Resin impregnated paper bushing, oil to SF$_6$, type GSBK
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:

**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.

**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.

**INFO**

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

1.1 Design

GSBK is a Resin Impregnated Paper (RIP) bushings intended for immersed oil – SF₆ service. The bushing can be mounted in any direction from vertical to horizontal and can also be used for oil – oil application.

The insulation core of the GSBK is produced by winding creped paper onto a centre tube, with aluminium foil insert for electrical stress control. The core is impregnated and cured under vacuum, giving a partial discharge free bushing with low dielectric losses.

As current conductor, GSBK uses the centre tube, which is moulded into the RIP core. Inner and outer terminals are fitted against the centre tube by bolted joint. Special terminals are available on request.

GSBK bushings are equipped with a test tap connected to the outer layer of the condenser core. Maximum test voltage of this test tap is 2 kV for one minute at 50 to 60 Hz. It serves as a test tap, and in connection with an external capacitance it can be used as a voltage tap. The operation voltage is limited to 600 V. A voltage tap, U_r=6 kV, and a test tap adapter for permanent connection, are available as option.
1.2 Operating conditions

The table below shows the standard technical specifications for the GSBK bushings. For conditions exceeding the below values, please contact ABB.

| Application: | Transformers |
| Classification: | Resin impregnated paper, capacitance graded, completely immersed bushing |
| Ambient temperature: | +40 to -40 °C as per temperature class 3 of IEC 60137 |
| Immersion medium on switchgear side: | SF₆ gas, max. daily mean temperature +75 °C |
| Max. pressure of medium on switchgear side: | 850 kPa (abs) |
| Min. pressure of medium on switchgear side: | 350 kPa (abs) |
| Immersion medium on transformer side: | Transformer oil. Maximum daily mean oil temperature +90 °C. Maximum temporary oil temperature +115 °C. |
| Oil level below bushing flange: | 30 mm |
| Max. pressure of medium: | 100 kPa (over pressure) |
| Angle of mounting: | Horizontal – vertical |
| Test tap: | Dimensions according to IEEE, type A, max service voltage 600 V |
| Voltage tap: | Dimensions according to IEEE, type A, max service voltage 6 kV |
| Capacitance C₂ of test tap: | < 5000 pF |
| Conductor: | Tube conductor |
| Markings: | Conforming to IEC |

1.3 Mechanical loading

The GSBK bushings are designed to meet loads stated in IEC 60137 and IEC 62217-211. Figures are shown in the tables below.

The following cantilever loads apply to the the midpoint of the terminal both on gas side and oil side.

<table>
<thead>
<tr>
<th>Bushing GSBK</th>
<th>Type test load 1 minute (N)</th>
<th>Max. service load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td>245</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td>362</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td>420</td>
<td>4000</td>
<td>2000</td>
</tr>
<tr>
<td>550</td>
<td>4000</td>
<td>2000</td>
</tr>
</tbody>
</table>

1.4 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.

1.5 Testing

During testing of the transformer a bushing type GSBK can be used as an oil-to-oil bushing, or be replaced by an oil-to-air bushing, with the same flange extension, in the following combination:
- GSBK 245 can be replaced by a bushing type GSB 245 or GOE(2) 1175-850
- GSBK 362 can be replaced by a bushing type GSB 362 or GOE(2) 1175-850 (the latter has 110 mm shorter oil side length than GSBK 362)
- GSBK 420 can be replaced by a bushing type GSB 420 or GOE(2) 1425-1050
- GSBK 550 can be replaced by a bushing type GSB 550

Note that if draw rod is used, GOE can not replace GSBK.
2. Installation

2.1 Tools
- Soft slings
- Soft bedding
- Tackle for mounting the bushing at a certain angle
- Torque wrench key for socket head screw 10 mm (M12)
- Flexible pull-through cord, 9760 669-A, for assembly of draw rod
- Box spanner, 9760 669-B, for assembly of draw rod

2.2 Consumables
- Water free vaseline, Mobilgrease 28 or other suitable lubricant not harmful to the transformer oil, to lubricate screws that come into contact with the transformer oil.
- Mobilgrease 28 or other suitable grease to lubricate and protect the earthing screw and the outer terminal o-ring gasket.
- Molykote 1000 or other suitable compound to lubricate the screws making the contact at the outer terminal.

2.3 Transportation, storage and handling

The bushing is surrounded by a sealed moisture-proof wrapping material together with a drying agent upon delivery. The supplied protective wrapping shall not be opened if the bushings are intended to be stored. After transformer test, it is also important to reseal the bushing with the supplied protective wrapping or a similar moisture-proof wrapping, together with a drying agent. The wrapping works as protection for transportation and storage (≤ 6 months). Note that bushings with standard wrapping shall be stored protected from precipitation.

