz	TEMP. RISE	WDG.	55K
RATED POWER	437. 44/3 MVAR		OIL	50K
RATED VOLTAGE	800/√3 kV	ALTITUDE LEVEL UP TO		1800M
RATED CURRENT	315. 7 A	AMBIENT TEMP.		-10~40° C
MAX. OPERATING VOLTAGE	800/√3 kV			
REACTANCE AT RATED VOLTAGE	Ω			

	LINE	NEUTRAL
INSULATION LEVEL	SI1425/LI1950/AC693-600-693kV	LI650/AC275kV

MASS			
TOTAL		MASS OF INS. OIL	L
UNTANKING	kg	MANUFACTURER'S SERIAL NO.	
TRANSPORTATION	kg	YEAR OF MANUFACTURE	

SPEC. NUMBER		STANDARD OF INS. OIL	
ORDER NUMBER		TANK WITHSTAND	FULL VACUUM
ESKOM ASSET NUMBER		FINISHED PAINTING COLOR	BS381C No. 632

LIMIT OF ACCELERATION IN TRANSPORTATION	OIL-FILLING UNDER FULL VACUUM
HORIZONTAL DIRECTION : 3. 0G	CAUTION : BAG FITTED
VERTICAL DIRECTION : 2. 0G	

IN-BUILT CURRENT TRANSFORMER TO BS 3938 (1973)		
APPLICATION		PROTECTION
CURRENT RATIO	(A)	1600/1
CLASS		X
KNEEPOINT VOLTAGE	(V)	>700
EXCITING CURRENT	(mA)	<63
TURNS RATIO		1/1600
SECONDARY WINDING RESISTANCE	(Ω)	<3. 2
TERMINALS		1AS1-1AS2

Figure 4: Typical Rating and Diagram plate

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3.10 Painting of Tanks and Parts

The painting of the reactor tank, the conservator tanks, the piping, the covers, the turrets and all other items that need to painted or galvanized shall done according to the requirement of the Eskom painting specification 240-56030674. The following items shall also be painted:

- the flange facing surfaces.
- the blanking plates that are used during transportation.

3.11 Special Auxiliaries

All auxiliary components used in the Eskom reactors shall comply with the relevant specification and must be approved by Eskom. An auxiliary component will be declared approved when it has been technically evaluated by relevant specialist and the approval is in writing

3.11.1 Buchholz Relay

An oil and gas actuated relay suitable for operation in transformer oil as specified over the temperature range from - 10°C to + 115°C shall be interposed in the connecting pipe between the oil conservator and the reactor tank. The relay shall be fitted in such a manner that all the gasses from the tank pass through and are trapped by the relay as the gasses move towards the oil conservator. The mounting angle shall be as per the relay OEM instruction so as not to compromise the reliability of the relay.

For the purpose of redundant protection, transformers and reactors having a voltage rating of 220 kV and above or a rating of 100 MVA(r) and above shall be provided with two Buchholz relays. The relays shall be installed in series in the connecting pipe between the oil conservator and the reactor tank, mounted at least five pipe diameters apart - measured from facing flanges.

The oil and gas actuated relay shall comply with the requirements of 240-56063908. A valve must be fitted between the Buchholz relay and the conservator.

3.11.2 Pressure relief devices

Reactors rated below 100 MVAr shall be equipped with one spring operated pressure relief device and those of 100MVA and above shall have two devices.

Pressure Relief Devices (PRD) shall comply with the requirements of 240-56063871 and shall be mounted so as not to entrap gases that may be generated or released inside the reactor. These devices shall be fitted directly to the side walls of the reactor tank at a level as near as possible to the top of the windings. Where one device is fitted it shall be positioned as close as possible to the centre phase. Where there are two devices they shall be arranged on opposite sides of the reactor, 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. All mounting positions shall be such that the PRD(s) is(are) positioned above the partial drain mark. This shall be subject to approval by the *Purchaser* and be discussed during a mechanical design review meeting.

A combined weather guard and oil deflector shall be fitted to ensure free deflection of the oil towards the ground and provide adequate protection from the environmental elements. These must however not reduce the oil evacuation capability of the device.

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

3.11.3 Rapid Pressure Rise Relay

Each new reactor and reactor rated ≥ 80 MVA and ≥ 132 kV shall be provided with at least one rapid pressure rise relay. In the case of large units ≥ 500 MVA and ≥ 400 kV, two units, one on each of the longitudinal end shall be fitted. The function of the rapid pressure rise relay is to detect dynamic over-

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pressure conditions caused by abnormal activity inside the main tank and to provide a trip signal to remove the equipment from service. A suitable double flanged gate valve shall be fitted between the relay and the reactor tank to allow for maintenance without the need to drain the reactor oil. The position of the relay shall be such that maintenance and/or replacement of the components (valve and relay) can be done with partial drain. The position shall be discussed during a mechanical design review and submitted for approval. The relay shall be provided with seal in and reset feature and test facilities.

