TRANSFORMER COMPONENTS

EasyDry bushings

Operating instructions for bushings

PREFACE

These operating instructions show general procedures and guidelines that must be observed when installing and using the product. These operating instructions makes no claim for completeness and possibly do not cover all the activities that can occur during the installation, operation or maintenance, as there can be special variations of this product. It is highly recommended that all the necessary information and drawings are obtained before the installation and use.

If in doubt or in need of additional information, please contact ABB Power Grids Switzerland Ltd. or your local ABB partner for further information.

GENERAL INFORMATION

MICAFIL bushings are designed specifically for mineral oil-filled IEC 60296 transformers and chokes for oil-oil applications. Our bushings comply with the standards IEC 60137, IEEE C57.19.00 and C57.19.01. Additionally, they must be qualified according to strict internal guidelines. MICAFIL bushings are produced exclusively at the ABB industrial site in Zürich, Switzerland.

Table of content

1. Safety information

1.1. Symbols and notes

Warnings in these operating instructions draw your attenetion to particular hazards and specify measures for avoiding them. There are three levels of warnings:

DANGER

THIS SAFETY SIGN WARNS OF IMMEDIATE DANGER. IF SUCH NOTICES ARE NOT OBSERVED, IT CAN LEAD TO HEAVY INJURIES AND EVEN DEATH. ADDITIONALLY, MATERIAL DAMAGE CAN OCCUR. EXAMPLES OF HAZARDS: ELECTRIC SHOCK, FIRE HAZARD, EXPLOSION, POISONOUS GASSES, SLIPPING, WORKING AT HEIGHT, IMPACTS...

CAUTION

THIS SAFETY SIGN WARNS OF POSSIBLE DANGER. IF SUCH NOTICES ARE NOT OBSERVED, IT CAN LEAD TO INJURY AND/OR MATERIAL DAMAGE.
EXAMPLES OF HAZARDS: BURNING, SKIN, EYE OR HEARING INJURY, TRIPPING HAZARDS.

NOTE

THIS SYMBOL IDENTIFIES IMPORTANT INFORMATION OR POINTS AT RISKS THAT CAN RESULT IN MATERIAL DAMAGE.

► This notice suggest a particular course of action.

SYMBOLS

TYPE AND SOURCE OF HAZARD
THE POSSIBLE RESULTS OF NOT INTRODUCING THE MEASURES ARE PUT HERE.
Ø DANGEROUS CONDITIONS OR ACTIONS TO BE AVOIDED ARE INCLUDED HERE.
► MEASURES FOR AVOIDING THE HAZARDS ARE LOCATED HERE.

1.2 Product safety

MICAFIL capacitor bushings of types RTKF, RTXF, RTZF, RTF, RTKG, RAKF, RTKK, DMB-OA, RAF, RTAK, RTIM, RMFF, RMF, RMI, ... are produced according to the state of the art and the recognized safety rules. Despite that, when handling the bushing and improperly using it, hazards to the health and life of the user or third persons, or damage to the bushing and other material assets can occur.
► The bushing must be used only in technically faultless state as well as in observance of the provisions and the operating instructions, and with awareness of safety and hazards.
► Damaged bushings must be decommissioned and replaced.

1.3. Personnel-related measures

► The executing personnel as well as those who supervise the work must have adequate training, have safety-related knowledge in connection with the various activities, and work accordingly.
► Personnel should trained and instructed concerning the planned works with the bushing based on the operating instructions.
► The personnel that must be trained, taught or instructed, or the personnel that is in the process of obtaining general training, must work with the bushing under the supervision of an experienced technical specialist in the field of high-voltage equipment.
► For working at height, the corresponding guidelines must be observed.
► Use compliant tools.
► Wear suitable PPE (personal protective equipment: helmet, working clothes, safety shoes, gloves, goggles).

1.4. Organizational measures

► Read the relevant chapters of the operating instructions carefully and observe all safety and hazard instructions.
► Keep the full and readable operating instructions ready, and provide all-time access to it to the operating personnel.
► Observe the safety rules of the national and international safety authorities.
► Only authorize trained and instructed specialist personnel.
► Clearly determine, make known and observe the areas of responsibility for the works with the bushing.
► Only the personnel that before the beginning of the work have read and understood the relevant chapters of the operating instructions may be assigned for activities with bushings.
► Safety and hazard-conscious work must be inspected regularly observing the operating instructions. Observing the 5 rules for voltage-free work: Switch off, secure, test, earth/close-circuit, protect.

2. Structure of the bushing

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Note Fig. 1
Structure of a transformer bushing EasyDry (oil-air) 24 kV-170 kV and 245 kV

2.1. General structure

The EasyDry type series are dry, oil-free and capacitive-controlled bushings. The main insulation body of the bushing comprises a resin-impregnated synthetic material, also called RIS Resin Impregnated Synthetics). The conductive surfaces in the insulating body are used for capacitive field control.

The outdoor side is directly molded in silicone. A vent screw is brought to the flange of the bushing to be able to ventilate the transformer. The central pipe can also be ventilated with a vent screw mounted in the conductor. Threads located on the flange can be used for mounting crane eyes or pushing the bushing away from the transformer flange. A self-earthing measuring connection is integrated in the flange, making possible the measurement of the capacity and the loss factor of the bushing in the installed state.

Depending on the design, EasyDry bushings can be fitted with a fixed conductor, dismountable conductor rod or a cable bolt for rope conductors. The bushings can be operated in any post-assembly position.

NOTE

MICAFIL BUSHINGS ARE DIMENSIONED AND DESIGNED FOR APPLICATIONS IN MINERAL OIL.
► FOR ORGANIC OILS, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER FOR FURTHER INFORMATION.

Current conductor terminal with central tube ventilation (air side)

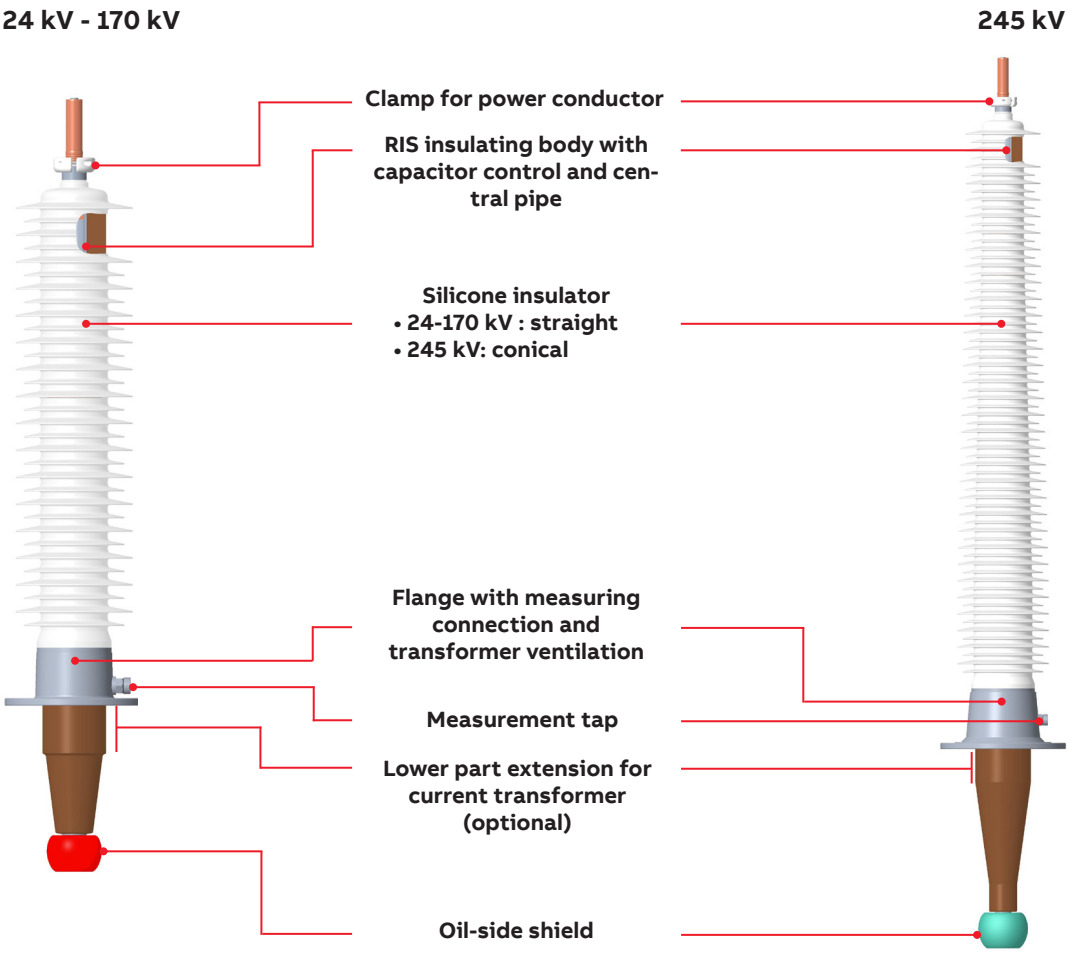

Fig. 1

3. Packaging and delivery

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Note Fig. 2
Packaging, delivered state, lifting

DANGER

PREVENTION OF LIFTING HAZARDS, CUTTING INJURIES, ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING ACTIVITIES.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES (REFERENCE MEASUREMENT NO. 1).
► OBSERVE WEIGHT DATA AND MARKINGS FOR THE CENTER OF GRAVITY.
► WEAR APPROPRIATE PPE.

3.1. Delivered state and lifting

The bushings are sent in wooden crates for protecting them against damage. The lower part of the bushing is packaged in a plastic bag. The cable bolt or conductor rod is installed in the bushing.

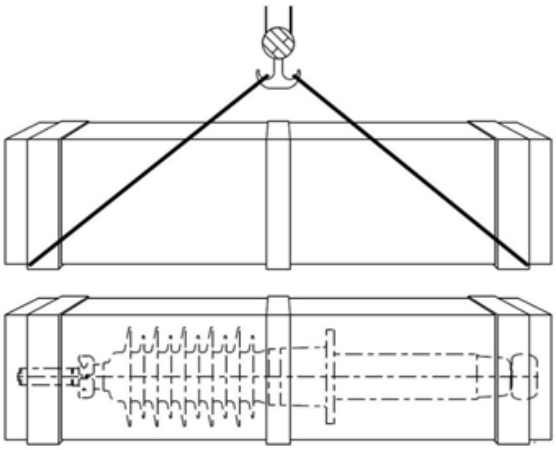

Fig. 2

NOTE

► IT MUST BE ENSURED THAT THE PACKAGING IS FULLY INTACT AFTER TRANSPORT.

3.2. Repackaging

It must be made sure that the bushing and the insulating body of the bushing are packaged in the same way as for delivery.

3.3. Transport wooden crate

Gross and net weight as well as dimensions are included in the dispatch note.
The center of gravity is normally market on the transport box if it is longer than 2 meters and if the center of gravity is not in the middle.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

4. Storage

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Note Tab. 1
Storage recommendations

DANGER

PREVENTION OF LIFTING HAZARDS, CUTTING INJURIES, ELECTRIC SHOCK, CHEMICAL HAZARDS, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING WORK.
► OBSERVE WEIGHT DATA AND MARKINGS FOR THE CENTER OF GRAVITY.
► WEAR APPROPRIATE PPE.