For longer storage times (>6 months) a container have to be ordered separately.

The bushing may be transported and stored in any angle. Carefully inspect the bushing on receiving with regard to shipping damage. Please note that the bushing has been routine tested in oil and some oil may be left, especially in the narrow opening between condenser body and flange.

2.4 Lifting from the box

CAUTION

For lifting the bushing from the box, apply two clean lifting slings as shown in the figure below. Support the bushing at the same points as in the box if placed on the ground or block it under the flange and the metal top piece. Light bushings may be handled manually. Do not lift the bushing in the silicone insulator.

![Fig. 3. Lifting from the box.](image-url)
2.5 Mounting

**CAUTION**

Lift the bushing with the aid of a lifting tool, see section 2.1 Tools. Lift the bushing to vertical position and to an angle according to the figures below. Use a soft bedding under the bottom end of the bushing, e.g. a rubber mat.

The bushing is delivered with two eyebolts for lifting. The weight of the bushing is stated on the nameplate. Carefully clean and inspect the oil end of the bushing and the inside of the centre hole before mounting on the transformer.

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Fig. 4. Raising of bushing.

Fig. 5. Raising of bushing to a certain angle.
2.5.1 Connection to SF₆ side terminal
Dimensions on the SF₆ side terminal fully comply with IEC 62217-211 and include 4 threaded holes for GIS connection. The SF₆ side terminal is mounted at ABB factory and should not need any further adjustment. However, to reassure the fitting is correct also after transport and handling, we recommend to check that there is a distance of 2-3 mm between terminal and pulling ring.

Cleaning of the gas side of the bushing and connection to the outer terminal are made according to instructions given by the manufacturer of the switchgear. See also section 1.3 Mechanical loading.

Fig. 6. Mounted cables and end shield.

2.5.2 Disassembling of SF₆ side terminal
To disassemble the SF₆ side terminal, loose the four M12 screws on top of terminal. Then use two screw drivers in the slots (one on each side of terminal) and put two soft rags between screw drivers and shield to avoid damage on painting. Pull gently the terminal out as straight as possible to avoid scratches inside the tube.

Fig. 7. Mounting of SF₆ side terminal.

2.5.3 Mounting of SF₆ side terminal
Mounting of the terminal must be performed according to the procedure below. Contact and sealing surfaces must be clean and without damage.

In order to obtain low contact resistance and proper sealing function, the following procedure must be carried out:

1. Clean the contact surfaces carefully both on the end of the conductor tube and on the terminal.
2. Clean the sealing surface carefully on the inside of the conductor tube and check that there is no damage to the surface.
3. Adjust the distance between pulling ring and tube end to 2-3 mm.
4. Lubricate the O-ring with Mobilgrease 28.
5. Mount the terminal on the conductor tube by gently hammering with a soft club, not damaging the contact surface of the terminal.
6. Orient the threaded holes in the terminal to meet the GIS connection.
7. Mount the M12 screws and tighten them by steps and alternately to a final torque of 76 ± 4 Nm.
2.5.4 Fixed bottom contact
The oil side terminal consists of a bottom contact with 4 threaded holes for cable lugs. The fixed bottom contact is mounted at ABB factory and should need no further adjustment. However, to reassure the fitting is correct also after transport and handling, we recommend the following procedure:

1. Check that there is a distance of 7 ±0.5 mm between the washer on top of the bottom contact and the pulling ring, see Fig. 8.
2. Check that the tightening torque on the six bolts is 40 Nm.

2.5.5 Connecting cable lugs to bottom contact and mounting oil side shield
The connection of the cable lugs and mounting of the shield proceeds as follows:

1. Check the fixed bottom contact as stated in step 1-2 above.
2. Place the shield temporarily as shown in Fig. 9. Make sure to position the wider end of the shield towards the bushing.
3. If the fixed bottom contact system is used, lower the bushing and fasten it to the transformer.
4. Connect the cable lugs to the bottom contact. Tightening torque 68 ± 6 Nm.
5. Push the shield gently against the bushing flange. Apply force until the top position is reached.
6. Turn the shield clockwise approximately 20 degrees and then release the force.
7. Make sure that the end shield is in the locked position.
2.6 Draw rod system

Mounting of the draw rod must be performed according to the procedure below. The contact surfaces must be clean.

The draw rod parts on the oil side of the flange are usually assembled and connected to the winding at the transformer factory.