This component shall comply with the requirements of 240-56063867.

3.11.4 Thermometers for Oil Temperatures

Oil temperature indicators (OTI's) are fitted to reactors to measure the oil temperatures. The indicators do not only display the temperature but are also used to start / stop forced cooling, provide high temperature alarm and trip signalling.

These shall comply with the requirements of 240-56063843

3.11.5 Fibre optic temperature probes

For all reactors when specified in the Schedules AB, for identification of hot spot temperatures, fibre optic temperature probes have to be installed based on mutual agreement between the *Contractor* and Eskom during the design reviews. The sensors will be installed permanently for future use with the connection points easily accessible 1.5m from ground level. A redundant sensor will be installed near the primary sensor.

For all the units fitted with fibre optic sensors, the units should have a through wall plate fitted at the top of the reactor tank (above the partial drain level) and extensions pre-fitted (factory supplied) terminating in to the marshalling kiosk. The position of the through wall plate and the internal extensions pathway within the tank must not follow a path whereby personnel entering the interior of the reactor would easily be able to damage them; furthermore the cover used for the plate must be a dedicated one and not an inspection cover.

3.11.6 Oil Level Indicators

Each conservator tank (main tank and OLTC) shall be provided with a dial-type oil level indicator that will show the correct oil level inside the tank. Direct reading fluid type oil level indicators shall not be used.

The indicators shall be suitable for the design of the conservator, i.e. free-breathing or bag type conservators.

Expected design life of the oil level indicator shall match the design life of a reactor, at least 40 years.

The oil level indicator shall comply with all the requirements of 240-56356191

3.11.7 Fans and Radiators

Transformers and reactors are fitted with radiators to reduce operating temperatures. Where forced air cooling is required, fans are installed beneath the radiators and air is forced in a vertical direction to increase cooling of the oil. The GSUs will be fitted with coolers.

All radiators shall be mounted onto the main tank of the reactor. Each radiator shall be provided with top and bottom shut-off valves and shall be detachable from the main tank. The radiators shall be hot dipped galvanised only. The galvanising shall comply with SANS 1461. Radiators shall not be positioned over manholes, hand holes or inspection covers.

Radiators shall be equipped with stainless steel type DIN 42 558 bleeding and drain plugs. Seals shall be UV, heat and oil resistant.

Radiators shall have the necessary lifting eye connections. For shipping and storage, all flanged openings shall be permanently sealed by means of a blank, bolted and gasketed cover.

The fans and the radiators shall comply to the requirements of 240-56535946 and the requirements indicated in Schedules AB.

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3.11.8 Air Bag

As indicated in Schedules AB certain units shall be fitted with an air bag in the conservator.

3.11.9 Air Bag Leak Detector

Each transformer and reactor fitted with an air bag shall be provided with a bag leak detector. The function of the bag leak detector is to detect a leaking air bag. The abnormality will be detected by this detector and an alarm will be signalled to the control panel of the respective transformer or reactor. A contact will provide an alarm signal that the bag leak detector has operated to alert maintenance staff.

The air bag leak detector shall comply with the requirements of 240-56356202, and shall be positioned about 100 mm from the top of the conservator tank, without compromising reliability. The proposal for the installation shall be submitted at tender stage and shall form part of the mechanical design review. A bleed pipe and valve must be brought to ground level and fitted with a locking device to prevent unauthorised opening of the valve. A tag complying with the requirements of 240-56062720 shall be provided written **: "BAG LEAK DETECTOR AIR RELEASE".**

A second valve to get the trapped air from the conservator must be provided. The associated text should read "**CONSERVATOR TANK AIR RELEASE".** Both valves should have mechanical tamper proof covers.

3.12 Insulating Oil

The *Contractor* shall approve the oil to be used, and such oil must comply with the requirements of the latest revision of the Eskom Oil specification 240 - 75661431 and must be from the list of the approved oils. The list is available from Commercial. In support of the Eskom drive for environmentally friendly products, the so called green oils shall be considered for acceptance.

The *Contractor* shall also ensure that the oil used during manufacturing and testing at the factory is mixable with the intended oil for use in service. The mixing of the two oils should not expose Eskom to any risk and this must be approved during design review.

