HVDC bushing, type GSD
Installation and maintenance guide
Original instruction

The information provided in this document is intended to be general and does not cover all possible applications. Any specific application not covered should be referred directly to ABB, or its authorized representative.

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Safety information

Keep this instruction available to those responsible for the installation, maintenance, and operation of the bushing.

The installation, operation, and maintenance of a bushing present numerous potential unsafe conditions, including, but not limited to, the following:

- High pressures
- Lethal voltages
- Moving machinery
- Heavy components
- Slip, stumble or fall

Specialized procedures and instructions are required and must be adhered to when working on such apparatus. Failure to follow the instructions could result in severe personal injury, death, and/or product or property damage.

Additionally, all applicable safety procedures such as regional or local safety rules and regulations, safe working practices, and good judgement must be used by the personnel when installing, operating, maintaining and/or disposing such equipment.

Safety, as defined in this instruction, involves two conditions:

1. Personal injury or death.
2. Product or property damage (includes damage to the bushing or other property, and reduced bushing life).

Safety notations are intended to alert personnel of possible personal injury, death or property damage. They have been inserted in the instructional text prior to the step in which the condition is cited.

The following warnings and notes are used in the manual:

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**WARNING**

WARNING indicates an imminently hazardous situation, which if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.

WARNING also indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

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**CAUTION**

CAUTION indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert of unsafe practices.

CAUTION may also indicate property-damage-only hazards.

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**INFO**

INFO provides additional information to assist in carrying out the work described and to provide trouble-free operation.
Recommended practices

ABB recommends careful consideration of the following factors when installing bushings:

- Before you install or commission a unit, make sure that the personnel doing the job have read and fully understood the Installation Guide provided with this unit.
- To avoid damaging the unit, never exceed the operation limits stated in delivery documents and on rating plates.
- Do not alter or modify a unit without first consulting ABB.
- Follow local and international wiring regulations at all times.
- Use only factory authorized replacement parts and procedures.

Warnings and cautions in this guide

**WARNING**
The bushing shall always be earthed and de-energized when being worked on.

**WARNING**
SF₆ gas is more dense than air, it is invisible and does not smell. If gas is released it will settle in low areas, and there is a significant risk of asphyxiation and death if entering the area.

**WARNING**
Before starting the gas filling procedure, go to a protected area and a safe distance from the bushing. An explosion can cause death or injury to personnel and/or damage equipment.

**CAUTION**
The test tap should never be open during operation. It should always be connected to earth directly or via an external impedance. The protective cover earths the test tap automatically when it is properly attached. Note that this does not apply when the tap box terminal is attached to the test tap.

A voltage divider may be mounted on the bushing test tap, if provided with an adapter. If this is the case, see the specific guide for the voltage divider.

**CAUTION**
Keep the components clean, dry and undamaged during installation.

**CAUTION**
Lifting and handling of heavy components. Also make sure that correct and undamaged lifting tools are used and that all screws are properly tightened.

**CAUTION**
Do not energize the bushing before all preparations in this guide are done.

**CAUTION**
Damaging the silicone insulator may lead to partial discharge during operation.

**CAUTION**
The condenser core must not be exposed to open air for more than 2 hours. However, the bushing is allowed to be without oil up to one week if it is mounted in the transformer or in the transport container. If necessary, this time may be prolonged up to a maximum of three weeks provided that the vacuum time for the transformer is increased with an additional 24 hours, and to have at least 5 days from the end of filling the transformer before voltage is applied to the transformer.

**CAUTION**
Any damaging of the condenser core during assembly must be avoided.

**CAUTION**
Filling pressure is 3.7 bar (abs), the bushing is designed and tested for maximum operating pressure (MOP) = 4.4 bar (abs). Do not allow the pressure to exceed 4.4 bar (abs) at any time.

**CAUTION**
Energizing the bushing without the appropriate corona shield may lead to flash over and serious damage to the equipment.

**CAUTION**
In view of the risks involved in lifting pressurized items, no lifting should take place at more than transport pressure.
CAUTION

Since $C_2$ usually is relatively small, the test tap must never be open-circuited when applying a voltage to the bushing. It must always be earthed or connected to an external impedance. After testing, check that the test tap cover is mounted correctly on the bushing.

CAUTION

SF₆ gas must be recycled and not released into the atmosphere.

The bushing is supplied with two density guards. In the event of too low SF₆ gas density inside the bushing, the guard if correctly connected, alarms the control system and correct measurements can be taken. The standard unit has three switches at three different density conditions, and gives the highest versatility when analyzing the switch settings in a logical way.

