Eskom	Standard	Technology

Title: **TECHNICAL SPECIFICATION FOR CAPACITANCE-GRADED BUSHINGS FOR APPLICATION IN POWER TRANSFORMERS AND SHUNT REACTORS IN ALL ESKOM DIVISIONS**

Unique Identifier:	**240-56062799**
Alternative Reference Number:	**32-633**
Area of Applicability:	**Engineering**
Documentation Type:	**Standard**
Revision:	**3**
Total Pages:	**18**
Next Review Date:	**June 2026**
Disclosure Classification:	**Controlled Disclosure**

Compiled by	Approved by	Authorized by
Khayakazi Dioka	**Sidwell Mtetwa**	**Bheki Ntshangase**
Corporate Specialist Transformers and reactors	**Corporate Specialist Transformers and reactors**	**Senior Manager – SE&D Engineering**
Date: 20 May 2021	Date: 1 June 2021	Date: 01 June 2021

Supported by SCOT/SC

Bheki Ntshangase

SCOT Plant SC Chairperson

Date: 01 June 2021

PCM Reference: **Perform High Voltage Engineering**

SCOT Study Committee Number/Name: **Plant Equipment Study Committee**

Content

Tables

1. Introduction

This document is required to clearly set out Eskom's requirements for the selection and purchase of oil to air capacitance graded bushings fitted to Power Transformers and Shunt Reactors.

2. Supporting Clauses

2.1 Scope

This specification covers the technical requirements for the selection and purchase of oil to air capacitance graded bushings fitted to Power Transformers and Shunt Reactors.

2.1.1 Purpose

This document shall be used as a minimum requirement for the selection and purchase of oil to air capacitance graded bushings fitted to Power Transformers and Shunt Reactors.

2.1.2 Applicability

This specification is applicable to;

- Bushings fitted to new Power Transformers and Shunt Reactors
- Bushings purchased for Strategic Spares or repaired Power Transformers and Shunt Reactors

It excludes;

- Single bushing replacement on an existing Power Transformer or Shunt Reactor where an exact match (**dimensions only**) to the older installation set is required.

2.2 Normative/Informative References

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

2.2.1 Normative

[1] IEC 60137 Insulated Bushings for alternating voltage above 1000V

[2] IEC 60076-7 Loading guide for oil-immersed Power Transformers

[3] IEC 60076-18 Measurement of frequency response.

[4] IEC 61463 Seismic Qualification of Transformer High Voltage Bushings

[5] IEC 60815 Guide for Selection of Insulators in Respect of Polluted Conditions.

[6] BS EN 13601:2002 Copper and copper alloys. Copper rod, bar and wire for general electrical purposes

2.2.2 Informative

[7] ISO 17025 General Requirements for the competence of testing and calibration laboratories.

2.3 Definitions

2.3.1 General

None

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
BIL	Basic Insulation Level
CoE	Centre of Excellence
CT	Current Transformer
HV	High Voltage
ID	Internal Diameter
Id	Rated Dynamic Current
ISO	International Organization for Standardization
kPa	Kilo Pascal
kV	Kilo Volts
mm	Millimetres
MVA	Mega Volt Ampere
Ø	Diameter
OIP	Oil Impregnated Paper
PCD	Pitch Circle Diameter
PD	Partial Discharge
RIP	Resin Impregnated Paper
SIL	Switching Impulse Level
STC	Short Time Current
SVC	Static Var Compensator
UV	Ultra Violet
°C	Degrees Celsius

2.5 Roles and Responsibilities

This document shall be revised by Power Transformer and Reactors CoE before it expires or whenever it becomes necessary, whichever comes first.

2.6 Process for monitoring

None

2.7 Related/Supporting Documents

None

3. Capacitance Graded bushings for application in power transformers and shunt reactors requirements

3.1 General Requirements

All bushings from 33 kV (system voltage) and above shall be of the condenser type and dry type. Paperless technology is preferred for classes where the technology has matured, and this shall be demonstrated by each supplier during each tender. Where the paperless is not matured, resin impregnated paper (RIP) dry type will be an alternative. External insulation material shall be manufactured from silicon composite rubber, except otherwise specified in the schedules. No movement of moisture must be possible through the external insulation to the condenser body, and proof of this must be supplied by the Contractor during a tendering stage.