3.13 Current Transformers

All current transformers shall comply in all respects with the requirements specified in Schedule AB and/or the following

3.13.1 Number and Location

The requirements for the CT shall comply with the **Table 1** and Table 4 below

3.13.2 Insulation levels and short circuiting for testing.

Current transformers shall withstand all dielectric tests applied to the power reactor windings, and shall be in position and in circuit during the power reactor voltage withstand and impulse tests. Open circuits shall be avoided during testing of the reactor. All current transformers shall be short circuited in the factory and so delivered to site.

3.13.3 Tests for current transformers

The current transformer shall be tested as per the latest IEC 60044-1:2003 specification and test certificates provided.

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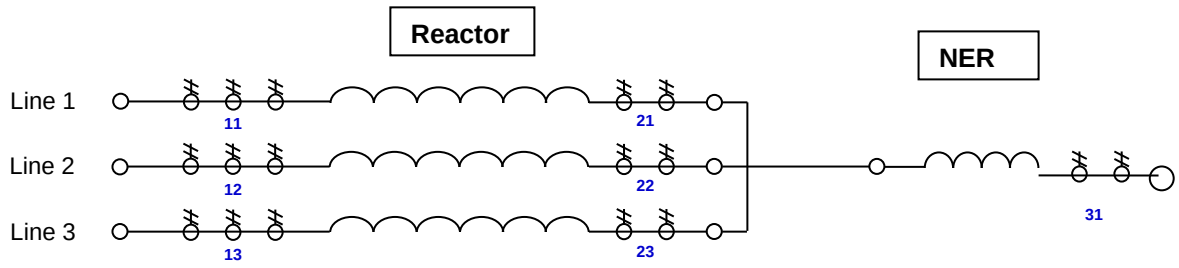
Table 3: CT Requirements for 765kV Reactors

	Unit	**Reactor CT**	**NER CT on earthed side**
Current transformer class		TPY	TPY
Rated primary current (Ipn)	A	**800**	**800**
Rated secondary current	A	2	2
Rated frequency	Hz	50	50
System voltage and insulation level	kV	765	765
System voltage and insulation level	kV	1550	1550
Ith (Ipsc)	kA	50 for 1 sec	50 for 1 sec
Idyn	kA	127.5	127.5
Ratio to which specified data applies	-	**800/1**	**800/1**
Alf (Symmetrical short circuit)	-	20	20
Kssc (Asymmetrical short circuit)	-	15	15
Tp	msec	100	100
DC Component	%	**55**	**55**
Duty cycle:Single: t', t'alDouble: **t'**, t'al, tfr, t", t"al	msec	100	100
Duty cycle:Single: t', t'alDouble: t', **t'al**, tfr, t", t"al	msec	40	40
Duty cycle:Single: t', t'alDouble: t', t'al, **tfr**, t", t"al	msec	500	500
Duty cycle:Single: t', t'alDouble: t', t'al, tfr, **t"**, t"al	msec	100	100
Duty cycle:Single: t', t'alDouble: t', t'al, tfr, t", **t"al**	msec	40	40
Rb	Ω	12	12

3.13.4 Number of CT cores for Reactors



CTs 11, 12 & 13	CTs 21, 22 & 23	CT 31
Bushing CTs on 765kV side	Bushing CTs on Neutral side	NEC CT (Dry Type)
Core 1 – 800/1 (M1 REF)	Core 1 – 800/1 (M1 Diff)	Core 1 – 800/1 (M1 REF)

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Core 2 – 800/1 (M2 REF) Core 2 – 800/1 (M2 Diff) Core 2 – 800/1 (M2 REF)

Core 3 – 302/1.5 (Winding Temp)

Table 4: CT Requirements for 400kV reactors

CT requirements for 100MVAr, 400kV Shunt Reactor (incl.with tertiary windings of 10MVA,22kV)							
C.T. No	**Application**	**Ratio**		**Output**		**Class**	**Rs**
				VA	Vk (V)	X	1.8
2 x 1A; 1B; 1C;	Relaying	400/1			400	X	1.8
2x 1YN(A,B,C)	Relaying	400/1			400	X	1.8
2B	WTI			10		X	1.8
1a; 1b; 1c;	Relaying	300/1		15		10 P 20	1.075
1yn	Relaying	300/1		15		10 P 20	1.075
2b	WTI	300/5		10		10 P 20	0.135

3.13.5 Terminal Connections

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

3.13.6 Termination of Leads - Internal

Particular attention shall be paid to the termination of leads inside the reactor tank with a view to ensuring secure connection of current carrying lugs, and the elimination of all possible tension in the leads plus any possible risk due to the presence of the electric field as stated in 13.14.1 of this document.

