HVDC transformer bushing with oil side porcelain, type GOF for outdoor mounting
Installation and maintenance guide
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 safety conditions are headed by one of the three hazard intensity levels which are defined as follows:

**DANGER**
Immediate hazard which will result in severe personal injury, death, or property damage.

**WARNING**
Hazard or unsafe practice which could result in severe personal injury, death, or property damage.

**CAUTION:** Hazard or unsafe practice which could result in minor personal injury, or property damage.
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1 Description

1.1 Design

The design principle is shown in Figs. 1a-c.

The air insulator of the bushing is either cemented to a flange or mounted with clamps. A set of concentric tubes are pre-stressed and serve as a spring that holds the main bushing components together and provide adequate pressure on the gaskets at all expected temperature and load conditions. The outermost tube is made of aluminium or copper and is also used as the current conductor.

The leads from the transformer is bolted to a bottom contact made of copper. This contact is drawn against the bottom end of the bushing by means of a draw rod made of steel. The upper part of this rod is connected to a spring device designed so that a constant contact force is achieved at all expected temperatures.

The bushing can be mounted at 0-60° from the vertical plane.

GOF bushings have a voltage test tap, according to Fig. 2, which can be used for checking of the bushing insulation by capacitance and dissipation factor measurements in service. The test tap is earthed via the test tap cover. For continuous measuring, the test tap can be furnished with a terminal box according to Fig. 3.

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Fig. 1a. Design principle
1) Top end nut
2) Flexible connection
3) Top housing
4) Oil level gauge (complete with gasket and screws)
   a) Prism type, 2744 322-A
   b) Magnetic type, 2744 322-B
5) Porcelain insulator, air side
6) Pre-stressed tubes
7) Transformer oil
8) Condenser body
9) Clamp or cemented flange
10) Mounting flange
11) Extension for current transformers
12) Porcelain insulator, oil side
13) Bottom end nut
14) Sealing plug
   a) M8; 2522 731-A
   b) M16; 2522 731-B

Oil level, A, see section 3.1.5
1 Description

Fig. 1b. Sealing plug, 2522 731-A
1) Bolt with flange DIN 6921, 2121 738-18
2) Gasket, 2152 899-132

Fig. 1c. Sealing plug, 2522 731-B
1) Bolt, 2121 2033-592
2) Conical spring washer, 2154 725-7
3) Gasket, 2152 045-513

Fig. 2. Test tap, 2769 522-T, and test tap cover, 2769 522-M
1) Cover, 2749 515-2
2) Cylindrical head screw, 2121 2459-220
3) Earthing spring, 9580 148-1
4) Gasket (O-ring) 64.5 x 3
5) Sealing plug, 2522 731-A, for oil filling, when use of potential device. Remove 15% of the total oil volume before sealing.
6) Bushing, 2769 522-N
7) Press screw, 2129 713-3
8) Disc spring, 2195 703-1
9) Gasket (O-ring) 24.2 x 3
10) Cable
11) Stud, 2769 517-6
12) Sealing washer 4.5 x 7
13) Stud, 2769 517-7

Fig. 3. Terminal box for permanent connection to measuring circuits, 2769 522-C
The terminal box shall be equipped with a suitable over-voltage protection in order to prevent damages during service. The cable gland shall be oriented downwards in order to prevent water from penetrating the equipment.
1.2 Operating conditions

The table below show the standard technical specifications for the GOF Oil - Air bushings. For conditions exceeding the below values, please contact ABB.

**Common specifications:**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Transformers</td>
</tr>
<tr>
<td>Classification</td>
<td>Oil impregnated paper, capacitance graded, outdoor-immersed bushing</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>+40 to -40 °C, minimum value as per temperature class 2 of IEC 60137</td>
</tr>
<tr>
<td>Altitude of site</td>
<td>&lt; 1 000 m</td>
</tr>
<tr>
<td>Level of rain and humidity</td>
<td>1-2 mm rain/min horizontally and vertically, as per IEC 60060-1</td>
</tr>
<tr>
<td>Pollution level</td>
<td>According to specified creepage distance and IEC 60815 (&quot;Guide for the selection of insulators in respect of polluted conditions&quot;)</td>
</tr>
<tr>
<td>Type of immersion medium</td>
<td>Transformer oil. Maximum daily mean oil temperature 90 °C. Maximum temporary oil temperature 115 °C</td>
</tr>
<tr>
<td>Oil level in transformer</td>
<td>Not lower than 30 mm from the bushing flange.</td>
</tr>
<tr>
<td>Max. pressure of surrounding medium</td>
<td>100 kPa overpressure</td>
</tr>
<tr>
<td>Markings</td>
<td>Conforming to IEC/IEEE</td>
</tr>
</tbody>
</table>