4.1. Storage

The bushing must always be protected against dust. For this reason, the recommendations specified in Tab. 1 must be observed..

NOTE

► WHEN STORED, THE BUSHING MUST BE COMPLETELY SEALED IN PROTECTIVE PACKAGING.
► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

Storage period	Outdoor not protected from rain	Outdoor protect from rain or indoor (recommended)
Delivery, short or long-term	Not permitted	The condenser core of the bushing shall be protected against dust as described below and stored in the original wooden crate: • Condenser core protected with PE tubular film. **Note** : This symbol on the wooden crate shall be taken into account

Tab. 1

5. Assembling

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Note Fig. 3
Recommended distance (A) from earthed parts (e.g. transformer wall)

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Note Tab. 2
Recommended distances A from earthed parts (e.g. transformer wall)

DANGER

PREVENTION OF LIFTING HAZARDS, CUTTING INJURIES, ELECTRIC SHOCK, CHEMICAL HAZARDS, FALLING, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING ACTIVITIES.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED.
► THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES (REFERENCE MEASUREMENT NO. 1).
► WEAR APPROPRIATE PPE.

NOTE

► THE PROTECTIVE COVER OF THE ISOLATING BODY SHOULD BE LAID UNTIL THE COMMISSIONING IN ORDER TO AVOID PARTIAL DISCHARGES TROUGH FINGERPRINTS.

5.1. Recommended distance from the transformer wall

The bushings are developed and tested for mineral oil applications. The field strengths in oil of the lower part of the bushing depend on the form of the surrounding parts as well as on the transformer oil. The corresponding gaps (A) to the earthed structures under standard conditions are listed as a guideline in the following table.This concerns the oil-side ends of the bushings according to the data of the dimension sheet of the bushing. Due to framework conditions, additional insulation measures and/or greater distances can be necessary. If necessary, the distance can also be reduced.
Non-insulated edges may only appear in the permitted area and should have a Rmin. = 5 mm.

CAUTION

► A CURRENT TRANSFORMER MUST NOT BE LONGER THAN L6 (SEE FIG. BELOW AND DIMENSION SHEET OF THE BUSHING) AS IT CAN DISRUPT THE FIELD AND HARM THE BUSHING.

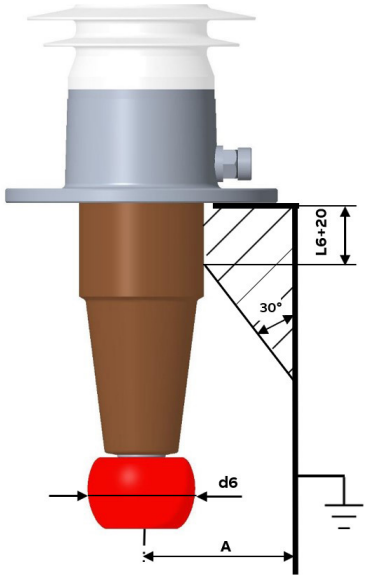


Fig. 3

Ur [kV]	AC test voltage [kV]	(1)	(2)	(3)	(4)
		Diameter of the shields (d6) [mm]			
		Ø 109	Ø 134	Ø 180	Ø 180
		Recommended min. distance (A) to the earthed parts of the transformer [mm]			
≤52	≤105	80	-	-	-
72.5	140	90	-	-	-
	160	110	-	-	-
123	185	-	115	-	140
	255	-	145	-	170
145	275	-	170	-	195
	310	-	210	-	225
170	325	-	210	-	235
	365	-	230	-	255
245	460	-		300	300

Tab. 2

(1): Cable bolt for conductor rope [Fig 7 (A)] and dismountable conductor rod for conductor rope [Fig 7 (C)]
(2): Cable bolt for conductor rope [Fig 7 (A)]
(3): Cable bolt for conductor rope [Fig 7 (A)]
(4): Fixed conductor rod [Fig 7 (B) and dismountable conductor rod [Fig 7 (D)]

5. Assembling

5.2. Lifting the bushing

Smaller types (<20 kg) can be picked up manually; larger types require textile slings and lifting gears (crane, hoist etc.) as described below:
To put the bushing from the horizontal to the vertical position, two textile slings shall be fastened on each crane eye (1) mounted on the flange of the bushing and properly connected to the hook of the first lifting gear.
After disassembly of the vent screw (2) at the head of the conductor, a crane eye (3) shall be mounted, and a textile sling shall be properly connected to the crane eye and to the hook of the second lifting gear.

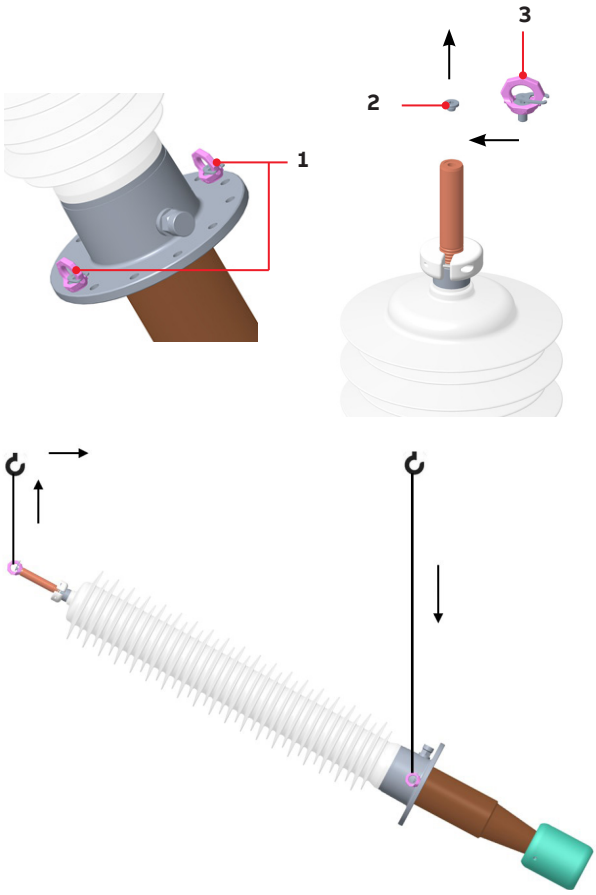


Fig. 4

Note Fig. 4
Lifting of the bushing:
1 Flange crane eye
2 Vent screw
3 Conductor crane eye

After installing of the bushing, all crane eyes shall be removed and the vent screw put back in place (screw M12 ,30 Nm unlubricated and 25 Nm lubricated).

CAUTION

► ALL CRANE EYES MUST BE PROPERLY INSTALLED.
► CLAMP HALVE MUST BE PROPERLY INSTALLED AND CLAMP SCREWS CORRECTLY FASTENED (SEE FIG. 6)
Ø THE WEIGHT OF THE BUSHING MUST NOT BE SUPPORTED BY THE CRANE EYE (3) SHOWN IN FIG.4

NOTE

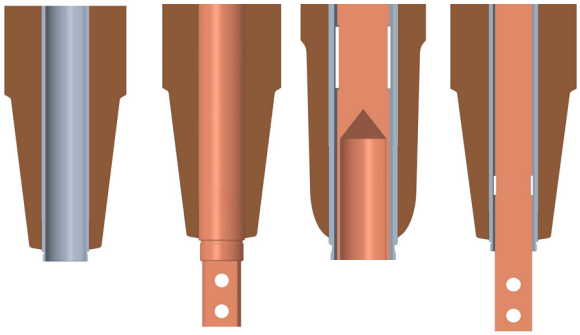
► THE CONNECTIONS OR THE SHIELD MUST NOT BE USED AS A SUSPENSION POINT TO PREVENT DAMAGE.

5.3. Reference measurement No. 1

Before installation, a reference measurement No. 1 (main capacity C1, capacity C2 and loss factor tan δ1 and tan δ2) shall be performed (see Chapter 8) to establish a reference point for later measurements.

5.4. Conductor and terminal

When connecting the bushing, a solid conductive contact surface shall be done to minimize the influence of possible contact resistance (see Chapter 5.12).
Depending on the order, four different conductor types are available as shown below.



Details of lower part of EasyDry bushing

(A)	(B)	(C)	(D)
Tube for conductor rope (cable bolt not shown)	Fixed conductor rod	Dismountable conductor rod (for conductor rope)	Dismountable conductor rod (flat terminal)

Fig. 5

Note Fig. 5
Details of the lower part of a bushing (schematic)

The connection details can be found in the dimension sheet of the bushing.

NOTE

NO RIGID CONNECTION
Ø FUTURE CONDUCTORS MUST NOT BE MADE RIGID (ABOVE AND BELOW), AS THE BUSHING MUST NOT PICK UP OR TRANSMIT ANY MOVEMENTS OR VIBRATIONS.
► THE USE OF FLEXIBLE TERMINAL CONNECTIONS MAKES IT ALSO POSSIBLE TO AVOID VIBRATIONS AND MOVEMENTS OF THE TRANSFORMER AFFECTING NEARBY PARTS.

5. Assembling

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Note Fig. 6
Steps for dismounting the cable bolt/conductor rod:
1 Vent screw
2 Lifting eye
3 Clamp screw
4 Clamp halve
5 Sealing sleeve
6 Grooves

NOTE

PREPARING THE CONNECTION
► THE FEED AND DISCHARGE LINES, INCLUDING THEIR CONNECTION ELEMENTS, SUCH AS TERMINAL LUGS OR ADDITIONAL CONNECTORS, MUST BE DIMENSIONED IN A WAY THAT NO HEAT IS BROUGHT TO THE CONNECTIONS OF THE BUSHING.
► THE CONNECTIVE SURFACES SHALL BE FLAT, CLEAN AND UNPROCESSED.

5.5. Dismounting of the cable bolt (A) or conductor rod (C)

Depending on the order, the bushing can be delivered with a cable bolt or a dismountable conductor rod. Before the bushing can be installed on the transformer, it is necessary to solder a conductor wire in the cable bolt or conductor rod. In order to be able to solder the conductor rope, the cable bolt or conductor rod must be dismounted and processed. Bushings with a conductor rod that oil-side has a flat terminal, need not be processed.
In order to remove the cable bolt or conductor rod, it is recommended that the vent screw (1) is replaced with a lifting eye (2). A rope is attached to the eyebolt preventing the slipping out of the cable bolt or conductor rod during the dismounting.
As shown in Fig. 6, first, the clamp screw (3) is loosened and the clamp halves (4) are removed to the side. The cable bolt or conductor rod can be fully pulled out with the sealing sleeve from the central tube by loosening the clamp halves.

NOTE

► BUSHINGS WITH A CONDUCTOR ROD THAT OIL-SIDE HAS A FLAT TERMINAL NEED NOT BE PROCESSED.
► BEFORE THE BUSHING CAN BE INSTALLED ON A TRANSFORMER, IT IS NECESSARY TO SOLDER THE CONDUCTOR WIRE IN THE CABLE BOLT. IN ORDER TO BE ABLE TO SOLDER THE CONDUCTOR ROPE, THE CABLE BOLT MUST BE DISMOUNTED AND PROCESSED.

NOTE

A SLIPPING OUT OF THE CABLE BOLT OR CONDUCTOR ROD IS POSSIBLE.
► SECURE WITH EYEBOLT AND WIRE.