3.13.7 Turns Compensation

Protective current transformers shall not be turns compensated.

3.13.8 Required Data

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

- magnetization curve;
- secondary winding resistance (temperature compensated to 20°C); and
- secondary winding leakage reactance.
- insulation resistance

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3.13.9 CT Designation

Where more than one protective current transformer is provided in any one phase, the current transformer designated "main protective current transformer" shall be located furthest from the reactor windings. In addition, protective current transformers together with current transformers in general, shall be given designations as indicated in figures 9 and 10 below

3.13.10 Type and Accessibility

Current transformers shall preferably be of the bushing type. Separately mounted CT's shall be located above the reactor core and winding assembly and be provided with adjacent hand holes in the tank side or cover of a size adequate for their removal and replacement, which must be capable of taking place without the lowering of the oil and exposure of the paper insulation. The terminal box shall be positioned in the area outside the zone of high electric field of the associated bushing. This shall be demonstrated during a design review meeting and be verified during production.

3.13.11 Data for Rating and Diagram Plates

Where current transformers are built into the reactor, the combined rating and diagram plate shall provide full details of each current transformer's location, polarity, secondary terminal markings and also all the information required by BS 3938 as applicable, with the provision that no information be duplicated.

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

IL = Secondary insulation Level (2 kV DC)

Hz = Rated frequency

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

Rs = Secondary winding resistance at 75 ºC;

N = Turns ratio

Vk = Kneepoint voltage

Im = Magnetising current

Ip = Primary current

Is = Secondary current

VA = Output in (VA).

3.13.12 Terminal Markings

See Figure 4**: Typical Rating and Diagram plate** for typical markings, but these shall comply as per each specific reactor.

3.14 Reactor Testing

3.14.1 Active Part and General testing

All reactors shall be tested to the latest IEC requirements. The *Employer* shall indicate in the schedules AB the required tests and the classification thereof. Eskom representative shall participate in the testing of each reactor as shall be indicated in the applicable document viz, Inspection and test plan, Product/Process Quality Plan or any equivalent. It is required that for the non-South African factories, the notification of such tests be given in writing at the latest of 10 weeks before date of testing. This date will be a preliminary date that can change by a few days as the time gets closer.

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After a successful testing, it is required that the *Contractor* carries out an internal inspection on each unit and where it is possible, and shall confirm through a report to the *Employer* that he is satisfied that all is still in order. This inspection shall be carried out when a reactor is in a cold condition. The reactor can only be shipped or transported once an official release from Eskom has been obtained by the *Contractor* in writing.

3.14.2 Reactor Tank Testing

3.14.2.1 **Tank and fittings**

Each reactor tank complete with all the fittings and attachments normally in contact with the insulating oil, and filled with oil with a viscosity not greater than that specified in 32-406, shall withstand, for 24 h, at room temperature, without leakage, a hydraulic pressure that is not less than 35 kPa above the maximum working pressure at every point in the reactor.

3.14.2.2 **Pressure relief valve**

One pressure relief valve of each make and type, set to open at the specified pressure, shall withstand, for 24 h, at room temperature, an internal pressure of oil of 20 kPa above the maximum working pressure at the position of the valve, without leakage.

3.14.2.3 **Internal hydraulic pressure withstand**

One tank, radiators and oil conservator of each type and size shall be subjected, for 1 min, 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 the schedules of this specification.

After a second application no further permanent deflection shall be measurable.

3.14.2.4 **Vacuum withstand**

One tank, radiators and oil conservator of each type and size, both empty of oil, shall be subjected, for 1 min, 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 14 of this specification. After a second application no further permanent deflection shall be measurable.

NOTE: The above two tests may, by agreement, be combined.

Table 5: Maximum permanent deflection of steel tank panels between stiffeners

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

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3.14.2.5 **Dye-penetration testing**

To avoid leaks, dye-penetration testing shall be done prior to corrosion proofing of the tank and other manufactured fittings after any welding.

3.15 Reactor Transportation

3.15.1 General Conditions

It shall be the *Contractor*'s responsibility to make all arrangements for transport with the appropriate authorities. Eskom will only accept delivery from the *Contractor* on site. It shall be the *Contractor*'s responsibility to co-ordinate the arrangements for all stages of the transport of the reactor from the manufacturer's works to site, including trans-shipping where necessary. Where off-loading is required, all apparatus, materials and packages shall be addressed to the *Contractor*, who shall take delivery of the same at site.