1.3 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 (Figs. 1-3, 14-17, 21 and 25), which may be damaged or lost during transport or installation, can be ordered from ABB.
2 Installation

2.1 Tools

- Soft slings
- Lifting gear, 9760 667-A, see Fig. 4, or 9760 668-A, see Fig. 5.
- Shackles, for hole Ø 28 mm, for connection of soft slings to the bushing flange
- Torque wrench key for hexagon head screws, head width 16 mm (M10) and 13 mm (M8)
- Tackle for mounting the bushing at a certain angle
- Soft bedding
- Flexible pull-through cord, 9760 669-A, for assembly of draw rod, see Fig. 6.
- Box spanner, 9760 669-B, for assembly of draw rod, see Fig. 7.
- Jack (12 tons) with accessories (Manometer class 2,5), 9769 897-A

![Diagram of lifting gear](image)

*Fig. 4. Lifting gear, 9760 667-A. Mass: 14 kg. For bushings max. 2000 kg (4400 lb).*
2 Installation

Fig. 5. Lifting gear, 9760 668-A. Mass: 12.5 kg. For bushings max. 3000 kg (6600 lb).

Fig. 6. Flexible pull-through cord, 9760 669-A.

Fig. 7. Box spanner, 9760 669-B.

2.2 Consumables

- Water free vaseline, Mobilgrease 28 or other 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 and sealing at the outer terminal.
2.3 Transport and handling

CAUTION: The bushing may be transported and stored horizontally up to 6 months. For storing over 6 months it is recommended to raise the bushing to vertical position with the top end upwards or inclined position with the top end upwards and at an angle of at least 7°. Keep the bushings dry and clean and protected against mechanical damage.

![Fig. 8. Long-term storage.](image)

"Top End"

Min. 7°

Keep the bushings protected from penetrating water when stored outdoors. This means that the case must not be stored in areas where it can be foreseen that the ground will be wet and muddy during heavy rains. Shelter the case from rain and snow with a tarpaulin or roofing.

Carefully inspect the bushing on receiving with regard to shipping damage. Please note that the bushing has been routine tested partly submerged in oil and some oil may be left. Vaseline is used for lubrication of threads, and at some temperatures the vaseline may appear as oil.

The bushings are normally delivered from ABB in boxes with the bushing supported by cellular plastic blocks and fibre boards. The boxes are marked with "Top End".

2.4 Lifting from the box

WARNING

For lifting the bushing from the box, apply two clean lifting slings as shown in the figure below. Slings shall not be applied around the air side insulator because the sheds may be damaged. If placed on the ground, the bushing shall be supported at the same points as in the box or blocked under the top housing and the fixing flange. It may not be supported by the porcelain sheds.

![Fig. 9. Lifting from the box.](image)
2.5 Mounting

**WARNING**

A soft bedding must be used under the bottom end of the bushing, e.g. a rubber mat or a wood board.

The mass of the bushing is stated on the nameplate. Bushings with the total mass equal to or smaller than 2000 kg may be lifted to the vertical position according to Fig. 10. Heavier bushings shall be lifted to the vertical position according to Fig. 11.

For lifting to a certain angle, the lifting gear shall be arranged according to Fig. 12.

If a lifting device for application at the top end of the bushing is not available, it is permitted to lifting bushings (BIL ≤ 900 kV) by applying a lifting sling around the insulator just below the top housing, provided that it is applied in such a manner that it does not damage the porcelain sheds. The centre hole in the bushing conductor and the oil end below the mounting flange shall be carefully cleaned and inspected before mounting on the transformer. A cord or a flexible wire with an M8 swivel (Fig. 6) is pulled through the centre hole and the top connection details according to Fig. 21 for draw rod system. The bushing is now ready to be lifted on to the transformer.

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**Fig. 10.** For vertical mounting.  
Bushings max. 2000 kg (4400 lb)

**Fig. 11.** For vertical mounting.  
Bushings max. 3000 kg (6600 lb)
Fig. 12. Mounting at a certain angle.
When a bushing has to be mounted at an angle, it should be installed with oil level gauges of prism type oriented sideways and with magnetic oil level gauge oriented downwards, in the leaning direction, according to Fig. 13.