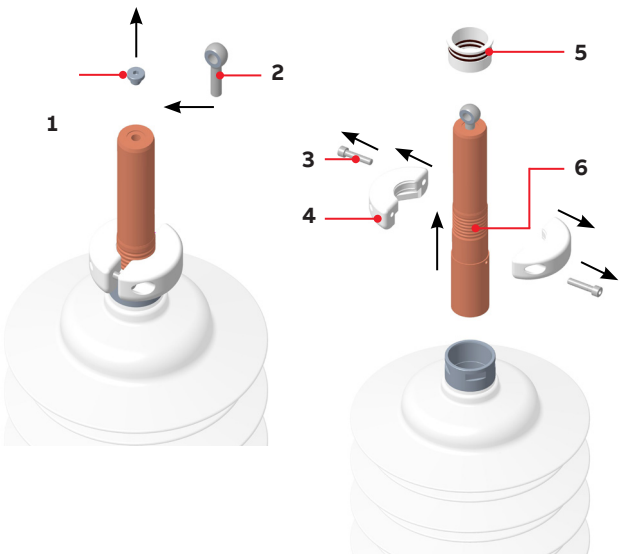

Fig.6

The grooves (6) on the cable bolt/conductor rod help shifting the conductor in the vertical direction ± 10 mm.

CAUTION

► TO AVOID DAMAGING THE GROVE (6) FROM THE CABLE BOLT AND THE CLAMP HALVES (3), THEY MUST BE ADJUSTED CAREFULLY.

CAUTION

Ø THE CABLE BOLT OR CONDUCTOR ROD MUST NOT BE SCRATCHED.
Ø DO NOT APPLY TORQUE TO THE CABLE BOLT, CONDUCTOR ROD OR FIXED CONDUCTOR.

5. Assembling

5.6. Connection of the conductor rope to the cable bolt (A) or to the conductor rod (C)

Standard EasyDry bushings with conductor rod fitted with a flat terminal on the oil-side do not need processing.
The conductor rope may be soft soldered or brazed to the cable bolt or conductor rod. The temperature necessary for the soft soldering must not exceed 450 °C, to avoid possible annealing of the cable bolt or conductor rod. The soldering must be performed carefully in order to ensure optimal contact. For brazing, the sealing and the terminal must be sufficiently cooled. Silver solders with melting temperature of under 700 °C must be used here.

NOTE

► BEFORE SOLDERING, THE VENT SCREW AND ALL THE SEALS MUST BE REMOVED FROM THE CABLE BOLT.
DAMAGE TO THE SEAL SYSTEM CAN LEAD TO MALFUNCTIONS IN THE BUSHING OR OF THE TRANSFORMER.

With an appropriate tool and an adjustment of the cable bolt, a pressing of the cable bolt is possible as an alternative.
The bolt or conductor is delivered unprocessed. For this reason, a hole suitable for soldering the conductor rope must be drilled in the bolt or conductor rod. The diameter of the drilled hole must be adjust to the diameter of the rope. Whenever possible, the drill design without a peak is recommended. The recommended maximum drilling depths and hole diameters for the standard cable bolt are provided in figure and table below.

NOTE

Ø DO NOT DRILL IN THE VENTILATION CHANNEL.

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Note Fig. 7
Processing on cable bolt. Turned (Fig. left) or drilled (Fig. right) hole:
1 Ventilation channel
2 Max. hole diameter
3 Cable bolt diameter
4 Diameter d3 (see bushing dimension sheet)
5 Max. drilling depth
6 Cable bolt lower part length

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Note Fig. 8
Split conductor rod srew joint:
1 Upper conductor rod
2 Screws and spring washers
3 Lower conductor rod

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Note Tab. 3
Recommended maximum drilling depth and hole diameter for a standard cable bolt

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Note Tab. 4
Recommended tightening torques for the screws of the divided conductor rod

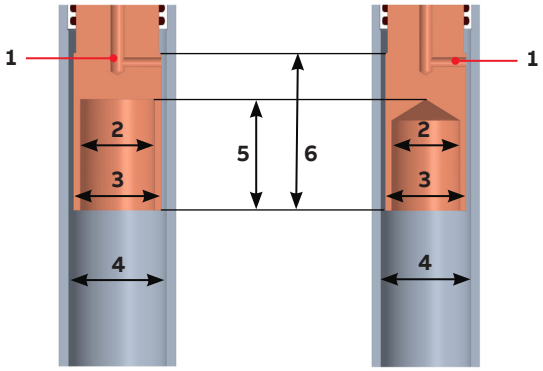

Fig. 7

Tube diameter d3 (4) [mm]	Max. hole diameter (2) [mm]	Cable bolt or conductor rod diameter (3) [mm]	Max. drilling depth (5) [mm]
38	33	36	(4)-20
50	40	45	(4)-20

Tab. 3

In order to make sure that the drilling is not performed too deeply, the following rules are recommended: maximum drilling depth (5) is the same as the length of the cable bolt or conductor rod (6) minus 20 mm.
The diameter of the power conductor should be at least a half of the tube diameter Ø d3 (4). The oil supply may not be impaired in the central bushing opening and in the open area of the shield.

5.7. Split conductor rod

If the bushing is fitted with a split conductor rod, the lower part of the conductor rod must be screwed to the upper part of the conductor rod after soldering. When installing, make sure that the screws are alternately tightened.

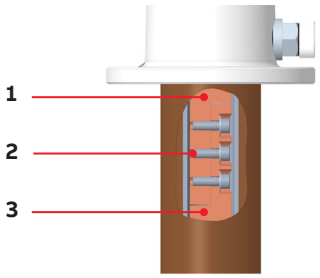

Fig. 8

The mounting screws can vary depending on the size of the conductor rod. Recommended tightening torques are:

Thread	Tightening torque [Nm]
M 8 (A2-70& A4-70)	12
M 10 (A2-70& A4-70)	25
M 12 (A2-70& A4-70)	45

Tab. 4

5. Assembling

5.8. Rope conductor insulation (A)

To prevent partial discharges caused e.g. by switching transients between the rope conductor and the central tube of the bushing, the rope conductor must be wrapped in at least 1 mm of insulation material. The use of aramide paper (heat-resistant) is recommended.

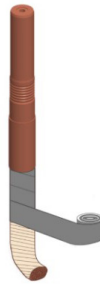

Fig. 9

Note Fig. 9
Rope conductor insulation. At least 1 mm insulation material thickness

CAUTION

► IF THE INSULATION MATERIAL THICKNESS IS TOO HIGH, THE BUSHING CAN OVERHEAT.

5.9. Centering of the dismountable conductor rod (C) and (D)

For a dismountable conductor rod, spark formation is avoided through insulating centering rings that separate the conductor rod from the central tube.

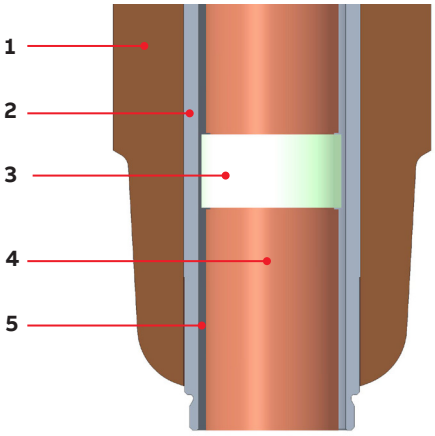

Fig. 10

Note Fig. 10
Insulation for the dismountable conductor rod:
1 Insulating body
2 Tube
3 Centering ring
4 Conductor rod
5 Oil-air gap

5.10. Fixed conductor (B)

This connection need no additional installation work and can be connected directly to the oil-side terminal. The connection details can be found in the dimension sheet of the bushing.

NOTE

► THE BASE TERMINAL SHALL NOT BE DISMOUNTED TO AVOID DAMAGING THE INTERNAL COMPONENTS.

5.11. Bushing without shield

Due to the resulting field strengths, bushings up to and including 72.5 kV do not need any shielding. For this reason, no further measures are needed on the bushing.

5.12. Fastening the shield

Depending on the execution of the bushing, fixed or dismountable shields are used and mounted on the bottom of the bushing. These prevent the excessive stress on the transformer oil and simplify the structure of the power conductor insulation under the bushing.
The originally delivered shields are dimensioned with the help of modern methods and have a high-value, solid insulation layer on the surface.
► Please observe installation recommendations (see Tab. 2).

5.13. Shields for rope (A) or dismountable conductor rod (C) applications

These shields are dimensioned for rope and dismountable conductor rod applications because they are considerably shorter than the other types of shields.

They are available for voltages ranging from 24 kV and caulked on the tube at factory and no longer removable.

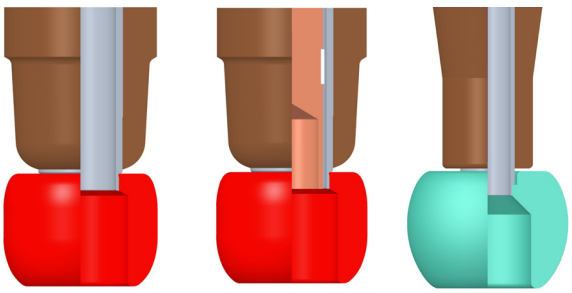

Fig. 11

Note Fig. 11
Shield for rope or conductor rod applications

5. Assembling

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Note Fig. 12
Shield bayonet catch:
1 Hexagon socket screw
2 Washer
3 Spring
4 Mounting ring
5 Epoxy-covered shield

—
Note Tab. 5
Recommended tightening torques

NOTE

Ø THE ROPE CONDUCTOR MUST NOT TOUCH THE SHIELD DUE TO VIBRATION OR OTHER DISPLACEMENTS.
Ø THE SHIELD FOR ROPE APPLICATIONS MUST NOT BE DISMOUNTED.

5.14. Shield with spring-loaded thrust piece

This shield is longer compared to shields described in chapter 5.13, for covering exposed edges at the terminal inside the shield.
The shielding is available for voltages ranging from 123 kV (optional, depending on the bushing type).
The shielding can be mounted on the mounting ring and dismounted from it at factory.
► In order to dismount the shield, the 3 spring-loaded pressure pieces must be loosened with a suitable wrench (not completely: unscrew it enough to keep them mounted on the shield).
► The shield can be shifted upwards or downwards.
► The terminal is then freely accessible and can be connected to the connection pieces. It must be in any case made sure that the contact resistance is kept as low as possible.
► Shift the shield back to its original position and place it to match the three threaded holes. The spring pressure pieces can be screwed on again.
► Finally, the screws must be tightened back with the specified torque.