The dimensions of the reactor shall be such that when packed for transport, it will comply with the requirements of the loading and clearance restrictions for the approved route. The max transport dimensions are limited to the following, otherwise indicated in the relevant purchase order.

Height 5 000 mm

Width 4 300 mm

Length 10 500 mm

All metal blanking plates and covers which are specifically required to transport the particular reactor, shall be considered part of the reactor and be handed over to Eskom after completion of erection. A listing of all these items and relevant drawings shall be included in the manuals, to enable Eskom to have the plates manufactured if required. The dimensions and quantity of each item required for transport shall be on the drawings. Where the supply of oil is included in the contract and where transport weight limitations permit, the reactors shall be transported with sufficient oil to cover the core and windings during all transport and storage conditions. The tank shall be sealed for transport to prevent all breathing.

Alternatively, where the above method is not applicable, the reactor shall be maintained continuously under positive pressure of dry air of at least 20 kPa during transport and storage until final installation. The pressure and the temperature at the time of filling shall be documented as part of the quality system. A pressure gauge, suitably protected shall be fitted to each reactor to facilitate checking of gas pressure during transit and on site. The pressure gauge shall be situated at ground level not higher than 1.5 m. The gauge, pipework and other accessories shall be protected against transportation and handling damage. The pressure gauge shall be clearly visible for routine checks without having to remove protective covers. A non-return valve shall be provided at the point of entry into the reactor to prevent loss of dry air due to pressurising equipment failure. The dry air cylinder shall be located at ground level fixed to the side of the main tank.

The total duration that the unit is filled with dry air shall be limited to six months where after the reactor must be appropriately processed and filled with oil as for service. Every precaution shall be taken to ensure that the reactor 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.

Full details of the proposed method of transport shall be submitted for approval.

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

3.15.2 Impact Recorders

The supplier shall attach to each reactor an impact recorder, which shall be capable of recording shocks in three axes. One impact recorder shall be mounted inside the tank on the active part and the other one on the tank wall. This shall remain the property of the *Contractor* and will be returned by the purchaser with transportation charges collect. The chart, or three copies of it, shall be delivered to Eskom.

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The *Contractor* shall inspect the impact recorder charts before unloading, and provide a report to the *Employer.*

3.15.3 Testing During Transport

Procedure 240-56030661 Requirements for transportation and movement of large electrical equipment shall be used.

The Contractor shall perform SFRA test and Core Insulation Resistance Test (500 V DC for one minute) during the following transport stages:

a) At the factory before loading into the transport

b) Alongside ship prior to loading

c) Before offloading from ship

d) After offloading from ship when on ground (in case of not loading direct to the road transport)

e) After loading on road transport, before start moving (Insulation resistance only for d) and e))

f) On arrival at destination port before loading for road transport

g) On arrival at site after final positioning

All test results shall match the original factory test results for acceptance. The results of the above tests shall be documented, signed off as part of the quality process and included in the reactor manuals, both hard copies and soft copies where applicable.

3.15.4 Sea Transport

The *Contractor* shall make the necessary arrangements for suitable slings or lifting tackle 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 Eskom in good order.

3.15.5 Road Transport

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

3.15.6 Transport support brackets

Attention is drawn to the necessity of receiving approval from the transport contractor of the design and spacing of transport support brackets to avoid overstressing of the relevant trailer carrying beams.

3.16 Erection

3.16.1 General

Erection shall include off-loading, installation, full assembly, oil treatment and testing of the reactor.

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

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3.16.2 Foundation Tolerances and Reactor Layout Details

Foundation tolerances and layout details shall be submitted for prior approval by Eskom. When the foundation has been constructed, before installation begins, the *Contractor* or his appointed representative shall inspect and confirm the suitability of it to handle the intended reactor.

3.16.3 Site Installation

Site installation shall be performed by the OEM.

All installation projects shall comply with the OSH Act No. 83 of 1993 and ORHVS.

Before commencement of site / store installation a Scope of Work shall be compiled and agreed upon between the OEM and the *Purchaser*. Compiling of the SOW shall be the responsibility of the *Contractor*. The requirements of the Eskom document 240-56062726 *Standard for Intrusive work and Oil filling, under vacuum of transformers and reactors on site* shall be the minimum requirements for handling the reactor during works on site. OEM requirements that are betterment of these requirements will be welcomed. An internal inspection, where possible, will be done by an Eskom employee at the completion of all the intrusive work to ensure that there is no risk when the unit returns into service. This activity does not relieve the supplier/ *Contractor* from his obligation to provide a risk free unit to Eskom.