The bushing can operate without any restrictions down to the lowest alarm density corresponding to a pressure of 0.31 MPa (20 °C, abs). By monitoring all alarm levels planned, counter measures can be made before damaging the equipment.

The density guard is a calibrated monitoring instrument. It must be handled with care and protected against careless handling or any kind of mechanical damage. Do not open the package of the density guard until the guard is needed.

Check during gas filling that all alarm levels works and are correctly connected to the control system.

For spare transformer stored outdoor, make sure that the cable gland is plugged if no cable is connected. Or store the density guard indoor.

The bushing may be transported and stored horizontally up to 6 months. For long term storage exceeding 6 months, the bushing shall be stored with the transport vessel tilted upwards about 5°.

The transport box is not designed for long term storage in high humidity and at varying temperatures. For long term storage in the transport box, keep it indoor with controlled temperature and low humidity.

Make sure that the supports do not damage the insulator. The bushing shall be handled with care.

Be careful not to damage the condenser core.

Make sure that the correct force is achieved in the draw rod. The tightening of the nut shall be done according to one of the two procedures described in section 2.9.8.

Dirt or damages on the corona shield may lead to partial discharge in air. Be careful during assembly and clean away all dirt.

To avoid external heating of the bushing, the connection of the external bus must be assembled and connected acc. to the instruction from the supplier.

The bushing is provided with a rupture disc, mounted on the flange. The disc is mounted under a protective cover and is indicated in Fig. 1. In order not to damage the sensitive disc, the cover may not be removed. The disc is designed to cope with Maximum Operating Pressure of the bushing (MOP=4.4 bar).

Capacitance $C_2$ may deviate from the value on the rating plate after installation and this is normal. It is therefore recommended that $C_2$ after installation is measured and recorded if any future comparison is planned.

The SF₆ gas must be recovered for reuse or destruction.

The permitted quality of the SF₆ gas is specified in the standard IEC 60376.
Safety precautions

- Transformer oil is slightly harmful. Fumes from unused warm oil may irritate the respiratory organs and the eyes. After long and repeated contact with transformer oil skin becomes very dry.

- First aid:
  - Skin contact: Wash the hands. Use skin cream to counteract drying.
  - In the eyes: Rinse the eyes in clean water.
  - Swallowing: Drink water or milk. Avoid vomiting. Contact medical attendance.

- Collect used oil in oil drums.

- SF₆ gas must be recycled and never released to the atmosphere.

- Waste and cleaning up: Should be absorbed by an absorber. Treat it as hazardous to the environment.

- Upon fire: The fire should be extinguished by using powder, foam or carbon dioxide.
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1. Description

1.1 Design
The GSD design combines the robustness of a conventional Resin Impregnated Paper (RIP) condenser core, with a SF$_6$ gas filled cooling section. The thermal stability and cooling design is highly relying on the thermal properties of the SF$_6$ gas, as well as low current loss and high heat transfer capacity of the copper center tube. The outer insulator, containing the gas filled section, is exposed to ambient air.

![Bushing design](image1)

**Fig. 1. Bushing design.**

1.2 Test tap

**CAUTION**

The test tap should never be open during operation. It should always be connected to earth directly or via an external impedance. The protective cover earths the test tap automatically when it is properly attached. Note that automatic grounding is not achieved when using the tap box terminal mounted on the test tap.

A voltage divider may be mounted on the bushing test tap, if provided with an adapter. If this is the case, see the specific guide for the voltage divider.

![Test tap](image2)

**Fig. 2. Test tap.**
1.3 Density guards, different types

The bushing is supplied with two density guards. In the event of too low SF₆ gas density inside the bushing, the guard if correctly connected, alarms the control system and correct measurements can be taken. The standard unit has three switches at three different density conditions, and gives the highest versatility when analyzing the switch settings in a logical way.

The bushing can operate without any restrictions down to the lowest alarm density corresponding to a pressure of 0.31 MPa (20 °C, abs). By monitoring all alarm levels planned, counter measures can be made before damaging the equipment.

The density guard is a calibrated monitoring instrument. It must be handled with care and protected against careless handling or any kind of mechanical damage. Do not open the package of the density guard until the guard is needed.

Check during gas filling that all alarm levels works and are correctly connected to the control system.

For spare transformer stored outdoor, make sure that the cable gland is plugged if no cable is connected. Or store the density guard indoor.

1.3.1 Density guard with three switches at three different pressure levels

Density guard 5693 822-17, see Fig. 3.

Pressure levels are given as absolute pressure.