	Strength class and tightening torque [Nm]			
Thread	**A2-70**	**A4-70**	**8.8**	**10.9**
M 6	5.1	5.1	6	8.4
M 8	12.6	12.6	15	21
M 10	24.6	24.6	29.4	41.4
M 12	43.2	43.2	51.6	72

Tab. 5 (maximum torque x 0.6)

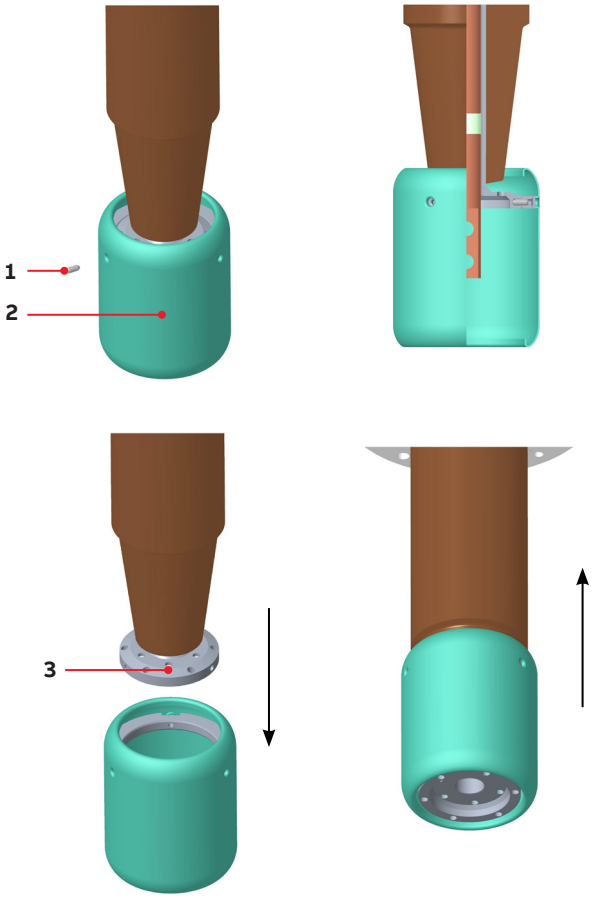


Fig. 12

NOTE

Ø DO NOT LET PARTS FALL INTO THE TRANSFORMER TANK.
Ø THE FASTENING RING (3) AT THE CONNECTOR MUST NOT BE DISMOUNTED.

5. Assembling

5.15. Preparation of the terminal surface (B and D)

The connecting to the bushing should always be made with special care with respect to the reduced contact resistance.
Before the connection to the silver-plated contact surface, the protective film (grease) must be removed with a cloth. No cleaning agents/solvents may be used.
Contact surfaces without painting must first be treated to remove the layer of oxidation. A fine steel brush, abrasive paper or similar can be used for this purpose. The contact grease for electric connection surfaces is applied onto the entire surface; the surface is then brushed cross-wise until the entire oxide layer is removed. The oxide-free surface must then be cleaned with a cloth, and fresh contact grease is applied.

5.16. Cleaning of the bushing surface and the interface

The sealing surfaces on the impregnation of the transformers and on the bushing flange must be free of corrosion and dirt, and have a high surface texture (max. Ra 3.2). The cleaning of these surfaces takes place by soaking a lint-free cotton cloth in the cleaning liquid and wiping the sealing surfaces.

5.17. Installing of the bushing

NOTE

► THE BUSHING SHOULD REACH THE AMBIENT TEMPERATURE BEFORE THE INSTALLATION TO AVOID CONDENSATION ON ITS SURFACE.

Now, the bushing can be brought to the final position (see lifting description in chapter 5.2).

5.18. Damage during installation

In order to prevent damage the silicone isolator, lifting tools such as chains, hooks, must be avoided in any case. Only textile slings must be used.

CAUTION

Ø WHEN INSTALLING THE BUSHINGS IN THE DESIRED POSITION, THEY MUST NOT BE SUPPORTED AT THE LOWER END OF THE CONDENSER CORE AS WELL AS ON THE SHIELD.
Ø DURING THE LOWERING, THE BUSHING MAY NOT TOUCH ANY NEARBY PARTS OR WALLS, AS THE INSULATING BODY OR ANY OTHER PART CAN BE DAMAGED.
Ø THE BUSHING MAY NOT BE LIFTED WITH A ROPE LOOP, AS IT CAN SLIP OUT.
Ø THE SUSPENSION ROPE MUST NOT TOUCH THE MEASUREMENT TAP, AS THE POTENTIAL CONNECTION CAN BE BROKEN DUE TO MECHANICAL DAMAGE.
Ø THE THREAD OF THE VENT SCREW MAY NOT BE USED TO LIFT THE BUSHING (APPLY TO CHAPTER 5.19).
Ø THE UNSHIELDED AREA OF THE BUSHING (OIL-SIDE INSULATING BODY) MUST NOT BE SCRATCHED.

5.19. Assembly of cable bolt (A) or dismountable conductor rod (C and D)

For retracting the cable bolt or the conductor, an eyebolt shall be screwed onto the frontal thread of the cable bolt or conductor rod. This thread is also used for the vent screw of the central tube.
Before the suspension rope is inserted through the central tube, the sealing sleeve with the inserted O-ring gaskets must be mounted on the central tube. In order to avoid damaging the O-ring or the gaskets of the sealing sleeve on the tube or cable bolt when inserting, the gliding surfaces must be lubricated with an acid-free grease. The gap between the bolt and the sleeve must be lubricated with grease.
The cable bolt together with the soldered rope conductor or conductor rod can now be drawn in from below through the bushing with the help of the eyebolt and a rope.

NOTE

Ø SILICONE O-RING GASKETS THAT ARE USED FOR TEMPERATURES <-30 °C MAY NOT BE LUBRICATED WITH SILICONE GREASE.

5.Assembling

Note Fig. 13
Inserting the conductor rope or conductor rod

Note Fig. 14
Flat seal system:
1 Flat seal
2 Flange
3 Hole circle diameter
4 Transformer/ switchgear plate
5 Washer and nut

Note Tab. 6
Recommended tightening torques

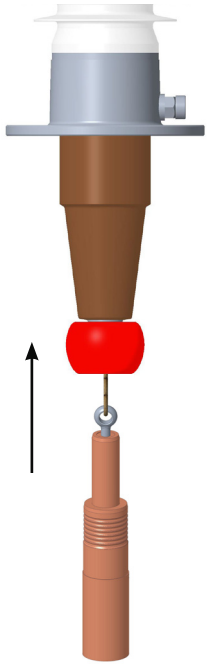


Fig. 13

After the insertion, the cable bolt or conductor rod is fastened to the head of the bushing, and a possible head shield is mounted using the clamp system. The torques provided below must be observed.

	Strength class and tightening torque [Nm]			
Thread	**A2-70**	**A4-70**	**8.8**	**10.9**
M 6	5.1	5.1	6	8.4
M 8	12.6	12.6	15	21
M 10	24.6	24.6	29.4	41.4
M 12	43.2	43.2	51.6	72
M 14	69	69	81	114
M 16	108	108	131.4	177
M 18	147	147	174	240

Tab. 6 (maximum torque x 0.6)

After dismounting the eye screw, the M12 vent screw must be mounted back again. The recommended tightening torque is as follows 30 Nm unlubricated and 25 Nm lubricated.

NOTE

IF THE VENT SCREW IS NOT MOUNTED CORRECTLY, WATER CAN GET INTO THE BUSHING AND INTO THE TRANSFORMER.

5.20. Flat seal system

The central position of the flat seal is located directly under the hole circle of the flange plate and must be on the both sides of the pitch circle to avoid flange deformation. The flat seal must be provided with the appropriate hole pattern for the flange. During installation, the flat seal must be put through the mounting bolts without tensile or compressive stress. If the flat seal is warped by the mounting bolt, the holes must be drilled out to avoid any stress on the flat seal.

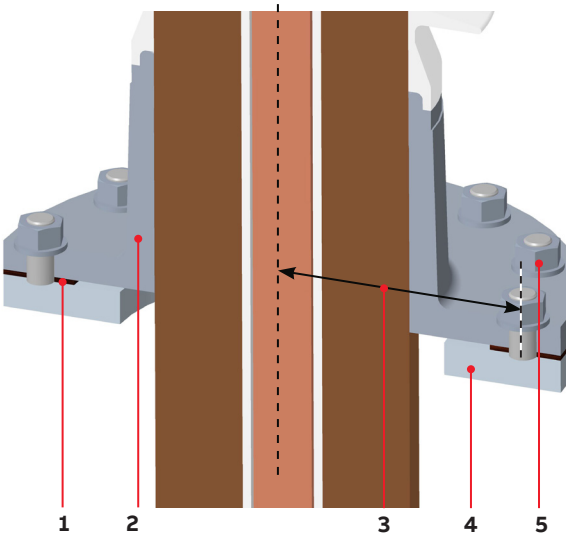


Fig. 14

NOTE

► IF AVAILABLE, IT MUST BE MADE SURE THAT THE VENTILATION HOLE ON THE FLANGE IS NOT BLOCKED BY THE FLAT SEAL.
► THE FLAT SEAL (1) MUST BE INSTALLED PROPERLY TO AVOID ANY SHEARING FORCES OR DAMAGE OF THE FLANGE.

5.21. O-Ring seal system

The position of the O-ring gasket is inside the hole circle of the flange plate, and inside the specified sealing surface (shown on the dimension sheet of the bushing).

5. Assembling

—
Note Fig. 15
O-ring gasket system:
1 O-ring gasket
2 Flange
3 Hole circle diameter
4 Transformer/ switchgear plate
5 Washer and nut

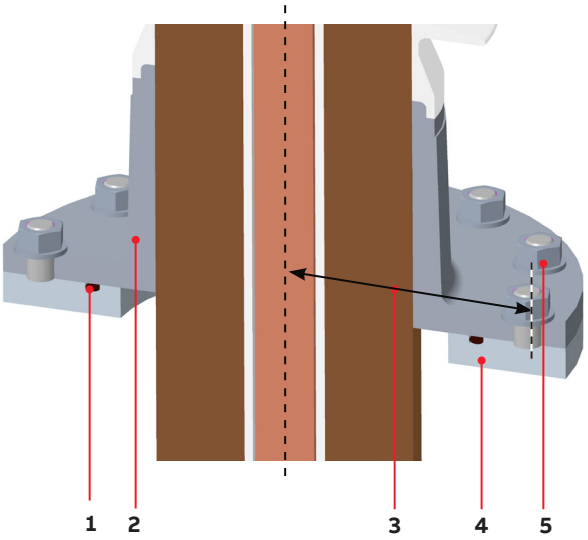


Fig. 15

—
Note Tab. 7
Recommended tightening torques

NOTE

► FOR SYSTEMS THAT MUST BE OPERATED UNDER PRESSURE, AN O-RING GASKET SYSTEM MUST BE PROVIDED.
► THE CONTACT AREA OF THE FLANGE PLATE (2) AS WELL AS THE SURFACE (4) SHOULD HAVE NO STEPS TO AVOID SHEARING FORCES OR DAMAGE.

5.22. Flange installation

NOTE

NOT DAMAGING THE SEALING SURFACE
► WHEN INSTALLING THE FLANGE, MAKE SURE THAT THE SEALING SURFACE IS NOT DAMAGED.
► IF THE LIFTING EYES ARE ON THE LOWER SIDE OF THE FLANGE, THESE MUST BE DISMOUNTED BEFORE THE FLANGE IS TIGHTENED.
► FOR TRANSFORMERS, THE CONTACT AREA MUST HAVE A FLATNESS TOLERANCE OF NO MORE THAN 0.3 MM.

5.23. Tightening sequence

When the flange of the bushing is put in place, the screws/nuts with washers must be first screwed as far as possible by hand. The flange fastening must be performed according to the following tightening sequence and figure below:
1. Light fastening with wrench.
2. Fastening with 50% of the recommended torque.
3. Fastening with 100% of the recommended torque.
4. Additional turn for control, with 100% of the recommended torque.
5. If possible, repeat steps 3 and 4 after 24 hours, as the clamp force can decrease in the first 24 hours.