3.16.4 Functional Tests

Functional tests shall be done on site after complete erection to verify that all the systems are working in harmony. These tests shall include but are not limited to

- Fan and oil pump direction and setting of overload protection relays.
- Correct operation and indication of tap changers.
- All valves in service position.
- Functional test for all alarm and tripping contacts.
- Pump start not tripping buchholz
- Cooling system philosophy

3.16.5 Electrical Tests According to IEC

The onsite testing shall include, but not limited to, the:

- Voltage ratios on all winding sets, tap positions and on all phases
- Impedance test at all tap positions
- Vector group
- Three-phase 380 V magnetising currents
- Winding insulation test – minimum 5kV
- Core insulation test (500 V DC for 1 minute)
- CT polarities, function and insulation
- Fan- and oil pump motor insulation test
- Control/power cabling insulation (minimum 1 kV)
- Tap changer continuity test
- Winding & bushings insulation integrity test (Doble M4000 instrument)
- SFRA after final assembly and oil filling (Doble M5000 instrument)
- Zero sequence impedance

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All the required tests shall be indicated in the relevant ITP or PQP document which shall be finalized between the *Employer* and the *Contractor* before installation commences.

3.17 Condition Monitoring

Condition monitoring is a very valuable tool for reactor life management. For a smart grid network it is important that reactor visualization is achieved at its best. It is preferred that all the condition monitoring signals from the reactor and from the components are available from one central point right at the reactor. These signals will then be sent to appropriate points where the operator can see them as well as to the APM tool for automated life assessment. The communication channels must comply with the requirements of IEC61850.

3.17.1 Condition monitoring data concentrator

The vendor should provide a suitable data concentrator in the marshalling kiosk whose function would be to collect all the condition monitoring signals from the reactor (from sensors around the reactor that it may have, including but not limited to: the oil and winding temperatures, DGA gas data, moisture data, cooling system data, bushing condition data, tap changer data, and load data) and digitally amalgamate them on this data concentrator. The data concentrator should collect the data and arrange it in a format that is fully IEC 61850 compliant. The system should then use IP based communication over multimode fibre to transmit this reactor data to either another data concentrator downstream or to a network server so it can be mapped to the Eskom enterprise historian. The fibre optic ports and interfaces should meet the requirements of [45]. The data concentrator should meet all the general requirements of of [43,44]. The number of inputs for devices should cater for all the sensors that will come with the unit. In addition for future sensors the data concentrator should have at least 2 x multimode 100BaseFX fibre Ethernet ports with LC connectors, 4 x Copper Ethernet ports RJ45 100BaseTX, 2 x RS232 inputs and 8 x 4-20mA inputs for the purpose of adding future sensors to this unit. The output of the system would be via multimode 100BaseFX fibre optic with LC connectors but there should be 2 additional copper Ethernet RJ45 100BaseTX outputs provisioned for alternative output of the data. In addition the device should have on board storage able to store all the unit's data with a minimum resolution of 5 minute sample intervals for a duration of 2 years.

3.17.2 Gas Analysers

An option for a gas analyser to be provided & installed together with the reactor should be given on the tender return, it should meet all the requirements of 240-64917195. If provided it should integrate with the data concentrator mentioned above. Two valves shall be provided, one as an intake from the reactor tank to the gas analyser and the other as the outlet back to the reactor from the gas analyser. The oil intake shall be from the top oil expanse level, with the pipe routed inside the main tank against the tank wall to the intake valve. These valves shall be 25mm double flanged gate valves and be at ground level (1.5m or below).

3.17.3 On line drying system

An option for an on line drying system to be provided & installed with the reactor must be given on the tender return, it should meet all the requirements of 240-59083215. Provision for online dryer system shall be made with two gate valves installed for supply and return oil with appropriate locations for effective drying. The valves shall be 25mm double flanged gate valves full flow design. A method of anti-vibration shall be provided for mountings of online dryers (moisture removers).

3.17.4 Fibre optic temperature sensors

Reactors shall be provided with fibre optic temperature sensors as indicated in the AB schedules. The vendor must provide with the reactor the fibre optic extensions and the signal conditioning device to present

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the temperatures as 4-20mA signals to be connected to the data concentrator mentioned above or directly to the Eskom protection panels. These should be terminated in the reactor marshalling kiosk.

3.17.5 General

The condition monitoring station should have a life span matching that of the reactor and must not introduce more frequent maintenance requirements.

All bidders shall provide a proposal for a condition monitoring system for active part, bushings, and on-load tap changers.