See Fig. 6:

Alarm level 1 (0.35 MPa): Switch number D1 is activated, circuit 11-13 is opened and 11-12 is closed. This indicates gas density lower than level 1.

Alarm level 2 (0.33 MPa): Switch number D2 is activated, circuit 21-23 is opened and 21-22 is closed. This indicates gas density lower than level 2.

Alarm level 3 (0.31 MPa): Switch number D3 is activated, circuit 31-33 is opened and 31-32 is closed. This indicates gas density lower than level 3.

D1: \( p = 0.35 \) MPa
D2: \( p = 0.33 \) MPa
D3: \( p = 0.31 \) MPa

Fig. 3. Density guard 5693 822-17.

Fig. 4. Terminal marking and circuit diagram.
1.4 Operation conditions
Table 1 shows the standard technical specifications for the GSD HVDC bushing. For conditions exceeding the values below, please contact ABB.

Table 1. Common specifications.

<table>
<thead>
<tr>
<th>Application</th>
<th>Converter transformers and DC smoothing reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>Transformer side: Resin impregnated paper, capacitance graded completely oil immersed bushing Air side: SF₆ gas insulated bushing</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>0 to +60 °C for use in valve halls, or project specific -40 to +45 °C outdoor</td>
</tr>
<tr>
<td>Altitude of site</td>
<td>&lt; 1 000 m</td>
</tr>
<tr>
<td>Type of immersion medium, transformer side</td>
<td>Transformer oil. Maximum daily mean oil temperature is current dependent and project specific</td>
</tr>
<tr>
<td>Pressure of medium</td>
<td>Oil volume: 100 kPa overpressure</td>
</tr>
<tr>
<td>Markings</td>
<td>Conforming to IEC/IEEE</td>
</tr>
</tbody>
</table>

1.5 Mechanical loading
Maximum static load on the bushing according to Fig. 5.
2. Assembly instructions

CAUTION

Keep the components clean, dry and undamaged during installation.

CAUTION

Lifting and handling of heavy components. Also make sure that correct and undamaged lifting tools are used and that all screws are properly tightened.

CAUTION

Do not energize the bushing before all preparations in this guide are done.

2.1 Required tools

- Shackles, for hole Ø 27 mm, for connection of soft slings to the bushing flange.
- Torque wrench key for hexagon head screws, head width from 13 mm (M8) to 36 mm (M24).
- Torque wrench key for hexagon socket head cap screws, socket width from 5 mm (M6) to 10 mm (M12).
- Open end wrench 13 and 24 mm.
- Soft slings minimum 4000 kg.
- 2 pcs. M6 x 40 screws threaded up to the head, for dismounting of the sealing plate.
- Pull through sling cord, for assembly of draw rod, 9760 669-A (Fig. 6)
- Lifting gear for fastening flange (Fig. 7)
- Jack (12 ton) with accessories for assembly of draw rod, 9769 897-A (Fig. 9)
- Box spanner for assembly of draw rod, 9760 669-B (Fig. 10)
- M16 x 20 and appropriate washer for earthing connection.

2.2 Tightening torque

Tightening torques according to Table 2.

Table 2. Tightening torques for screw joints.

<table>
<thead>
<tr>
<th>For metallic screw joints (Nm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M6</td>
<td>10 ±10%</td>
</tr>
<tr>
<td>M8</td>
<td>24.5 ±10%</td>
</tr>
<tr>
<td>M10</td>
<td>49 ±10%</td>
</tr>
<tr>
<td>M12</td>
<td>84 ±10%</td>
</tr>
<tr>
<td>M16</td>
<td>203 ±10%</td>
</tr>
<tr>
<td>M20</td>
<td>396 ±10%</td>
</tr>
<tr>
<td>M24</td>
<td>685 ±10%</td>
</tr>
</tbody>
</table>
The nut shall be mounted so that the free thread above it is > 10 mm.

Fig. 6. Pull through sling cord, 9760 669-A.

Fig. 7. Lifting gear fastening flange, 2020 808.

Fig. 8. Lifting gear top, 2021 107.

Fig. 9. Hydraulic jack 12 ton, 9769 897-A.

Fig. 10. Box spanner, 9760 669-B.
2.3 Required consumables
- Vaseline 8401 (water free), 1171 5011-102
- Fomblin OT20, 1171 4016-616
- Locking liquid, 1269 0014-408

Water free vaseline is not harmful to the transformer oil. Lubricate bottom end for bottom contact. Fomblin to grease screws and sealings for the sealing plate at top end, the top end for top contact, screws for the top contact, screws for the corona shield, lifting tool screws and earthing screws.