► In order not to overlook any screws/nuts, the tightened screws/nuts must be marked with a felt pen.

	Strength class and maximum allowable tightening torques [Nm]			
Thread	**A2-70**	**A4-70**	**8.8**	**10.9**
M 12	43.2	43.2	51.6	72
M 14	69	69	81	114
M 16	108	108	131.4	177
M 18	147	147	174	240
M 20	207	207	246	348

Tab. 7 (maximum torque x 0.6)

5. Assembling

5.24. Fastening sequence

The sequence to be maintained is defined in the sectional drawings for the different hole patterns :

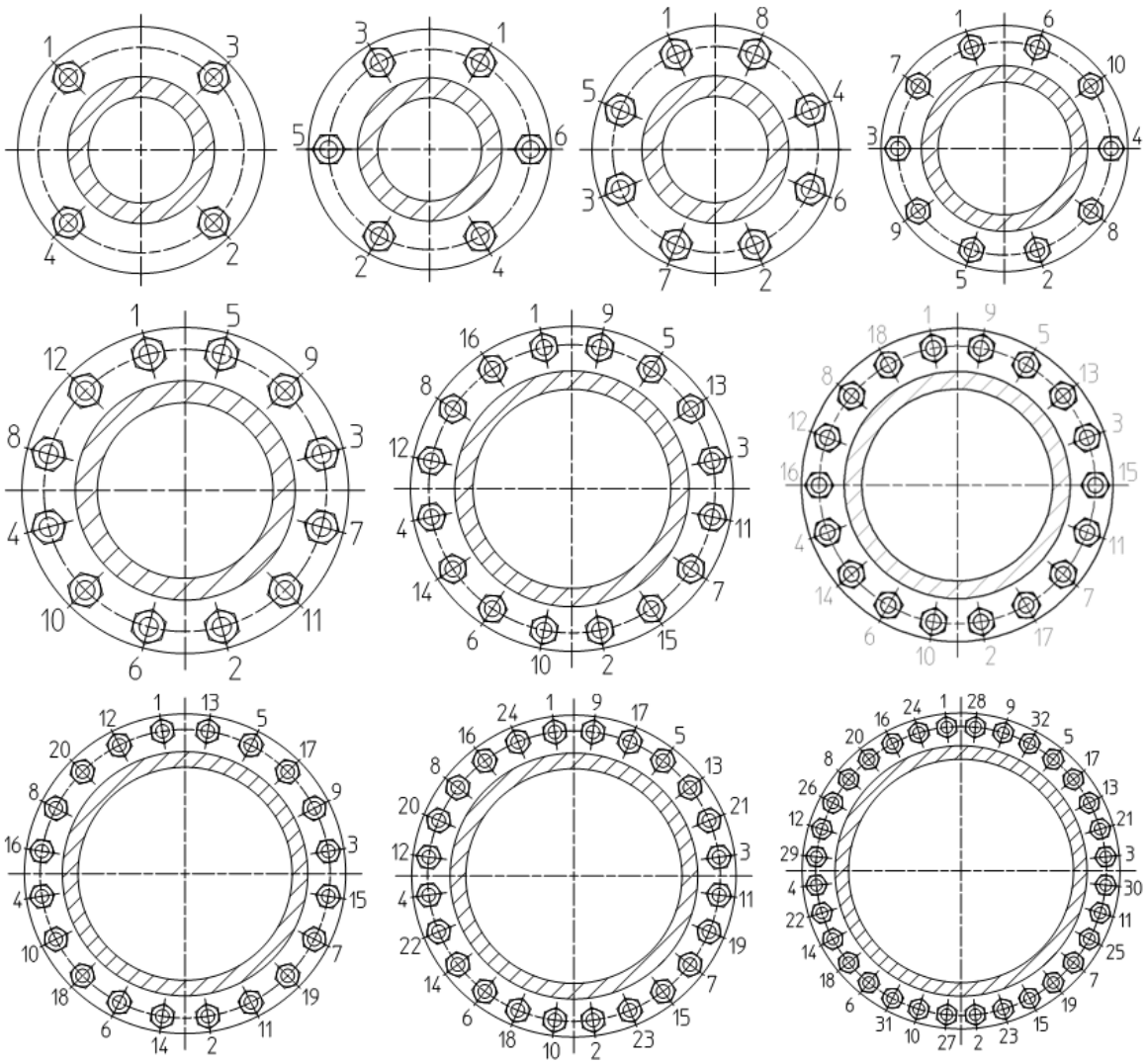


Fig. 16

Note Fig. 16
Fastening sequence for various flange models

5.25. Flange earthing

The bushings have one or two threads on the flange for its earthing.

NOTE

► THE FLANGE OF THE BUSHING MUST ALWAYS BE EARTHED VIA A SECURE CONNECTION AFTER INSTALLATION.

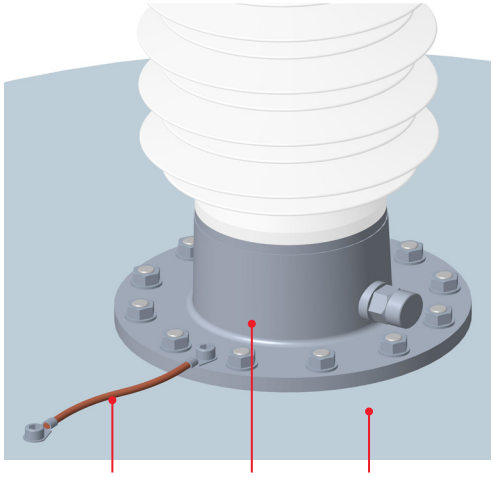


Fig. 17

Note Fig. 17
Flange earthing:
1 Earth lead
2 Flange
3 Transformer plate

6. Commissioning

DANGER

PREVENTION OF LIFTING HAZARDS, ELECTRIC SHOCK, CHEMICAL HAZARDS, FALLING, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING ACTIVITIES.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED.
► THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES (REFERENCE MEASUREMENT NO. 2).
► WEAR APPROPRIATE PPE.

6.1. Evacuation of the transformer

The use of a vacuum when filling the transformer is not problematic for the installed bushing. If the transformer oil is drawn in under vacuum, a following ventilation for the bushing or the transformer dome is normally not necessary. However, there is an exception in the bushings that protrude over the expansion vessel. For these, ventilation via the screw provided frontally on the cable bolt/conductor rod is recommended.

6.2. Ventilation and downtimes

Before each first-time commissioning, the central bushing tube must be ventilated via the screw located frontally on the cable bolt/conductor rod. As a result, the transformer oil in the central tube rises to the corresponding elevation of the transformer expansion vessel. If the bushing is not mounted vertically, the transformer dome should be ventilated with the vent screws on the flange of the bushing. The M12 vent screws are tightened on the cable bolt/conductor rod and on the flange as follows: 30 Nm unlubricated and 25 Nm lubricated. Bushings with a fixed conductor can only be ventilated at the flange. During the installation of the bushing, it must already be made sure that the flange ventilation and the terminal of the Buchholz relay is at the highest position as possible.

NOTE

► AFTER THE VENTILATION AND BEFORE THE COMMISSIONING OF THE BUSHING, IT MUST BE CHECKED THAT ALL VENT SCREWS ARE TIGHTENED.
► FURTHERMORE, THE VENT SCREW CAVITY IN THE CABLE BOLT/CONDUCTOR ROD SHOULD BE FILLED WITH SILICONE PASTE.
► AN INITIAL SET-UP SHOULD ONLY BE CARRIED OUT AFTER AT LEAST 12 HOURS AFTER COMPLETING THE OIL FILLING OF THE TRANSFORMER.

6.3. Reference measurement No. 2

After installation of the bushing and before switching on the transformer, a reference measurement No. 2 of main capacity C1, capacity C2, loss factors tan δ1 and tan δ2 shall be carried out (see Chapter 9).
These could be a good basis to analyse future measurements results.

6.4. High voltage connection

DANGER

EXPLOSION, FIRE

► SCHWITCHING-ON OF THE TRANSFORMER SHOULD ONLY BE CARRIED ON AFTER CONFIRMATION OF THE NOMINAL VALUES OF C1 AND TAN δ1.
► DURING THE INITIAL SWITCH-ON, AS WELL AS WHEN SWITCHING-ON AFTER A REVISION, ALL PERSONNEL MUST LEAVE THE SITE OF THE INSTALLATION FOR AT LEAST 2H.

NOTE

► WHENEVER POSSIBLE, A MEASUREMENT OF C AND TAN δ SHOULD TAKE PLACE WITH THE HIGH-VOLTAGE CONDUCTOR DISCONNECTED, ESPECIALLY IF OTHER TRANSFORMER LOAD THE NETWORK WITH HARMONICS.
► THE C AND TAN δ VALUES MUST ALWAYS BE CALCULATED FOR THE REFERENCE VALUE AT 20°C.

7. Measuring tap

7.1. Measuring tap structure

The measuring tap at capacitance-graded bushings gives access to the outermost control layer of the bushing. Thereby, the characteristic values of a busing (C & tan δ) can be measured using a suitable measuring device, e.g Omicron CPC 100, Tettex 28xx or Doble. In operation, this layer must be connected to the flange via the spring contact in the measurement tap, and thus be earthed, or be connected to earth via an accordingly large capacity, to avoid voltage of more than 300 V or 1.5 kV (see Chapter 7.2).

—
Note Fig. 18
Measurement tap in operating state, earthed with protective cover :
1 Sealing
2 Spring
3 Protective cover

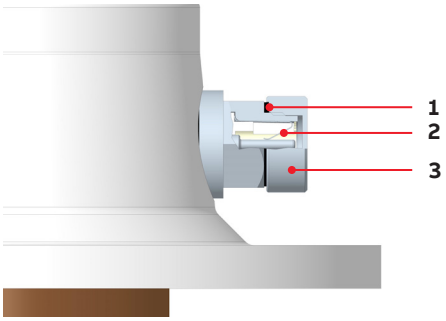


Fig. 18

—
Note Fig. 19
Measurement tap.
Connecting coupling

—
Note Fig. 20
Measurement tap.
Transition coupler (N or UHF connector)

—
Note Fig. 21
Measurement tap.
Any manipulation prohibited

The structure of the measurement tap provides automatic earthing of the measurement pad via the flange. This earthing can be opened by full insertion of a 4 mm connecting coupling or by connecting a transition coupler (see figures below). If there is no measurement performed at the measurement tap, it must be closed with the provided protective cover and an intact seal, to avoid weather effects.