3.18 Documentation

Drawings, Photographs, Instruction Books, and Test Reports-As listed below shall be sent to Eskom. All drawings shall include the following information: Eskom, Serial Number, Design Fault Levels, gravitational force design limits, Power Ratings, Voltage Ratio, and Eskom Purchase Order Number.

Five (5) copies of outline, nameplate, base, bushings, schematics and complete wiring diagrams, terminal block arrangement drawings showing physical locations with dimensions are to be submitted for approval. The nameplate, schematic and wiring diagrams shall be submitted one month after the receipt of Purchase Order. The remaining drawings shall be submitted together a minimum of 8 months prior to delivery. The base drawings shall indicate the dimensions, jacking points, load bearing surfaces, and approximate total weight to facilitate the customer's foundation design. *Purchaser* shall return one copy of each drawing with comments or approval. All approved drawings are to be submitted in paper and in a CD. A late drawing penalty shall be assessed according to the schedule A of the specification.

Four (4) Photographs of the core and coil assembly shall be taken at such angles as to provide the maximum of design and construction information for records.

Quality Control Information-after an order has been, a copy of the manufacture quality control manual will be provided upon request to Eskom for their review.

One (1) complete reactor manual shall be delivered with the reactor. The manual shall be easily accessible and protected from moisture / water damage during transport and storage. This manual shall be used for erection and commissioning purposes and shall include the factory test results and diagrams.

A further (4) manuals and one (1) electronic copy on CD shall be delivered not later than 14 days after completion of all commissioning tests. This manual shall include the electrical results from the commissioning testing carried out on site as well as testing done during transport. All oil sample results from tankers and main tank shall also be included. In the CD an original file in the original format for the SFRA test shall be included for the future reference purposes.

All drawings are to comply with the Eskom drawing standard TPC 41-246 .

3.19 Adjudication of Tenders

3.19.1 Failure Rates, Reliability and Manufacturing Experience of *Contractor*s

The failure rate, reliability and manufacturing experience of the transformers, reactors and phase-shifters supplied from the transformer factory from which the Employer's reactor(s) will be sourced during the contract duration are to be provided in Schedules A&B. The statistical data of failure rates and manufacturing experience reflects the experience of the factory from which the Employer's reactors 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.

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3.19.2 Population

The population of units to be considered in the calculations of the in failure rates is all the transformers and reactors with a rating above 10 MVA(r) that was manufactured at the factory over the past 10 years, irrespective of who was the customer.

3.19.3 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, un-tank or remove the top yoke in order to repair a failure or defect caused during testing is defined as a factory failure.

3.19.4 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 10 years data must be 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. Eskom allows for a maximum of 3% factory failure rate per annum. Eskom reserves the right to audit these figures at any given point. If an approved supplier's performance during the contract period deteriorate and is above this 3% figure, Eskom may terminate placing further orders at any given time.

3.19.5 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 failure is only regarded as an in-service failure if the transformer had to be removed from its bay for the defect to be repaired.

3.19.6 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 10 year's data must be 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.

3.19.7 On Time Delivery

The On-Time Delivery Rate is defined as the number of the units that were delivered on or earlier than the agreed contractual date. This shall be calculated on ex-works.

3.19.8 On Time Delivery Rate

The On-Time Delivery Rate is defined as the number of the units that were delivered on or earlier than the agreed contractual date over the number of units delivered over the period of 12 months. Eskom requires an on time deliver rate of ≥95%. If an approved supplier's performance during the contract period deteriorate and is below this 95% figure, Eskom may terminate placing further orders.

3.20 Quality Assurance

The official Eskom Standard for "Quality Assurance Requirements for the Procurement of Assets, Goods and Services" is TST41-168.

Eskom or the representative reserves the right to inspect the materials, equipment manufacture and witness the tests. The manufacture shall allow access to the Eskom representative without any hindrance or additional charges to the Eskom. The Manufacture shall notify Eskom at least 10 weeks prior to commencement of the tests.

The Manufacturer shall submit a schedule within four weeks of the award of the contract.

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This shall show dates for:

- Engineering
- Submit reactor Outline drawing to allow foundation design
- Submit Drawings for approval
- Supply of Instruction Manuals
- Purchasing and Delivery of Components
- Manufacturing and Assembly
- Testing of Reactor
- Shipment to Site

If a unit fails under test, the supplier will officially notify the employer in writing within 24 hrs of the failure, the *Contractor* will set up a meeting with the employer to discuss and agree on a way forward. The *Contractor* will supply a written report on the failure within 30 days of the failure.

3.21 Loss Evaluation

All losses will be capitalised using the formula below when adjudicating the tenders.