2.4 Spare parts
In case of major damage to the bushing, we recommend that it is sent back to ABB for possible repair and re-testing. Certain parts, which may be damaged or lost during transport or installation, can be ordered from ABB.

O-rings for sealing plug, see Fig. 31:
- O-ring 1ZSC004442-CAF, Ø44, 2x3,0 2 pcs
- O-ring 1ZSC004442-DAF, Ø74, 2x5,7 1 pcs

2.5 Transport and storage
Note that this is opposite from conventional porcelain bushings! This arrangement allows the air cushion in the transport vessel to be located as far away as possible from the condenser of the bushing.

Care must be taken when storing the bushing so that the silicone rubber sheds are not damaged. For instance, rodents, insects or birds can destroy the sheds.

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The transport box is not designed for long term storage in high humidity and at varying temperatures. For long term storage in the transport box, keep it indoor with controlled temperature and low humidity.

The bushing shall also be protected from penetrating water if stored outdoors. This means that it shall not be stored in areas where it can be foreseen that the ground will be wet and muddy during heavy rain. Shelter the bushing from rain and snow with a tarpaulin or roofing.

For long term storing of the bushing, when mounted on oil filled spare transformer, protect the bushing as described above. If the density guard is assembled but not connected, make sure that the connection box is protected from any moisture penetration through the cable gland. Also protect the silver plated top end of the conductor by re-mounting the protection cap, see Fig. 17.

The bushing is supplied with the gas volume filled with nitrogen gas (N₂) at a pressure of 25 kPa gauge. This pressure should be maintained during shipping and storage.

The bushings are normally delivered from ABB in boxes with the bushing supported by blocks and fibreboards. The boxes are marked with “Top End”. This information can be important and shows how the bushing is oriented inside the box. See Fig. 11.

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![Fig. 11. Box marked “Top end”. Figure illustrates desired lifting points for slings and fork lift respectively](image-url)
2.6 Receiving the bushing

2.6.1 Unpacking
Check that the packages are free from transport damage. Open the covers of the transport boxes, see Fig. 12. Remove the supporting block of wood, see Fig. 13. If any package is damaged, a careful investigation must be carried out. If needed, lift the bushing according to Figs. 14 and 15.

2.6.2 Inspection on receipt
1. Check that the bushing and accessories are undamaged.
2. If transport damage is found and it is judged that correct operation of the bushing is not possible, a damage report should be sent to the insurance company. It is also recommended that photographs are taken of the damage details. Mark the photos with ABB’s reference number and the serial number of the bushing. Send them to ABB for comments.
3. Check that the parts delivered, type designations and the serial number agrees with the delivery documents, e.g., the packing list or ABB’s order acknowledgement. The serial numbers to be checked are those on the rating plate, see Fig. 1.

2.6.3 Temporary storage before assembly
If the bushing is not assembled immediately once the delivery has been approved, the bushing must be kept protected if stored outdoors. Keep it also in the plastic enclosures.

2.6.4 Handling of the box
The transportation box should only be lifted with a fork lift at designated locations or with slings in loop eyes if present on box.

The box should be transported and stored with support over at least 75% of its length. For convenience the box is marked “Top end”. See Fig. 11.

2.6.5 Document placement
Installation guide and other related documents are placed in a sealed plastic bag inside the transportation box.

2.6.6 Open and lifting the lid
Proceed with removing wooden cover, in the same manner, after ensuring all screws or nails are removed. See Fig. 18.

2.6.7 Removing the top supports and putting them on the floor
See Fig. 16.

Fig. 12. Cover should be lifted in sections if a lifting yoke is not used.
2.7 Lifting from the box

2.7.1 How to enter the box

**CAUTION**

If needed, use a stairway or likewise to enter the box; inside as well if needed. Never enter the box climbing on the box or on the bushing itself.

2.7.2 Removal of plastic cover

Remove plastic wrapping as late as possible prior to attaching the bushing on the transformer, or even after assembly, to avoid damages and dirt on the bushing during handling. If moisture has entered the box or plastic wrapping during shipping or storage prior to assembly, once the bushing is indoors in a clean environment, remove the plastic to allow the surface to dry.

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Fig. 13. Loosen the tightening straps at flange and at cover.

Fig. 14. Point of interest with respect to lifting bushing out of box. Slings around transport container to the left and transport hood to the right shown.
2.7.3 Lifting points
The transport container and transport hood, shown to the left and to the right respectively in Fig. 14, shall be used for lifting the bushing out of the box. For lifting at tilted angle, the lifting tools listed in chapter 2.1 shall be used.