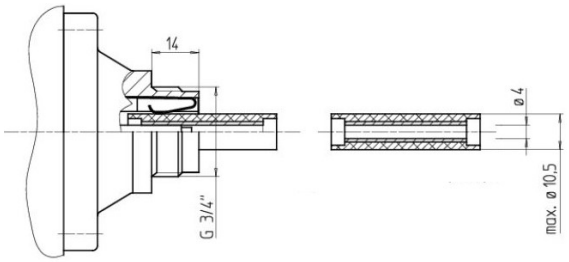


Fig. 19

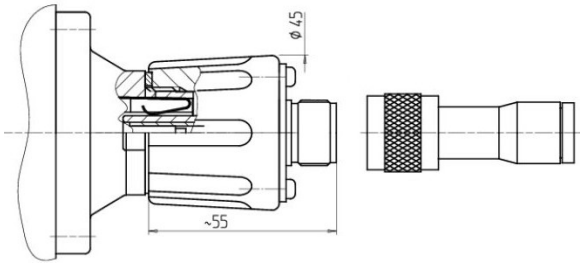


Fig. 20

CAUTION

TRANSITION COUPLER N OR UHF (ONLINE MEASUREMENT)
► CABLE WIRING MUST BE CONTROLLED REGULARLY FOR CORRECT CONTACT: CABLE OXIDATION AND CABLE BREAKAGE LEAD TO BUSHING FAILURE. FOR THIS REASON, PERMANENT RELIANCE ON ONLINE MEASUREMENTS IS NOT PREFERABLE.

CAUTION

MEASUREMENT TAP TAMPERING
Ø USING SCREWDRIVERS OR OTHER TOOLS TO TAMPER WITH AND PUSH AWAY THE EARTHING SPRING IS STRICTLY FORBIDDEN (SEE FIGURE BELOW).
► USE A CONNECTING COUPLING OR THE TRANSITION COUPLING FOR MEASUREMENT.

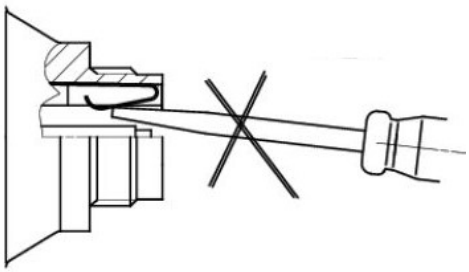


Fig. 21

DANGER

PROTECTIVE COVER
Ø THE BUSHING MUST NEVER BE COMMISSIONED WITHOUT INSTALLING THE PROTECTIVE COVER ON THE MEASUREMENT TAP OR CONNECTING A MONITORING SYSTEM.
► THE CORRECT FUNCTION OF THE SPRING CONTACT IN THE MEASUREMENT TAP MUST ALWAYS BE TESTED BEFORE LOCKING THE COVER. IF THIS IS NOT OBSERVED, THE BUSHING OR THE TRANSFORMER CAN SUFFER SEVERE DAMAGE. UNDER UNFAVORABLE CONDITIONS, HEAVY PERSONAL INJURIES ARE ALSO NOT OUT OF THE QUESTION.

7. Measuring tap

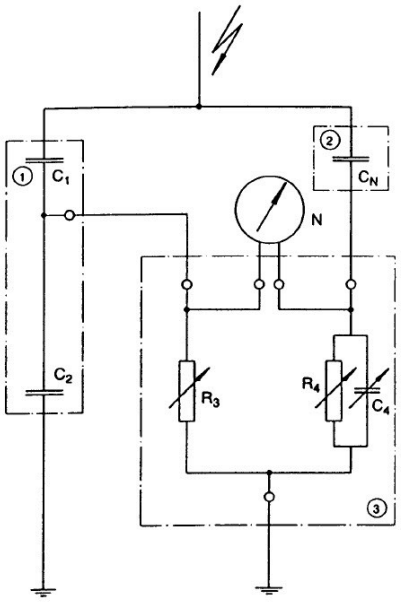
—
Note Fig. 22
Measuring setup

DANGER

LIFE-THREATENING VOLTAGES
► THE DESCRIBED MEASUREMENTS TAKE PLACE UNDER DANGEROUSLY HIGH MEASURING VOLTAGES. THE LOCAL SAFETY REGULATIONS MUST BE OBSERVED.

7.2. Measurement tap purpose of use

The measuring connection serves for the measurement of the main capacity C1 of the bushing and the loss factor tan δ. The most common test circuit is shown below.



1	Bushing	C1: Capacity - high-voltage conductor tapping layer C2: Capacity - tapping layer flange
2	Reference condenser	CN
3	Schering bridge	R3, R4, C4: Bridging elements N: Null indicator

$C_1 = CNR_4 / R_3$; tan δ1 = $R_4 2\varpi f C_4$

Fig. 22

The measuring tap can also be used to perform voltage and partial discharge measurement as part of monitoring. It must be made sure that the maximum permissible continuous voltage between the measurement surface and flange is 300 V or 1.5 kV (=U2). Depending on the voltage and capacity of the bushing, the power put over the measurement tap can be approx. 5... 10 VA. To limit voltage, an impedance must always be added in parallel to C2. In most cases, this is capacity Cz, that must have a capacity of at least:

$$C_{z\,\min} = C_1 \cdot \left(\frac{U_N}{\sqrt{3} \cdot U_2} - 1 \right) - C_2$$

The values for C1 and C2 can be found in the test report for the bushing in question.

The capacity Cz must be used to set voltage U.

$$C_z = C_1 \cdot \left(\frac{U_N}{\sqrt{3} \cdot U} - 1 \right) - C_2 \geq C_{z\,\min}$$

To remove active power P from the bushing, an ohm resistance Rz must be switched on in parallel to C2. The P power is produced as a result of:

$$P = \frac{\left(U_N / \sqrt{3}\right)^2}{R_z} \cdot \frac{1}{a^2 + b^2}$$

with:

$$a = 1 + \frac{C_2}{C_1}$$

and:

$$b = \frac{1}{\omega C_1 \cdot R_z}$$

A condition in this case, however, is that U ≤ U2. This can be controlled with:

$$U = \frac{U_N / \sqrt{3}}{a^2 + b^2} \cdot \sqrt{a^2 + b^2} \leq U_2$$

8. Measurements of C1, C2, tan δ1, tan δ2 (reference No. 1)

—
Note Fig. 23
Lifting of the bushing

DANGER

PREVENTION OF RELOADING HAZARDS, ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS
► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► THE PERSONNEL SHOULD BE TRAINED FOR THE RELOADING ACTIVITIES.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► WEAR APPROPRIATE PPE.

DANGER

HAZARDOUS VOLTAGE
► THE MEASUREMENTS ARE PERFORMED USING HIGH VOLTAGE. THE LOCAL SAFETY REGULATIONS OF HIGH VOLTAGE INSTALLATION MUST BE OBSERVED.

NOTE

► THESE MEASUREMENTS SHALL BE PERFORMED BEFORE THE INSTALLATION, AFTER THE DELIVERY AND AFTER LONG (≥ 1 YEAR) OR INCORRECT STORAGE.

8.1. Reference measurements No. 1

The lifting of the bushing from the transport wooden box can be carried out with a lifting gear, as well as a crane, a hoist etc. and two suspension ropes. One of the suspension ropes is fastened with a textile rope sling directly or on the crane eyes mounted on the flange. The other suspension rope is fastened with a textile rope sling to the insulator between the shields, near the head.
The bushing should be lifted at least 1.5 m above ground to reduce parasitic influences when measuring main capacity C1, capacity C2 and loss factors tan δ1 & tan δ2.
The purpose of the measurements is to test the condition of the bushing. The results must be compared with the ABB test report.

NOTE

► WHEN CONDUCTING THE MEASUREMENT, THE SURFACE MUST BE CLEANED AND DRY.
► IN A HUMID ENVIRONMENT, THE MEASUREMENT TAP SHOULD BE DRIED — E.G. WITH A HOT-AIR DRYER.
► THE MEASURED TANδ AND CAPACITY MUST BE CALCULATED TAKING INTO ACCOUNT THE REFERENCE VALUE AT 20 °C.
► IN ORDER FOR THE BUSHING FULLY TO REACH THE AMBIENT TEMPERATURE BEFORE THE MEASUREMENTS, IT SHOULD BE STORED FOR E.G. 24 H IN THE AMBIENT OF THE MEASUREMENT SITE.

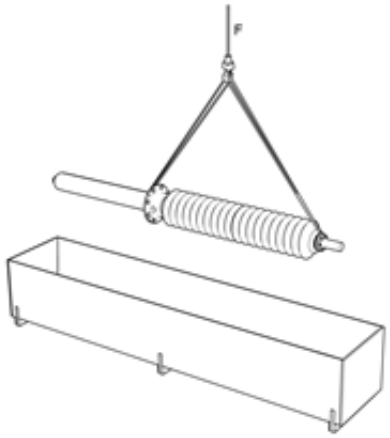


Fig. 23

8. Measurements of C1, C2, tan δ1, tan δ2 (ref. No. 1)

—
Note Fig. 24
Typical measurement of C1 and tan δ1:
1 High voltage (red lead)
2 Measuring lead (black lead)
3 Earth lead

—
Note Fig. 25
Measurement tap

—
Note Fig. 26
Typical measurements of C2 and tan δ2:
1 High voltage (red lead)
2 Measuring lead (black lead)
3 Earth lead

—
Note Tab. 8
C1 and tan δ1 measurement overview

—
Note Tab. 9
C2 and tan δ2 measurement overview

8.2. C1 & tan δ1 measurements

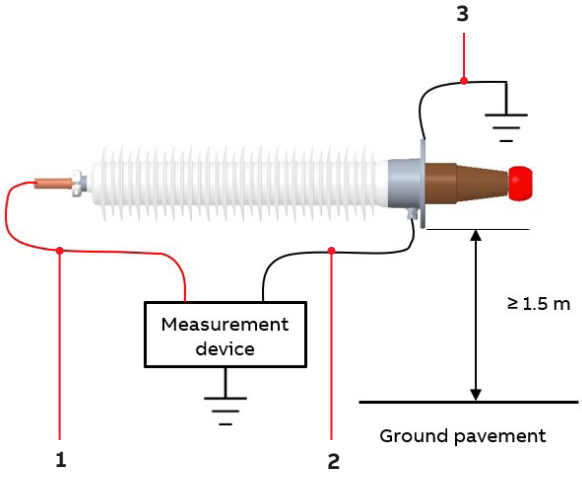


Fig. 24

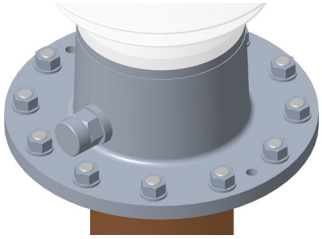


Fig. 25

8.3. Measurements overview of C1 & tan δ1

Voltage	On-site measurements			On-site measurements, correction for temperature	
[V]	[°C]	C1 [pF]	tan δ1 [%]	C1 [pF]	tan δ1 [%]
200					
500					
1000					
2000					
3000					
6000					
9000					
12000					

Tab. 8

NOTE

► THE VALUES OF THE MEASUREMENTS SHALL BE COMPARED WITH THOSE INDICATED IN THE ABB TEST REPORT (FOR 12KV).

8.4. C2 & tan δ2 measurements

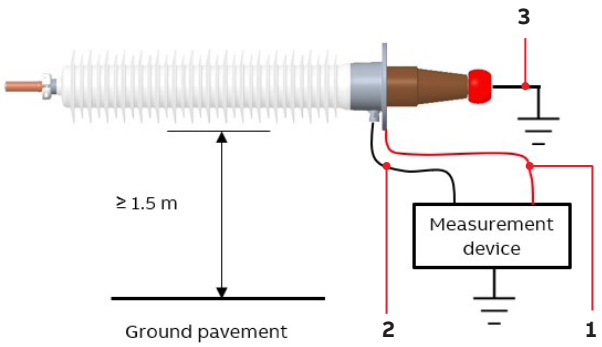


Fig. 26

8.5. Measurements overview of C2 & tan δ2

Voltage	On-site measurements			On-site measurements, correction for temperature	
[V]	[°C]	C2 [pF]	tan δ2 [%]	C2 [pF]	tan δ2 [%]
200					
500					
700					
1000					
1500					
2000					

Tab. 9

DANGER

► THE VOLTAGE OF 2 KV MUST NOT BE EXCEEDED DURING THIS TEST.