3.21.1 Guaranteed losses

The manufacture shall guarantee the following losses for each reactor:

- No-Load loss in kilowatts at rated voltage and rated frequency.
- Total losses in kilowatts at rated output, rated voltage and rated frequency
- Auxiliary losses – 50% of the total of the auxiliary supply load to be added to the load losses to give total load losses.
- Load losses shall be evaluated for MVA rating as specified in schedule A of the rating for each reactor.
- Reactor losses determined under tests shall be corrected to 75°C. No-Load loss shall not be corrected.

The reactor cost shall be evaluated as follows:

Evaluated Cost = P + [A * E] + [B * L]

Where: P = Reactor tender price

A = Evaluated Cost of No-load loss per kW

B = Evaluated Coast of Load loss per kW

E = No-load loss in kW

L = Load loss in kW

No load losses A (R/kW)	Load losses B (R/kW)
R63 000	14 000

3.21.2 Non Conformance on losses

If the measured no-load losses and/or load losses exceed the IEC tolerances Eskom reserves the right to reject the reactor.

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If the no-load losses and/or load losses measured exceed the guaranteed value then the incremental cost of loss evaluation shall apply as a penalty multiplied by the factor 4.

If the measured temperature rises exceed the guaranteed values, the highest deviation in degrees (top oil rise, average winding rise, hot spot rise) will be penalised. For each 1°C exceeding the guaranteed value, 1.5% of the reactor purchase price will be penalised. If the deviation is more than 5°C the reactor will be rejected or countermeasures have to be implemented to mitigate against the deviation.

There will be no credit or payment of premium if actual values are better than guaranteed values.

3.22 Training of Purchaser's staff

The *Contractor* shall propose an appropriate and cost effective training program for the operating, maintenance and engineering staff of the *Purchaser*. This shall include 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 *Purchaser*'s home country, the *Purchaser* shall be responsible for all the direct travelling and subsistence expenses involved for a maximum number of four (4) of the *Purchaser*'s staff.

The *Purchaser* shall have the option at his own expense, to add a further two (2) staff members.

The *Contractor* shall provide a complete and detailed broken down schedule of the training events but is not expected that formal training should last less than 5 consecutive working days nor more than 10 consecutive working days.

The *Contractor* shall advise the *Purchaser* 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 shall include as a minimum, an on-site component covering:

- on site preparation for transportation
- loading and off-loading procedure and precautions
- Installation procedures and precautions
- functional testing of tap changers, sensors and protective devices
- vacuum treatment, drying filtering and impregnation
- general maintenance and in-service inspections and checks
- all electrical testing of the completed system to ensure that it is ready for service

Special emphasis shall be placed on quality control processes and the maintenance of the oil and insulation system to keep it in the best possible condition to ensure maximum life for the reactor, as well as the underlying theoretical aspects.

These training requirements shall form part of the hand over for each installation.

The *Contractor* shall make available in electronic form training material that is adequate for the *Purchaser* to execute all handling and maintenance necessary in the future. The copy of such material will form part of the manual.

3.23 Local Support

Potential reactor suppliers shall have an established local technical support base. A Supervisor from the *Contractor* shall be available on site within 24 hours of notification of an emergency by the *Purchaser*.

The supplier shall be fully equipped to attend to emergencies and equipment failures within the guarantee period of the reactor.

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3.23.1 Local Support's Requirements

It is required that the local technical support cater for:

- Emergency breakdowns
- Failure investigations
- Maintenance & breakdown spares
- Operational enquiries
- Training

3.24 Safety on Reactors

Safety is very important in Eskom, and this includes when working with reactors. It is important therefore that all reactors designed and manufactured for use in the Eskom network take into consideration the safety needs. This includes but not limited to

- Safety of people working on a reactor, especially on top of the tank. The employees and the contractors should be able to do so with no risk of falling.
- Safety of the people working inside the reactor (e.g. making connections or doing inspections). A worker must be able to safely execute this with no risk of falling as reasonably as possible.
- Safety of people around the reactor when in operation. There must be no possibility of inadvertent contact with live apparatus while on ground level and where this is not achieved, it must be highlighted to the *Purchaser* at the tendering stage.
- Tank designs and components arrangement should be such that as practically reasonable as far as possible, tank rupturing is avoided.

The technology and the materials used in the construction of reactors must support the safety drive of Eskom.

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5. Revisions

Date	Rev.	Compiler	Remarks
May 2014	Draft 1	NS Mtetwa	Compiled using TST41-143 and making it independent of the transformer specification.

6. Development team (Working Group)

The following people were involved in the development of this document:

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