3.2 Environmental Requirements

Outdoor installation

Altitude above sea level – 1800m

Ambient temperatures

- Maximum +40°C
- Yearly average +25°C
- Minimum – (minus) 10°C

Average humidity 90%

Solar radiation 2500kW/m²

Atmospheric UV radiation High

Symmetrical three phase supply voltage, negative and zero phase sequence voltages up to 2% and total harmonic distortion of 3%.

Seismic conditions at a minimum of 0.3g, this requirement can be proved by test or by calculations.

Pollution level: Very Heavy

The bushings shall withstand the effects of the transformer or reactor being subjected to full vacuum at sea level as well as an extended positive pressure of at least 100 kPa.

3.3 Factory Testing

Each bushing shall be subjected to electrical tests performed at room temperature to measure the C1 and C2 power factor and capacitance. This test shall be carried out at 10 kV for the C1 measurement and at maximum allowable voltage for the C2 measurement.

Type tests shall be carried out according to IEC 60137. Type test reports shall be submitted to the Purchaser for approval.

Measurements for detection of internal PD shall be made. If a bushing fails the PD test, it shall be rejected and not be reprocessed for Eskom use.

All factory tests shall be performed in accordance with IEC 60137. All test facilities to be accredited to ISO 17025.

All test certificates and documentation shall be supplied to Eskom on delivery. For the type tests, they shall be submitted with the tender returns.

3.4 Electrical Creepage Distance

Electrical creepage distance of external insulation shall comply with “for very heavily polluted areas”.

All bushings shall have a creepage distance of 31 mm/kV. Protected creepage shall not be more than 50% of the total creepage distance.

3.5 Generic Business requirements

Table 1 Standard sizes for capacitance graded bushings

System Voltage	Rated Voltage	Type (note 1)	Rated Current	Stem Ø	Oil Ext	CT Ext	CT Ext Ø	Flange Ø	PCD	Fixing bolts	Thermal Short-time current (Ith) 2 sec	Dynamic current (Id)	Cantilever Force	BIL (1.25/50)	Power Frequency	SIL
U_n kV	kV		A	mm	L1 mm	L2 mm	D mm	D1 mm	D2 mm	No & Hole Ø (# x mm)	kA RMS	kA peak	kN	kV peak Micro sec	kV rms 60 sec @ 50 Hz	kV peak Micro sec
33 – 44	52	Dry [1]	1000	26	440	300	130	290	250	8 x 16	25	63	2.0	250	95	
33 – 44	52	Dry [1]	2500	38	440	300	130	290	250	8 x 16	50	125	2.0	250	95	
66	72.5	Dry [1]	1000	26	540	300	96	225	185	6 x 16	25	63	2.0	450	155	
66	72.5	Dry [1]	1600	38	560	300	140	290	250	8 x 16	30	75	2.0	450	155	
88	123	Dry [1]	1250	38	560	300	140	290	250	8 x 16	25	63	2.0	550	230	
132	145	Dry [1]	1250	38	660	300	160	290	250	8 x 16	25	63	2.5	650	275	
132	145	Dry [1]	2700	38	660	300	160	290	250	8 x 16	50	125	2.5	650	275	
220 – 275	300	Dry	2000	38	890	300	225	450	400	8 x 20	40	100	4	1175	510	950
400	420	Dry	1000	38	1090	300	290	680	620	16 x 22	25	63	5	1550	630	1175
400	420	Dry	1600	38	1090	300	290	680	620	16 x 22	30	75	5	1550	630	1175
500	550	Dry	1600	38	1090	300	290	680	620	16 x 22	30	75	5	1550	630	1175
765(A)	800	Dry	2500	Pad	2350	685	555	800	740	12 x 32	50	125	6	2400	1000	1600
765 (B)	800	Dry	2500	Pad [2]	1955	640	528	780	711	12 x 32	50	125	6	2400	1000	1600

NOTE 1: The paperless technology will be given preference on the classes where it has been evaluated and approved by Eskom in writing. In cases where this technology has not been approved by Eskom, Suppliers must provide a reference list, type test certificates, in-service experience (tan delta and capacitance) for at least 12 months.

NOTE 2: See the diagram in Appendix A

3.6 Bushing Terminal Stem Sizes

Air side bushing terminals shall be solid copper. Terminal stems shall be silver plated to minimum thickness of 20 micron. Dimensional tolerances shall be as specified in BS 1433: Copper for electrical purposes – rod and bar.