⚠️ CAUTION
Damaging the silicone insulator may lead to partial discharge during operation.

2.7.4 Lifting horizontal
See Fig. 13.

2.7.5 Placing the bushing on the floor
Make sure that the supports do not damage the insulator (Fig. 16). The bushing shall be handled with care.

Place the bushing on supports, Fig. 16.

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Fig. 15. Horizontal lifting, center of gravity (COG) according to dimension drawing.

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Fig. 16. Placing the bushing on supports on the floor. Use non-harmful supports when placed on the ground.
2.8 Preparing for mounting on transformer

2.8.1 Removing the protection cap
Loosen 8 x M12 screws and remove the protection cap. Save the protection cap for long term storage of bushing on spare transformer, to protect the plated top end of the conductor.

2.8.2 Mounting the lifting gear at the top
See Fig. 18.

2.8.3 Lifting gear at the middle flange
See Fig. 19.
2.8.4 Mounting the pull through cord

The end of the conductor is sealed with a sealing plug, see in Fig. 20.

To remove the sealing plug, all of the M6 screws have to be removed completely. Two of the screws are intended to use for ejecting the plug by attaching them to the two threaded holes in the plug.

Now, the conductor end should expose the top end of a draw rod with its washers and M16 nut.

The pull through cord should be attached to the M8 hole in the end of the draw rod prior to disassembling the M16 nut from the draw rod.
2.8.5 Lifting of the bushing

2.8.5.1 Vertical installation
Raise the bushing with the transport container still attached. See Fig. 21.

2.8.5.2 Lifting the bushing to the desired angle
When lifting the bushing, make sure the sling from the top end of bushing fulfill the two following demands, see Fig. 23:
- the top sling point upwards from the bushing, with respect to the horizontal plane
- the sling point at least 30° away from the bushing.

This is to make sure that the stresses is not to high in the bushing, lifting tools and slings.

Be careful no to damage the condenser core.

Fig. 21. Raise the bushing with the transport container still attached.

Fig. 22. Lifting bushing to the desired angle.
2.8.6 Dismounting the transport container
Put the bushing on the bottom of the transport container or on flat ground, supported by the lifting by the crane. See Fig. 23. Remove the transport container and lift the bushing to installation. Dismount the transport container as close as possible to the transformer turret, to avoid humid air damages and dirt on the bushing during handling.
2.9 Mounting on transformer

2.9.1 Draw rod
Lower the draw rod, and remove the screw and the washer according to Fig. 25. Assemble and tighten the draw rod to the bottom draw rod in the transformer turret.

2.9.2 Mounting bushing into the transformer turret
Retract the pull-through cord at the same time as the bushing is lowered into position.

CAUTION
Any damaging of the condenser core during assembly must be avoided.

Fig. 25. Mounting the draw rod and mounting of the bushing into the transformer turret.
2.9.3 Tightening the screw joint
See Fig. 26.

2.9.4 Dismounting lifting gear at middle flange
See Fig. 27.

2.9.5 Dismounting lifting gear at top end
See Fig. 29.
2.9.6 Tightening the draw rod

Make sure that the correct force is achieved in the draw rod. The tightening of the nut shall be done according to one of the following two procedures.

**Tightening method A**

In order to obtain required contact force of approximately 40 kN, the tightening expansion difference before and after, \( b-a \) should be according to Table 3.

1. Dismount the outer terminal completely and loosen the tightening nut without removing the nut.
2. Apply a generous amount of Molykote Multilub (art. no. 1236 0011-127) on the nut, washer and draw-rod bolt. Remove any excess of the Molykote Multilub with a rag.
3. Tighten the nut with 20 Nm and measure the distance \( a \), from the top of the nut to the top of the draw-rod bolt.
4. Continue tighten the nut until the measuring distance \( b = a + 9 \text{ mm} \). Each turn corresponds an extension of 2 mm.

<table>
<thead>
<tr>
<th>Bushing GSD (kVDC)</th>
<th>( b-a ) (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>9</td>
</tr>
</tbody>
</table>

**CAUTION**

If the measured distance \( b = a + 9 \text{ mm} \) is not achieved before reaching 160 Nm indicates that the threads are too poorly lubricated. If the threads are not damaged, dismount the nut and draw-rod bolt to apply more Molykote Multilub and tighten again. If the threads are damaged, the nut and draw-rod bolt need to be replaced.

Please contact the supplier if it is not possible to reach the specified values even though following the instructions above.