1. If the draw rod is supplied with an additional joint, e.g. to make it possible to remove a bushing turret for transport, the additional jointing sleeve shall be locked with locking fluid (Loctite 242 and activator Loctite T747) at site in order to avoid an unintended loosening of this joint at an eventual dismounting of the draw rod system later on. Fig. 14 shows the joints that are locked at delivery.

2. The cord, pulled through the bushing with the two washers, the nut, and the box spanner in place, as shown in Fig 13, is used for lowering of the upper part of the draw rod to the correct position for jointing with the threaded sleeve of the lower end part, Fig 12.

3. The bushing is then lowered into the transformer with the cord well stretched.

CAUTION

If fixed stud bolts are used for fastening of the bushing flange, it is recommended to apply plastic sleeves on 2 or 3 of the studs in order to guide the flange and prevent cutting of metal chips, which may fall down into the transformer.

4. Fix the bushing to the transformer cover.

5. The washer and the nut are fastened according to Fig. 15.

The threads and the nut are treated with lubricant at the factory. If the nut cannot be screwed on the bolt smoothly, carefully apply Molykote 1000 on the bolt. Remove excess of the Molykote with a rag.

Each bushing with draw rod is supplied with an information sheet about the measurement (b-a), which was measured at the factory, and the tightening force. If a bushing is non-standard, the value shall be according to this information. The torque is to be between 70 and 140 Nm.

Make sure that the right 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**

1. Tighten the nut with 10 Nm and measure the distance (a) from the top of the nut to the top of the bolt.
2. Continue tighten the nut until the difference between the first and second measurement (a-b) shall be according to the value given in table 4. Each turn corresponds to an extension of 2 mm.
3. Check with a dynamometric wrench that the nut is tightened with a torque of more than 70 Nm and less than 140 Nm.

**Tightening method B**

Use a jack to pull the draw rod bolt to a force according to the value given in Table 4. Tighten the nut by the hand and then release the jack.

<table>
<thead>
<tr>
<th>Bushing</th>
<th>Difference (b-a) (mm)</th>
<th>Force (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.3</td>
<td>0.6</td>
</tr>
<tr>
<td>GSBK</td>
<td>170</td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td>245</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>362</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>420</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>25.5</td>
</tr>
</tbody>
</table>

2.6.1 Assembly of draw rod parts at transformer factory

The draw rod is normally delivered assembled inside the bushing. Therefore the first step at transformer factory is to disassemble it. Start to disassemble the SF6 side terminal according to 2.5.x and then the M16 nut in top of the draw rod. The draw rod can now be pulled out of the bushing tube.

Perform the connections to winding and assembly of shield according to 2.5.5, step 2, and 4 to 7.

During transport to site, support the oil side parts of the draw rod in the transformer transport cover, Fig. 11.

2.6.2 Final assembly of draw rod
Supported in transformer cover during transport
Transformer tank
Draw rod, lower part
End shield
Bottom contact
Connection to the winding

Fig. 11.

Bushing lifted over the transformer
Upper draw rod, hanging in pull-through cord
Threaded sleeve for connection between upper and lower draw rod

Fig. 12.

Flexible pull-through cord
Box spanner
Hexagon nut M16
Washer
Draw rod

Fig. 13.
Locked with locking liquid 1269 0014-408 (upper thread)

Unlocked at delivery (lower thread)
2.7 Flange earthing
The bushing flange is provided with a tapped hole M12. 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.

Alternative 1
Insert a greased (Mobilgrease 28 recommended) pointed set screw M12 (stainless steel A4-80 preferrably). Tighten to 40 Nm, penetrating the paint of the transformer tank down to the metal underneath. This makes an electrical connection between the bushing and the transformer tank, keeping them at the same voltage.

Alternative 2
Apply a flexible cable between the M12 earthing hole in the bushing flange and a corresponding connection point in the transformer. Grease the screw (Mobilgrease 28 recommended) and tighten the M12 in the bushing to 40 Nm. Connect the other end of the cable to the transformer.

2.8 Waiting time before energizing

Some waiting time may be necessary before energizing, in order to avoid flashovers or partial discharges due to air bubbles at the bushing surface. Choose a suitable procedure below.

Vacuum filled transformer
No waiting time is necessary from the bushing point of view.

De-gassed oil-filled transformer
During mounting, use a clean and dry paintbrush to release surface bubbles. Wait 6 hours before energizing.

Gas-saturated oil-filled transformer
During mounting, use a clean and dry paintbrush to release surface bubbles. Wait 24 hours before energizing.