Terminal stems shall be manufactured to the correct size from a single piece of copper conductor. Spacers to increase the size of the copper conductors to the correct diameter are not acceptable.

Table 2: HV Bushing Terminal Sizes

Nominal System Voltage	Rated Current	Main HV Terminal Stems	
		Diameter	Length
Up to 400 kV	Up to 1000 A	26 mm	125 mm
	1001 to 2500 A	38 mm	125 mm
	>2500 A	60 mm	125 mm
765 kV	2500 A	8 hole pad (See attached picture for dimensions)	

3.7 Bushing Internal electrical connection

Bushing connection to the active part shall be designed to allow (as far as possible) replacement of any bushing by performing a partial drain on a transformer, i.e. draining to a level without exposing cellulose insulation. Bushings fitted with draw leads and separate terminal stems are required on capacitance-graded bushings.

On all bushings for new Power Transformers, flexible draw lead with separate terminal stem must be supplied wherever possible. When this is not possible or the current rating does not allow it, bushings shall be fitted with a removable copper rod. The removable copper rod shall extend to the full length of the bushing.

On all replacement bushings, the internal electrical connection will be dictated by the actual terminations of the transformer active part. This shall be specified on the order.

The bushing internal electrical connections shall be made as per the table below:

Under no circumstances are non-removable solid rods acceptable on Eskom transformer bushings.

Table 3: Bushing Conductor Requirements

Bushing current rating	Type of electrical connection
Up to 1000A	Flexible draw leads with separate terminal stems must be supplied.
1001A up to 2500 A	Wherever possible on new bushings for new transformers flexible draw leads with separate terminal stems must be supplied. Where not possible solid removable copper conductors must be supplied.
>2500 A	Removable solid conductor.

3.8 Test Point Construction

The bushing test point shall be provided to allow field testing of the internal insulation of the bushing without having to remove the HV bushing connections. The test point shall be positioned at an angle not more than 45° from the de-aeration point in order to facilitate safe testing while keeping the de-aeration at a highest point when installed in a transformer.

In line with developing online condition monitoring techniques, two test points will be considered, one for the fundamental frequency testing and the other for high frequency signals measurement. Each test point shall be located 45° from the bleeding point.

The test point shall be fitted with a dust cover that shall be removed and fitted by hand only. The test point shall be manufactured from non-corrodible material. An oil, heat and UV resistant seal shall be provided to prevent water and other impurities from entering the test point. If an O-ring is used, its thickness shall not be less than 3mm.

Connection of the test point to the internal insulation shall be by means of permanent electrical connection. Spring-loaded connections are **not** acceptable. Where special attachments have to be used to enable connection of test leads to the insulation of the bushing, it shall be provided with the bushing packaging. The method of connecting test leads must be fail-safe – if the external cover is left off.

3.9 Corrosion Proofing

Corrosion shall be eliminated by the use of non-corrodible materials, and by avoiding the contact of dissimilar metals.

All fasteners shall be stainless steel – grade 316 bolts with grade 304 nuts and washers shall be used. Thread lubrication shall be applied to all threaded areas on bolts, studs and screws. Any good quality high temperature grease is acceptable, but silicone based grease is preferred.

Where cast components are used, they shall be of high quality and non-porous castings. External copper terminal stems shall be silver-plated.

3.10 Bushing lifting lugs

Two lifting lugs shall be located on opposite sides of the base flange, positioned 90° to the air vent plug. The lugs shall form part of the base flange casting or removable lugs may be fitted. Where necessary, lugs fitted on the top flange may be installed if required.

Lifting lugs shall be positioned to allow installation of bushings fitted at an angle with the air release plug and test point located in close proximity to each other, in order to avoid the risk to the bushing tester having to lean to the farthest part of the bushing.

3.11 Bushing installation position

All bushings shall have an easily accessible test points that shall face inwards towards the centre of the tank after bushing installation.

In the case of the 765kV oil type bushings, the test tap shall face inwards and the oil level gauges/glass shall face outwards and shall be visible from the ground level. Only glass or polycarbonate shall be used as gauge glass material – and seals must all be compatible with the transformer and bushing oil.