**Tightening method B**

Use a hydraulic jack (Fig. 9) to pull the draw rod bolt to a force according to the value given in Table 4. Make sure that the hydraulic jack is supported towards the support tube. See Fig. 32. Tighten the nut by the hand, using box spanner, 9760 669-B, and then release the jack.

<table>
<thead>
<tr>
<th>Bushing GSD (kV DC)</th>
<th>Force (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>40</td>
</tr>
</tbody>
</table>
2.9.7 Mounting the sealing plate
See Fig. 33.

2.10 Flange earthing
After tightening the bolts fixing the bushing to the transformer tank, the flange should be earthed. This prevents electrical discharges between bushing flange and transformer tank during service.

Apply a flexible cable between one of the lower M16 holes to the lifting gear, and a corresponding connection point in the transformer. Grease the screw (fomblin recommended) and tighten the M16 in the bushing to 40 Nm. The other end of the cable shall be properly connected to the transformer.
2.11 Corona shield and external connections
The corona shield is not delivered with the bushing itself. However, due to design aspects the appropriate corona shield, according to Table 5, have to be included in the bushing setup. The electrical data on the dimension drawing is not valid with any other corona shield.

CAUTION
Energizing the bushing without the appropriate corona shield may lead to flash over and serious damage to the equipment.

Table 5

<table>
<thead>
<tr>
<th>Bushing GSD (kV DC)</th>
<th>Article numbers</th>
<th>Dimension drawing</th>
<th>Corona shield</th>
<th>Alternative corona shield, allowed to be used</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>1ZSC004639-AAA</td>
<td>1ZSC004639-ABF</td>
<td>none</td>
<td></td>
</tr>
</tbody>
</table>

2.11.1 Mounting of external connection
See Fig. 35. Tightening torque according to Table 2.

2.11.2 Mounting of corona shield
Eight (large) washers, spring washers, and M8x30 screws, all stainless steel, should be used.

Dirt or damages on the corona shield may lead to partial discharge in air. Be careful during assembly and clean away all dirt.

2.11.3 Connection to the external bus
To avoid external heating of the bushing, the connection of the external bus must be assembled and connected according to the instruction from the supplier.
2.12 Gas filling

WARNING

In case filled to higher pressure at 20°C, there is a risk of the rupture disk to break in operation and SF$_6$ gas insulation will be evacuated, causing internal flash over and serious damage to the equipment.

CAUTION

Filling pressure is 3.7 bar (abs), the bushing is designed and tested for maximum operating pressure (MOP) = 4.4 bar (abs). Never fill to more than 3.7 ± 0.1 bar at 20°C to avoid pressure higher than 4.4 bar (abs) in operation.

CAUTION

In view of the risks involved in lifting pressurized items, no lifting should take place at more than transport pressure.

CAUTION

Energizing the bushing without appropriate gas and gas pressure may lead to internal flashover and serious damage to the equipment.

CAUTION

Do not rely only on density guard signals to control system on site when filling bushings. If connected wrong, control signals show filled when not filled.

The purpose of the compressed SF$_6$ gas is primarily to electrically insulate the internal of the bushing but also to cool the tubular conductor. Its capacity for doing so depends on the density of the gas.

From the manufacturer the bushing is filled with N$_2$ gas at a transport pressure of 25 kPa (gauge). The SF$_6$ filling procedure starts with evacuating all of the N$_2$ gas to a vacuum of 20 Pa. The SF$_6$ nominal filling pressure at 20 °C is 370 kPa absolute (270 kPa gauge).

For filling gas at other temperatures, Table 7 should be used as a guide to adjust the final pressure when filling. Note that the pressure levels apply after the complete gas volume has reached the given temperature. If the gas is colder than ambient temperature, it is therefore recommended not to fill up to final pressure before the gas has reached the ambient temperature.

<table>
<thead>
<tr>
<th>Ambient temperature (°C)</th>
<th>-30</th>
<th>-20</th>
<th>-10</th>
<th>0</th>
<th>+10</th>
<th>+20</th>
<th>+30</th>
<th>+40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure, kPa absolute</td>
<td>300</td>
<td>320</td>
<td>330</td>
<td>340</td>
<td>360</td>
<td>370</td>
<td>380</td>
<td>400</td>
</tr>
</tbody>
</table>

The bushing is provided with a rupture disc, mounted on the flange. The disc is mounted under a protective cover and is indicated in Fig. 38. In order not to damage the sensitive disc, the cover may not be removed. The disc is designed to cope with Maximum Operating Pressure of the bushing (MOP = 4.4 bar).