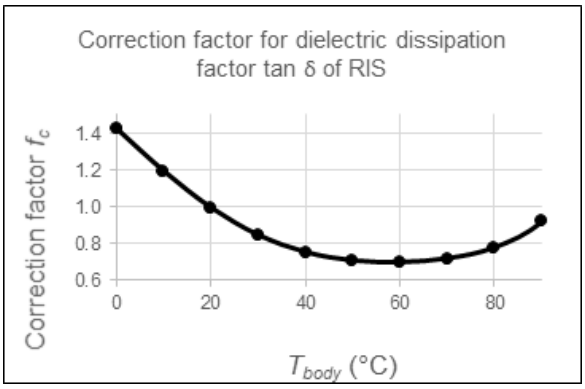
8.6. Temperature-dependent correction factors for tan δ1 & tan δ2

The tan δ values must be calculated for the reference value at 20 °C, see below:

1. During the measurement, the ambient temperature must be measured ($T_{ambient} = T_{bushing}$).
2. With the curve or the table specified below, the correction factor fc can be determined at the corresponding ambient temperature, with which tan δ relative can be calculated with the following formula:
   $\tan \delta_{relative} = \tan \delta_{measured} / fc$

8. Measurements of C1, C2, tan δ1, tan δ2 (ref. No. 1)

—
Note Ta. 10
Correction factors



—
Note Tab. 11
Tolerances

NOTE

► IF THE MEASURED VALUES DO NOT FIT WITH THE SET TOLERANCES, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

RIs body temp. [°C]	tan δ Corr. Factor fc
0	1.43
10	1.19
20	1.00
30	0.84
40	0.75
50	0.70
60	0.69
70	0.72.
80	0.78
90	0.92

Tab. 10

8.7. Temperature-dependent correction factors for C1 & C2

The C1 and C2 values must be calculated for the reference value at 20 °C as described below (the capacity increases by about 0.3‰ per °C):

1. During the measurement, the ambient temperature must be registered ($T_{ambient}$ = $T_{bushing}$). The temperature difference should be calculated with the following formula:
   $\Delta T = T_{bushing} - 20$ [°C]
2. The measurement should be corrected with the following formula:
   $C\ 20°C = C_{measured} * (1 - \Delta T * 0.0003)$

8.8. Permissible tolerances for C & tan δ

8.8.1. For bushings ≤ 145kV

C1	tan δ1	C2	tan δ2
+/- 5% (Relative)	+/- 0.05% (Absolute)	+/- 20% (Relative)	+/- 0.15% (Absolute)

8.8.2. For bushings > 145kV

C1	tan δ1	C2	tan δ2
+/- 5% (Relative)	+/- 0.05% (Absolute)	+/- 20% (Relative)	+/- 0.15% (Absolute)

Tab. 11

9. Measurements of C1, C2, tan δ1, tan δ2 (ref. No. 2)

—
Note Fig. 27
Typical measurement of C1 and tan δ1:
1 High voltage
2 Measuring lead

—
Note Fig. 28
Measurement tap

DANGER

PREVENTION OF FALLING ACCIDENTS, ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED. THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► THE SYSTEM IS SWITCHED-OFF, SECURED AND TESTED.
► THE PRIMARY AND SECONDARY SIDE OF THE TRANSFORMER OR THE SWITCHGEAR IS SHORT-CIRCUITED AND EARTHED.
► THE WORK CAN ONLY BE STARTED AFTER A COMPLETE ELECTRIC DISCHARGE OF THE SYSTEM.
► WEAR APPROPRIATE PPE.

NOTE

► THESE MEASUREMENTS SHALL BE PERFORMED AFTER INSTALLATION OF THE BUSHINGS ON THE TRANSFORMER AS WELL AS WHILE MAINTENANCE.

9.1. Reference measurements No.2

After the installation of the bushings and before switching on the system or during the maintenance, main capacity C1, capacity C2 and the tan δ1 & tan δ2 loss factors must be measured. The results must be compared with the ABB test report. These measurements function as an important assessment basis during the entire service life of the bushings.

NOTE

► WHEN CONDUCTING THE MEASUREMENT, THE SURFACE MUST BE CLEANED AND DRY. IN A HUMID ENVIRONMENT, THE MEASUREMENT TAP SHOULD BE DRIED — E.G. WITH A DRYER.
► THE MEASURED TAN δ AND CAPACITY MUST BE CALCULATED TAKING INTO ACCOUNT THE REFERENCE VALUE AT 20 °C. IT MUST BE MADE SURE THAT THE TRANSFORMER (FOR TRANSFORMERS) COOLS DOWN VERY SLOWLY AND THAT THE TAN D VALUE OF THE BUSHING IS HEAVILY INFLUENCED BY THE TRANSFORMER OIL TEMPERATURE IN THIS PERIOD.
► THE ADVANTAGE OF THE DFR METHOD IS THAT IT ALWAYS GIVES THE SAME CURVE OF THE TAN δ VALUE OVER THE FREQUENCY INDEPENDENTLY FROM THE TEMPERATURE; THIS CURVE CAN BE USED WITH THE ARRHENIUS EQUATION TO APPLY TO ANY TEMPERATURES.

9.2. C1 & tan δ1 measurements

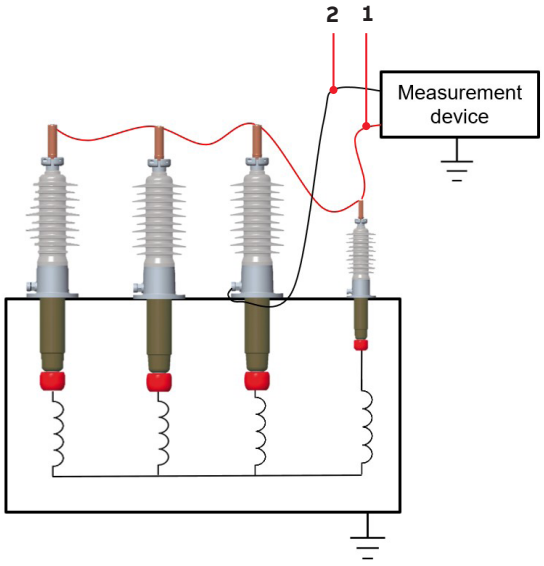


Fig. 27

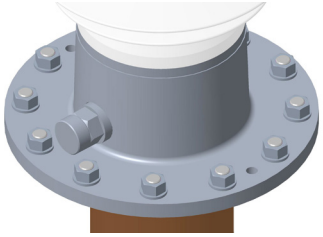


Fig. 28

9. Measurements of C1, C2, tan δ1, tan δ2 (ref. No. 2)

—
Note Fig. 29
Typical measurements of C2 and tan δ2:
1 High voltage (red lead)
2 Measuring lead (black lead)

—
Note Tab. 12
C1 and tan δ1 measurement overview

—
Note Tab. 13
C2 and tan δ2 measurement overview

9.3. Measurements overview of C1 & tan δ1

Voltage	On-site measurements			On-site measurement, correction for temperature	
[V]	[°C]	C1 [pF]	tan δ1 [%]	C1 [pF]	tan δ1 [%]
200					
500					
1000					
2000					
3000					
6000					
9000					
12000					

Tab. 12

NOTE

► THE MEASURED VALUES ARE REGARDED AS THE FIRST MEASUREMENT IN THE INSTALLED STATE, AND CANNOT BE COMPARED WITH THE TEST REPORT.

9.4. C2 & tan δ2 measurements

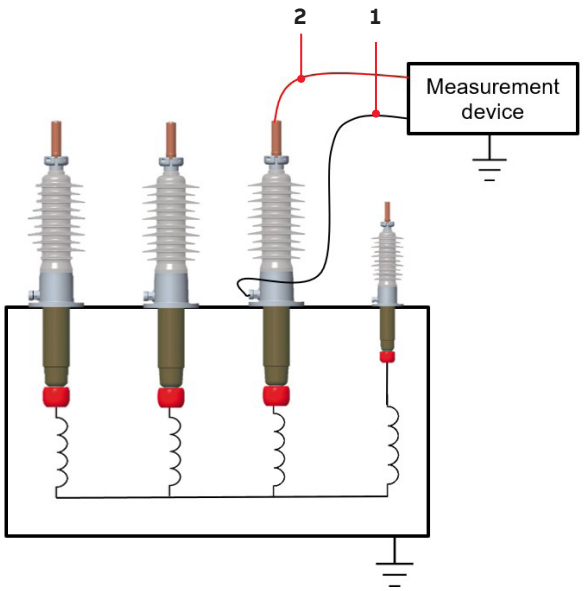


Fig. 29

9.5. Measurements overview of C2 & tan δ2

Voltage	On-site measurements			On-site measurement, correction for temperature	
[V]	[°C]	C2 [pF]	tan δ2 [%]	C2 [pF]	tan δ2 [%]
200					
500					
700					
1000					
1500					
2000					

Tab. 13

DANGER

► THE VOLTAGE DURING THIS TEST MUST NOT EXCEED 2000 V.

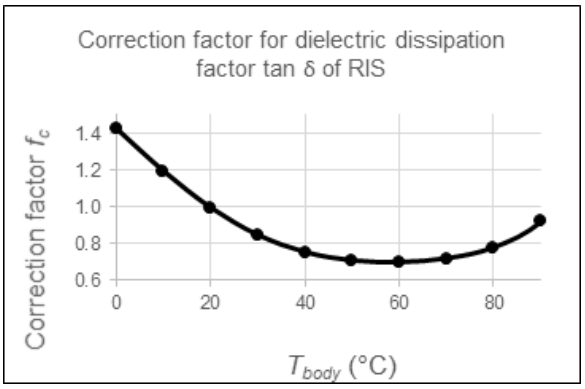
9.6. Temperature-dependent correction factors for tan δ1 & tan δ2

The tan δvalues must be calculated for the reference value at 20°C, see below:

1. While the measurement, record ambient and oil temperature, and calculate the temperature of the condenser core:
   $T_{bushing} = (2 * T_{air} + T_{oil}) / 3$ [°C]
2. With the curve or the table specified below, the correction factor fc can be determined at the corresponding ambient temperature, with which tan δ relative can be calculated with the following formula:
   $\tan \delta_{relative} = \tan \delta_{measured} / fc$

9. Measurements of C1, C2, tan δ1, tan δ2 (ref. No. 2)

Note Tab. 14
Correction factors



RIP body temp. [°C]	tan δ Corr. Factor fc
0	1.43
10	1.19
20	1.00
30	0.84
40	0.75
50	0.70
60	0.69
70	0.72.
80	0.78
90	0.92

Tab. 14

9.7. Temperature-dependent correction factors for C1 & C2

The C1 and C2 values must be calculated for the reference value at 20 °C as described below (the capacity increases by about 0.3‰ per °C).