3.12 Airvent plugs

Bushings shall be provided with air release plugs on the head of the bushing to release trapped air inside the central bushing tube.

Bushings must be provided with air release plugs on the base flanges these shall be positioned in the same area as the test point. This will allow installation with the test point facing inwards on bushings fitted at an angle. Vents must be in the highest point when bushing is installed

3.13 Nameplate Information

Bushing information shall be recorded on the bushing nameplate. The bushing nameplate shall be permanently engraved and manufactured from stainless steel. The labels shall be permanently fixed to the bottom flange next to the bushing test point.

The following information shall be recorded on the nameplate:

- Manufacturer
- Factory
- Relevant IEC standard

- Type
- Serial Number
- Year of manufacture
- Nominal Voltage Rating (kV)
- Nominal Current Rating (A)
- Short Time Current (kA)
- Lightning Impulse Level [BIL] (kV)
- Switching Impulse Level (kV) for ≥ 275 kV only
- C1 dissipation factor (%) and capacitance (pF)
- C2 dissipation factor (%) and capacitance (pF)
- Bushing mass (kg)
- Maximum angle to vertical (degree)
- Frequency (Hz)
- Design altitude 1800 m

3.14 Documentation

Each bushing shall be provided with the following documents placed inside the transportation crate and protected against the effects of moisture.

- A manual, which shall contain the following information at minimum:
  - Bushing handling, transportation and installation procedures
  - Bushing storage procedures for crate and fitted applications (temporary and long term)
  - Bushing maintenance and repair procedures
  - Any special material required and procedures for cleaning and maintaining the bushing
  - Acceptable test values for C1 and C2 tested and the range for safe in service operation
- Factory test results
- Bushing drawing
- Impact limitations and action after indicator operation

In addition, a full electronic version of the same manual and test reports shall be made available to Eskom.

3.15 Impact Indicator for Transportation

Bushings shall be fitted with visual impact indication on the crate and bushing body and set to the design impact levels of the particular bushing. The impact indication shall be non-resettable and operate in x, y and z planes.

3.16 Stress Shields

Stress shields to be supplied and included and they must be aluminium, epoxy coated stress shields. Insulation paper covered stress shields are not acceptable, this is due to the need to eliminate the additional requirement of drying out the paper covered unit before fitting. All stress shields must be fitted with mountings which limit attachment to the bushing in only one direction (there must be no possibility of incorrectly installing the stress shield) and the mounting mechanism once the stress shield is fitted must be secure and locked in place to ensure no disconnection due to through faults, nor vibrations while in service nor seismic occurrences within the limits of the IEC requirements.

Directions for correctly fitting the stress shield must be included in the documentation, listing the method of assembly and all precautions to be taken.

3.17 Corona Shields

The air side corona shield shall be of aluminium type and continuously round type. No separate sides will be accepted for assembly at site.

3.18 Packing for Shipment and Storage

The oil side of the bushings shall be covered with permanent bolted and gasketed steel cover (ONLY when specified for storage) with a corrosion resistant coating. The bushing shall be protected against the elements of corrosion and moisture. Moisture absorbing material shall be placed inside the protective cover. The insulator body of the bushings shall be protected against dirt and moisture. Plastic sleeving covering the entire insulator body and secured at the top and bottom flanges is acceptable. Corona shields shall be packed inside the crate and protected against corrosion and damage.

Bushings shall be placed in non-returnable wooden crates suitable for handling by overhead crane and forklift truck. Transport securing blocking on top of the bushings shall be removable to facilitate handling of the bushing. Securing of the removable top blocking by means of nails through the side of the crate is not acceptable.

The top lid of the bushing crate shall be completely removable to allow for easy handling of the bushing. The complete inside of the crate and top lid shall be lined with water tight plastic sheeting to prevent water and dirt from entering the crate. The crate shall bear permanent markings for: correct side up, centre of gravity, sling connections and total weight (crate & bushing).

Bushings shall not be transported or stored without insulator covering, permanent oil side protective cover, removable stiffeners and crate top lid.

3.19 Technical Evaluation and Final Approval

This specification serves as a minimum requirement for manufacturers that supply bushings. Any deviation from this specification has to be approved by Eskom in writing.

Final written approval shall be provided once a technical evaluation has been completed and equipment found in compliance with this specification and Eskom requirements.