2.12.1 Description of SF$_6$ gas

Sulfur hexafluoride (SF$_6$) is a synthetic gas, it is colorless, does not smell and does not burn. The gas is chemically very stable, and it does not react with any other substance at room temperature. The stability of the gas is the reason for being used in electrical equipment, because it provides very high electrical insulation. These properties of SF$_6$ gas makes possible the construction of devices and equipment with small dimensions, using less material, that are safe and have long service-lives. For electrical equipment, the SF6 gas is only used in closed and sealed systems, e.g. as insulation gas in substations.

Chemical name: Sulfur hexafluoride
Colorless, odorless, non-toxic, non-flammable, chemically inert
High dielectric strength, almost 3 times higher than air or N$_2$
Climate-effecting CO$_2$ equivalent: 22,800
Lifetime in the atmosphere: 3,200 years

2.12.2 Quantity and quality needed

The quality of the SF$_6$ gas should adhere to standards IEC 60376, 2005-06, and IEC 60796b, 1990-10.

Approximate SF$_6$ need to fill a certain type of bushing is presented in Table 8.

<table>
<thead>
<tr>
<th>Bushing GSD (kVDC)</th>
<th>Mass SF$_6$ gas</th>
<th>CO$_2$ gas equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>19 kg approx.</td>
<td>433.2 tonne approx.</td>
</tr>
</tbody>
</table>
Fig. 37. Nozzle for connection to gas valve.

Fig. 38. Gas filling and view of rupture disc position.
2.13 Recommended tests before energizing

2.13.1 Tightness test between transformer and bushing
Several different methods may be used and we thus refer to instructions given by the company responsible for the field erection. As a simple example, the tightness of the seal between transformer and bushing flange may be checked when the transformer is oil-filled by using chalk or with paper strips. Same method can also be used, to check the tightness of the sealing plate at top end of the conductor.

2.13.2 Measurement of capacitance and tan δ

**CAUTION**

Since $C_2$ usually is relatively small, the test tap must never be open-circuited when applying a voltage to the bushing. It must always be earthed or connected to an external impedance. After testing, check that the test tap cover is mounted correctly on the bushing.

After mounting, a capacitance measurement is recommended. A measuring bridge is connected between the outer terminal and the test tap. This is possible without removing the bushing from the transformer as the bushing has an insulated test tap, see Fig. 2.

More details can be found in product information 2750 515-142, Bushing diagnostics and conditioning.

With the transformer de-energized and the bushing outer terminal disconnected, the test tap cover is removed. The measuring equipment is connected to the test tap and the measuring voltage source is connected to the bushing terminal.

The capacitance $C_1$ and $C_2$ according to the rating plate.

**Capacitance $C_2$ may deviate from the value on the rating plate after installation and this is normal. It is therefore recommended that $C_2$ after installation is measured and recorded if any future comparison is planned.**

2.13.3 Check of through-resistance

The through-resistance measurement method depends on the design of the transformer. Generally, a current is applied from bushing to bushing. The voltage drop from outer terminal to outer terminal is measured. The resistance is calculated with Ohm's law, $U = R \cdot I$. ($U$: Measured voltage drop. $I$: Through-current. $R$: Total circuit resistance.)

The total through-resistance is the sum of the transformer winding, the lead resistance, the bushing conductor and the contact resistance. The additional resistance from the bushing conductor should not be more than 10 to 100 μΩ. Since the through-resistance of the HV winding of a typical power transformer is in the order of 0.1 to 1 Ω, this is a very rough method that can only be used to detect very large faults in the current path, such as disruptions.

Less-than-perfect contacts can only be detected by making an accurate measurement across each connection point, or by measuring the temperature increase during operation with an infrared sensitive camera (thermovision).
2.14 Transport to site
2.14.1 Removal of SF₆ gas
The bushing must not contain SF₆ gas during transport. Before dismounting or other handling of the bushing, the gas needs to be removed into a bottle or other gas container suitable for SF₆ gas. Fill the bushing with nitrogen (N₂) at a transport pressure of $P_{\text{abs}}$ 125 kPa.

**WARNING**
SF₆ gas is more dense than air, it is invisible and does not smell. If gas is released it will settle in low areas, and there is a significant risk of asphyxiation and death if entering the area.

**WARNING**
Before starting the gas filling procedure, go to a protected area and a safe distance from the bushing. An explosion can cause death or injury to personnel and/or damage equipment.

**CAUTION**
SF₆ gas must be recycled and not released into the atmosphere.

Procedure for removing SF₆ gas:

5. Connect the SF₆ gas to a service unit.
6. Remove all SF₆ gas to a vacuum of $P_{\text{abs}}$ 20 Pa.

The SF₆ gas must be recovered for reuse or destruction.