De-gassed oil filled transformer with reduced oil-level
After restoring the oil-level, wait 24 hours before energizing.

For all alternatives except vacuum filled transformer, oil will fill the centre tube enough without removing the terminal.

2.9 Recommended tests before energizing
The following tests may be performed to check the insulation, sealing and current path of the bushing. The tests should be made after mounting, but before connecting the SF$_6$ side terminal of the bushing to the rest of the gas-insulated substation power circuit.

1. Tightness test between transformer and bushing
2. Measurement of capacitance and tan $\delta$
3. Check of through resistance

2.9.1 Tightness test between transformer and bushing flange
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, perhaps easier, with paper strips.

2.9.2 Measurement of capacitance and tan $\delta$

CAUTION
Since $C_2$ usually is relatively small, the test tap must never be open-circuited when applying a voltage to the bushing. It shall always be earthed or connected to an external impedance. No connection may destroy the bushing.

When not measuring, always make sure that the cap nut is properly tightened with the gasket in place. This is to prevent dust and water from coming in to the test tap.

After mounting, a capacitance measurement is recommended. Connect a measuring bridge 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 to the bushing terminal.
The capacitances $C_1$, between the outer terminal and the test tap, and $C_2$, between the test tap and the flange, are marked on the marking plate. The nominal capacitances $C_1$ of the different bushing types are listed in Table 4. $C_2$ is highly dependent on the surrounding parts inside the transformer and it is not possible to give a nominal value valid for all service conditions.

Table 5. Nominal capacitances of $C_1$ in pF (Manufacturing tolerances ± 10%).

<table>
<thead>
<tr>
<th>Bushing</th>
<th>CT space = 300 mm</th>
<th>CT space = 600 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSBK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>496</td>
<td>656</td>
</tr>
<tr>
<td>245</td>
<td>500</td>
<td>622</td>
</tr>
<tr>
<td>362</td>
<td>405</td>
<td>494</td>
</tr>
<tr>
<td>420</td>
<td>346</td>
<td>424</td>
</tr>
<tr>
<td>550</td>
<td>286</td>
<td>353</td>
</tr>
</tbody>
</table>

2.9.3 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 and lead resistance and the bushing conductor and contact resistance. The additional resistance from the bushing conductor should not be more than $10 \ldots 100 \ \mu\Omega$. Since the through resistance of the HV winding of a typical power transformer is in the order of $0.1 \ldots 1 \ \Omega$, 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 a sensitive measurement across each connection point, or by measuring the temperature increase during operation with an infrared sensitive camera (thermovision).
3. Maintenance

The GSBK bushings are in principle maintenance free; no regular maintenance is needed.

**WARNING**

No work at all can be performed on the bushing while it is energized or not earthed.

3.1 Recommended maintenance and supervision

3.1.1 Measurement of capacitance and tan δ

Please refer to Chapter 2, Installation.

3.1.2 Check for leakage

Make a visual inspection for oil leakage between bushing and transformer flange during normal station supervision.

3.2 Disposal after end of service life

The GSBK is delivered in a transport box containing plywood, wood, steel profiles, desiccants, plastic film protection and foamed plastic cushioning.

The GSBK bushing consists of the following:

- Resin impregnated paper condenser core containing mainly epoxy, creped paper and an embedded conductor tube in aluminium or copper. The core also contains a smaller amount of aluminium foil inserts, rubber bonded cork, rubber sealings, braided copper wire (tinned), braided copper strap, silver glue and lead. By crushing the core, the conductor tube can be separated and sorted, while the rest of the core can be incinerated in a suitable oven.
- Removable flange in cast aluminium containing test tap, locking ring in aluminium, bolts in stainless steel and o-rings in rubber. Unscrew the locking ring and slide the flange off to separate it from the condenser core. O-rings fitted in the flange are easily removed. For test tap, see below.
- Removable test tap containing test tap body in epoxy, test tap cover in aluminium, cable and contacts in brass and rubber o-rings. These components can easily be separated except for the embedded brass center bolt of the test tap body. Crushing the test tap body can separate this bolt.
- On the voltage tap option the flange is filled with approximately 2 dl silicone gel. When flange is separated from the condenser core this gel can be scraped out and separated.
- Removable connection details on gas side containing pulling ring in stainless steel, terminal in silver plated aluminium, bolts in stainless steel, shield in epoxy painted aluminium and o-rings in rubber. These components can easily be separated.
- Removable connection details on oil side containing pulling ring in stainless steel, bottom contact in pure copper, bolts in stainless steel, shield in epoxy painted aluminium and o-rings in rubber. These components can easily be separated.