4. Authorisation

This document has been seen and accepted by:

Name and surname	Designation
Prince Moyo	General Manager – Transmission Asset Management
Bheki Ntshangase	Senior Manager Substation Equipment and Diagnostics - SCOT Plant SC Chairperson

Name and surname	Designation
Sidwell Mtetwa	Corporate Specialist and SCOT Transformers Care Group Chairperson
Mashilo Moabelo	Senior Engineer – Substation Equipment and Diagnostics - Transmission
Mantsie Hlakudi	Chief Engineer - Substation Equipment and Diagnostics - Transmission
Thapelo Ndlovu	Transmission Transformers ETT Chairperson
Mohamed Mukuddem	Distribution Transformers ETT Chairperson
Lionel Jordaan	Generation Transformers ETT Chairperson

5. Revisions

Date	Rev	Compiler	Remarks
Feb 2015	1	L Jordaan	Draft document for review created from 32-633 Paperless technology added as an option Dry technology added as an option on 765kV 400kV at 1675kV BIL removed SIL for 275kV reduced to 950kV from 1050kV Fixed conductor removed on Table 3 Schedules AB added as part of the standard Document number changed.
December 2018	2	K Dioka	**Clause 3.1 & 3.3**: OIP requirement for 765kV bushings removed. **Clause 3.5, Table 1**: 72.5kV bushings added to the standard sizes. **Clause 3.5 Table 1**: BIL for 765kV (Type B) bushings changed to 2400kV. **Clause 3.5 Table 1**: Bushing types changed from RIP or OIP to Dry type only **Clause 3.5 Table 1**: Thermal Short-time current and Dynamic Current values changed to align with IEC 60137. **Clause 3.8**: Test point requirements amended to include on line condition monitoring techniques requirements. **Clause 3.8**: Air side corona shield requirements added
May 2021	3	K Dioka	**Clause 3.14,** Bushing drawing added as a required document to be transported with the bushing