1. After the measurement, the temperature ΔT difference should be calculated with the following formula:
   $\Delta T = T_{bushing} - 20$ [°C]
2. The measurement should be corrected with the following formula:
   $C\ 20°C = C_{measured} * (1 - \Delta T * 0.0003)$

9.8. Site-dependent correction for C1

The measurement of the C1 capacity of installed bushings on site is always smaller than in the test area.

Note Tab. 15
Tolerances

9.9. Permissible tolerances for C & tan δ

9.9.1. For bushings ≤ 145kV

C1	tan δ1	C2	tan δ2
+/- 5% (Relative)	+/- 0.05% (Absolute)	+/- 20% (Relative)	+/- 0.15% (Absolute)

9.9.2. For bushings > 145kV

C1	tan δ1	C2	tan δ2
+/- 3% (Relative)	+/- 0.05% (Absolute)	+/- 20% (Relative)	+/- 0.15% (Absolute)

Tab. 15

NOTE

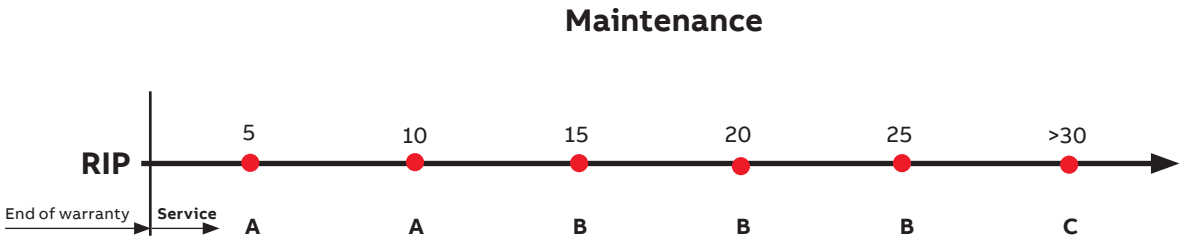
► IF THE MEASURED VALUES DO NOT FIT WITH THE SET TOLERANCES, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

10. Maintenance

10.1. Maintenance shedule

Note Tab. 16
Maintenance schedule and maintenance intervals

		tan δ1 & tan δ2	Capacitance C1 & 2	Visual inspection	Thermography	Insulator cleaning	Risks
Level A	**Installation in operation**	-	-	●	● (all 5 years)		See warning (a)
Level B	**Installation switched off and earthed**	●	●	●		● (If needed)	See warning (b)



Level A: Visual inspection (diagnostics recommended, depending on the condition)
Level B: Diagnosis
Level C: Replacement or conservation

Tab. 16

DANGER (a)

PREVENTION OF FALLING ACCIDENTS, CHEMICAL HAZARDS, ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED.
► THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► THE SYSTEM IS SWITCHED-OFF, SECURED AND TESTED.
► THE PRIMARY AND SECONDARY SIDE OF THE TRANSFORMER OR THE SWITCHGEAR IS SHORT-CIRCUITED AND EARTHED.
► THE WORK CAN ONLY BE STARTED AFTER A COMPLETE ELECTRIC DISCHARGE OF THE SYSTEM.
► WEAR APPROPRIATE PPE.

DANGER (b)

PREVENTION OF ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► WEAR APPROPRIATE PPE.

NOTE

THE MAINTENANCE SCHEDULE ACCORDING TO TABLE ABOVE SHOWS THE TYPICAL MAINTENANCE INTERVALS RECOMMENDED FOR RATED LOADS OF THE BUSHING. THE SERVICE LIFE ESTIMATES ARE BASED ON CONSERVATIVE EMPIRICAL VALUES AND ARE AS A RULE HIGHER.

10. Maintenance

10.2. Bushing maintenance

Tab. 17 provides a schedule for the expected service life as well as the maintenance intervals of the RIS product. This overview is only a recommendation.

10.3. High voltage connection check

During the maintenance level A and after the first commissioning it is recommended to check the quality of the connection by thermography between the bushing and the power grid (reasons: possible loose or oxidized connection, insufficient crimping).

NOTE

► THERMOGRAPHY IS ONLY USEFUL AFTER 24 HOURS UNDER NOMINAL LOAD.

10.4. Cleaning the silicone insulator

Cleaning the silicone insulator is not normally necessary in operation, as silicone due to its hydrophobic nature and the transfer of the hydrophobia in the contaminated surface maintains its water-repellent properties even with high contamination and age.
However, if the silicone surface becomes dirty, it can be cleaned with water. If it is not enough, the following can be used for cleaning:
- Light contamination: 5% water solution of cleaning agents (e.g. soap).
- Medium to strong contamination: alcohol.
The cleaning of these surfaces takes place by soaking a lint-free cotton cloth in the cleaning liquid and wiping the silicone surface.

The technical specification concerning the measurement of the wettability of insulator surfaces is describe in the standard IEC TS 62073 and annex D.

DANGER

► CLEANING OF THE BUSHING MAY ONLY TAKE PLACE IF THE INSTALLATION IS SWITCHED OFF AND SECURED.

CAUTION

► CLEAN ONLY IN WELL-VENTILATED ROOMS.
►AVOID SKIN AND EYE CONTACT WITH THE CLEANING LIQUID, DO NOT INHALE THE VAPORS.
►NO OPEN FLAMES WITH VOLATILE SOLVENTS.
► WORK AND PROTECTIVE MEASURES MUST COMPLY WITH THE SAFETY DATA SHEET AND LOCAL GUIDELINES.
► WAIT FOR 24 HOURS AFTER THE CLEANING BEFORE COMMISSIONING.

10.5. Capacity and tan δ loss factor checks

Detailed information about measuring the capacity and tan δ can be found in chapters 8 and 9.

10.6. Spare parts

When ordering spare parts, the serial number from the rating plate on the flange of the bushing must always be provided.

10.7. Replacement of bushings

If a reserve bushing is needed, the serial number from the rating plate on the flange of the bushing must always be provided.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

11. Dismounting (transport, repair or disposal)

DANGER

PREVENTION OF LIFTING HAZARDS, CUTTING INJURIES, ELECTRIC SHOCK, CHEMICAL HAZARDS, FALLING, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED. THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING ACTIVITIES.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► THE SYSTEM IS SWITCHED-OFF, SECURED AND TESTED.
► THE PRIMARY AND SECONDARY SIDE OF THE TRANSFORMER OR THE SWITCHGEAR IS SHORT-CIRCUITED AND EARTHED.
► THE WORK CAN ONLY BE STARTED AFTER A COMPLETE ELECTRIC DISCHARGE OF THE SYSTEM.
► FOR TRANSFORMERS, THE AVAILABLE CURRENT TRANSFORMER MUST ALWAYS BE SHORT-CIRCUITED AND EARTHED AT THE TRANSFORMER, PREFERABLY IN THE TERMINAL BOX. THIS IS TO SUPPRESS THE DISPLACED EARTH POTENTIALS.
► WEAR APPROPRIATE PPE.

11.1. Dismounting the bushing for transport, repair or disposal

The work steps described in Chapter 5 must be performed in reverse order.
To ensure safety for this activity, the above recommendations must be observed.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

12. Repair

DANGER

PREVENTION OF FALLING ACCIDENTS, CHEMICAL HAZARDS, CUTTING INJURIES, ELECTRIC SHOCK, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.
► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.
► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED.
► THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.
► THE PERSONNEL SHOULD HAVE APPROPRIATE TRAINING FOR WORK WITH DANGEROUS VOLTAGES.
► THE SYSTEM IS SWITCHED-OFF, SECURED AND TESTED.
► THE PRIMARY AND SECONDARY SIDE OF THE TRANSFORMER OR THE SWITCHGEAR IS SHORT-CIRCUITED AND EARTHED.
► THE WORK CAN ONLY BE STARTED AFTER A COMPLETE ELECTRIC DISCHARGE OF THE SYSTEM.
► WEAR APPROPRIATE PPE.

12.1. Bushing repair

Extensive repairs should be conducted in consultation with Powerr Grids at ABB Switzerland Ltd. The serial number as well as a precise description with pictures of the damage do be repaired are necessary for this.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

12.2. Silicone insulator repair

Damaged silicone insulators must be replaced or repaired.
As the manufacturers of the silicone insulators use different types of silicone for shielding, different repair compounds (LSR or HTV) must be used, and the corresponding vulcanization times must be observed. For this reason, in case of repairs please consult Powrer Grids at ABB Switzerland Ltd, providing them with ppictures of the damaged area as well as the serial number of the bushing.
Depending on the damage case, a repairs kit can be provided. For this reason, in every case please consult High Voltage Components at ABB Switzerland Ltd before repair.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

13. Disposal

DANGER

PREVENTION OF LIFTING HAZARDS, CUTTING INJURIES, CHEMICAL HAZARDS, FALLING, SLIPPING AND TRIPPING ACCIDENTS

► THE WORK AREA MUST BE MARKED AND KEPT CLEAR.

► ALL ACTIVITIES MUST BE SUPERVISED BY A QUALIFIED PERSON.

► APPROPRIATE CLIMBING AIDS AND SUPPORTING STRUCTURES SHOULD BE USED. THE PERSONNEL SHOULD BE AUTHORIZED TO WORK AT HEIGHT.

► THE PERSONNEL SHOULD BE TRAINED FOR THE LIFTING ACTIVITIES.

► WEAR APPROPRIATE PPE.

13.1. Special hazards during disposal

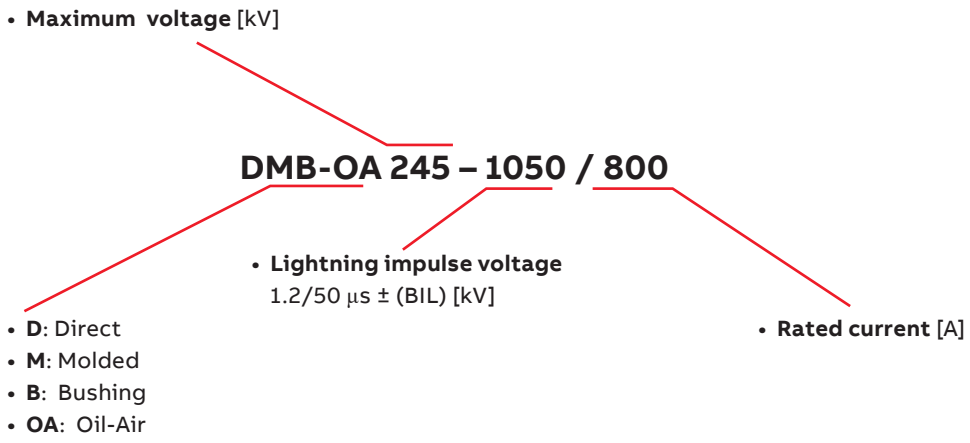
After the service life of the bushing expires, it should be disposed of in accordance with the local laws and regulations.
The disposal should be performed by a recycling company that specializes in these activities.
The product, including accessories, does not contain any toxic basic components.

NOTE

► FOR FURTHER INFORMATION, PLEASE CONTACT ABB POWER GRIDS SWITZERLAND LTD. OR YOUR LOCAL ABB PARTNER.

14. Type designation

14.1. Rating plate



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