The permitted quality of the SF₆ gas is specified in the standard IEC 60376.

7. Fill the bushing with dry nitrogen (N₂) to a pressure of $P_{\text{abs}}$ 100 kPa.
8. Remove again all the nitrogen (N₂) to a vacuum of $P_{\text{abs}}$ 20 Pa.
9. Fill the bushing again with dry nitrogen (N₂) to a transport pressure of $P_{\text{abs}}$ 125 kPa.

2.14.2 Dismounting before transport
The bushing is usually transported without accessories (density guards), to prevent damage. Dismounting of the bushing is done in the opposite order of assembly.

2.14.3 Packing the bushing
See Fig. 39.

Place the bushing in the box with the lifting points up, see Fig. 40.
2.15 Final installation at site
This chapter describes tasks to be carried out on the bushing when the transformer is being installed and tested on site.

Follow chapter 2.1 - 2.14 for mounting bushing on the transformer.

The density guards are usually delivered in a separate package and installed at commissioning.

When the bushing is delivered, the air side gas volume is filled with N₂ at transport pressure, approximately 25 kPa gauge. Please use relevant parts of this manual to carry out commissioning.

For information about tools, materials and oil required, see relevant parts in this guide.

2.15.1 Density guards
Follow appropriate parts of chapter 1.4.

2.15.2 Accessories
Remount all other accessories, if any, that have been dismounted for the transport.

2.15.3 Gas filling
Follow appropriate parts of chapter 2.13.

2.15.4 Electrical connection and testing
Make all wiring work and make the appropriate tests according to chapter 2.14.

Fig. 40. Placement of bushing in transportation box. View from air side of bushing.
3. Maintenance and supervision

**WARNING**

The bushing shall always be earthed and de-energized when being worked on.

GSD bushings normally require no maintenance. The maintenance described below cover aspects of bushing supervision to be carried out, for example, on the occasion of station overhauls or normal scheduled maintenance.

3.1 Recommended maintenance and supervision

3.1.1 Handling and cleaning of composite insulators

The weather sheds do not normally require any cleaning for their lifetime. The surface may appear to be dirty, but this has no significance to its function. If the insulators have been exposed to extreme pollutions under installation or during service, it can be cleaned according to SEPTPT/PL/T/MB 2193.

Should, for any reason, the insulator be subjected to washing with water, care should be taken so that the sheds are not exposed to excessive forces (e.g. do not use high pressure nozzlers directly on the sheds).

For more information about handling and cleaning, please refer to SEPTPT/PL/T/MB 2193.

3.1.2 Gas

The gas density should not be allowed to fall below a corresponding pressure of 3.1 bar (20 °C, abs), see Table 7. Gas moisture content may be checked according to IEC 60376, 2005-06. Checking of gas characteristics may be carried out according to IEC 60480, 2004-10.

3.1.3 Measurement of capacitance and tan δ

Please refer to chapter 2.13.2.

3.1.4 Thermovision (infrared camera) check for local overheating on connectors

At maximum rated current, the temperature on the bushing outer terminal is normally about 35 to 45 °C above the ambient air. Significantly higher temperatures, especially at lower current loading, can be a sign of bad connections.

3.1.5 Hydrophobicity check

The hydrophobicity of the silicone rubber may be checked as directed in product information 2750 515-142, Bushing diagnostics and conditioning. This check is less relevant for indoor applications.
The bushing consists of the following material:

- Conductor tube of copper.
- Terminals of copper or low-alloy aluminium may be plated with silver.
- Resin impregnated condenser core consists of 21 % paper, 71 % resin, and 1 % Al foils.
- Test tap consist of Al alloys and epoxi.
- Flanges, cover and gas filling valves are made of aluminium.
- Insulators consist of glass fibre reinforced epoxy. Outer insulators also have silicone sheds of filled HTV silicone compound.
- Insulation medium is sulphur hexafluoride ($\text{SF}_6$).
- Contact spring in ground shield on oil side consists of silver plated copper and copper alloys.
5. References

- Markings: Conforming to IEC/IEEE
- Bushing diagnostics and conditioning, 2750 515-142
- Specification of Dew Point Measuring, IEC 60376, 2005-06
- Guide for checking SF$_6$ taken from electrical equipment, IEC 60480, 2004-10
- The quality of the SF$_6$ gas should adhere to standards IEC 60376, 2005-06, and IEC 60796b, 1990-10
- Transformer oil, IEC 60296, 2012-02, class 2
- Handling and Cleaning of Composite Insulators, SEPTPT/PL/T/MB 2193