6. Development team

The document was revised and influenced by the following working group members

Khayakazi Dioka

Andries Smit

Lionel Jordaan

Mohamed Mukuddem

Keneilwe Seleme

Nompilo Mkhonza

Janine Jagers

Billy Call

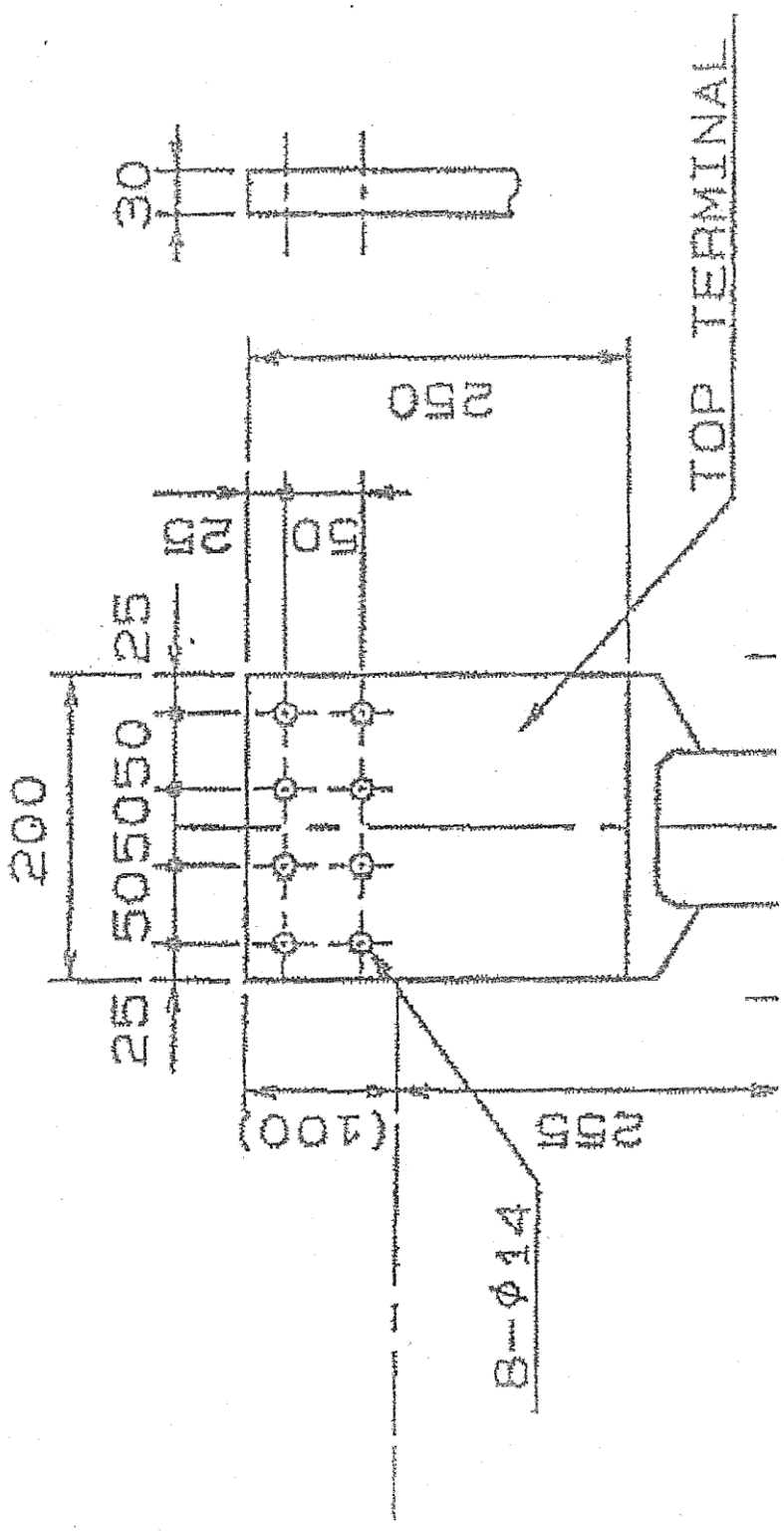
Lester Geldenhuis

Bulelwa Tina

7. Acknowledgements

The team acknowledges the team involved in compiling the previous revisions of this document.

Annex A – : Diagram



Annex B – - Schedule A&B template

Specification for dry capacitance graded bushings as per specification **240-56062799**.

Item	Description	Units	Schedule A	Schedule B
1	Purchasing Details			
1.1	Delivered to			
1.2	Quantity			
1.3	Delivery Date			
2	Operating Environment			
2.1	Altitude	masl		
2.2	Rated ambient temperature range	°C		
2.3	Yearly Average Ambient	°C		
2.4	Seismic requirements	g		
2.5	Thermal Short-time current 2s	kA peak		
2.6	Dynamic Current	kA rms		
3	Technical Data			
3.1	Application	Indoor/Outdoor		
3.2	Condenser Technology	Paperless/RIP/OIP		
3.4	Condenser Housing	Porcelain/Composite		
3.5	Angle of mounting	degrees		
3.7	Rated voltage	kV		
3.8	Rated lightning impulse test	kV		
3.9	Rated switching impulse test	kV		
3.10	Rated AC voltage test	kV		
3.11	Rated current	A		
3.12	Maximum Continuous Current	A		
3.13	Conductor type	Flexible draw lead/removable solid conductor/fixed rod		
3.14	Length of C.T. space min	mm		
3.15	Creepage distance	mm		
3.16	Cantilever load (IEC 60137)	N		
3.17	Flange diameter	mm		
3.18	Stem length	mm		
3.19	Stem diameter	mm		

Item	Description	Units	Schedule A	Schedule B
3.20	Oil Side length	mm		
3.21	PCD	mm		
3.22	CT ext diameter	mm		
3.23	Fixing bolts	no. X hole diameter(#Xmm)		
3.24	Stress shield material			
3.25	Stress shield coating or covering	Epoxy/Paper		
3.26	Stress shield dimensions			
3.27	Test Point of permanent connection and self grounding with cap off	Yes/No		
4	Testing Requirements			
4.1	Wet Power Frequency voltage withstand			
4.2	Dry power frequency voltage withstand			
4.3	Long duration power frequency			
4.4	Dry lightning impulse voltage			
4.5	Wet switching impulse voltage withstand			
4.6	Thermal stability test			
4.7	Electromagnetic compatibility test			
4.8	Temperature rise test			
4.9	Thermal short time current withstand			
4.10	Cantilever load withstand			
4.11	Verification of dimensions			
4.12	Tan delta and capacitance at ambient temperature			
4.13	Partial discharge measurements			
4.14	Test tap insulation			