*Fig. 13. Orientation of oil level gauges on bushings that are installed leaning from vertical.*
2.6 Connection to bottom contact and mounting of shield

If an end shield is ordered, it can be mounted in different ways depending on bottom contact (N1=4 or 6). The shield and the mounting details are packed in a plywood box.

2.6.1 Small bottom contact with 4 threaded holes (N1=4) for cable lugs

1. Mount the guiding sleeves, the springs, the pressing rings and the socket screws on the bottom end of the bushing.

   The function of the guiding sleeves is to permit the end shield to be mounted exactly 17 mm from the tapped holes (M10) and to permit the pressing ring and the spring to move along the socket screws.

2. Place the shield temporarily as shown in Fig. 14.

3. Lower the bushing and fasten it to the transformer.

4. Connect the cable lugs to the bottom contact. Tightening torque 68 ± 6 Nm.

   **CAUTION:** It is extremely important that the cables do not provide any tension and thus do not apply any extra force to the bottom contact.

5. Push the shield to the bottom end nut of the bushing.

6. Press the springs together.

7. Guide the socket screws through the key holes in the shield.

8. Turn the shield back somewhat to check that the heads of the screws are in the locking position, see Fig. 15.

9. Turn the shield to stop (approx. 20°). Let the springs press the shield down.
2.6.2 Large bottom contact with 6 threaded holes (N1=6) for cable lugs

2.6.2.1 Mounting of shield on the bottom end nut of the bushing

1. Connect the cable lugs to the bottom contact. Tightening torque 68 ± 6 Nm.

**CAUTION:** It is extremely important that the cables do not provide any tension and thus do not apply any extra force to the bottom contact.

2. Mount the guiding sleeves, the springs, the pressing rings and the socket screws on the bottom end of the bushing.

   The function of the guiding sleeves is to permit the end shield to be mounted exactly 17 mm from the tapped holes (M10) and to permit the pressing ring and the spring to move along the socket screws.

3. Push the shield to the bottom end nut of the bushing.
4. Guide the socket screws through the key holes in the shield.
5. Press the springs together.
6. Turn the shield to stop (approx. 20°). Let the springs press the shield down.
7. Try to turn the shield back somewhat to check that the heads of the screws are in the locking position, see Fig. 17.
8. Lower the bushing and fasten it to the transformer.

![Fig. 16. Connecting to bottom contact.](goek_023)

![Fig. 17. Mounting of shield.](goek_017)

1) Bottom end of bushing  
2) Spring, 2129 2011-488  
3) Guiding sleeve, 12/10 x 17  
4) Pressing ring  
5) Socket screw, M10 x 25  
6) Cable lugs  
7) Shield  
8) Connections to the winding  
9) Shielding tube  
10) Bottom contact with holes M12, thread insert with locking turn
2.6.2.2 Mounting of shield on the bottom contact

1. Connect the cable lugs to the bottom contact. Tightening torque 68 ± 6 Nm.

**CAUTION:** *It is extremely important that the cables do not provide any tension and thus do not apply any extra force to the bottom contact.*

2. Mount the guiding sleeves, the springs, the pressing rings and the socket screws on the bottom contact.

   The function of the guiding sleeves is to permit the shield to be mounted exactly 17 mm from the tapped holes (M10) and to permit the pressing ring and the spring to move along the socket screws.

3. Push the shield on the bottom contact.

4. Guide the socket screws through the key holes in the shield.

5. Press the springs together.

6. Turn the shield to stop (approx. 20°). Let the springs press the shield up.

7. Turn the shield back somewhat to check that the heads of the screws are in the locking position, see Fig. 19.

8. Lower the bushing and fasten it to the transformer.

---

**Fig. 18. Connecting to bottom contact.**

1) Bottom contact  
2) Spring, 2129 2011-488  
3) Guiding sleeve, 12/10 x 17  
4) Pressing ring  
5) Socket screw, M10 x 25

**Fig. 19. Mounting of shield.**

6) Cable lugs  
7) Shield  
8) Connections to the winding  
9) Shielding tube  
10) Bottom contact with holes M12, thread insert with locking turn
2.7 Draw rod

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

Observe that the shield, if mounted on the bottom contact, shall be mounted according to Fig. 19. Mounting on the opposite side will result in high field stresses and risk of major failure.

The parts below the transformer cover are usually supported in the transport cover as shown in Fig. 20. At erection the smaller cover shall be opened first and the support for the connection parts loosened. The bigger transport cover is then removed.

1. As shown in Fig. 21, the compensating device is placed on top of the bushing inner tube. The end of this tube is always at the same distance from the bottom parts regardless of the tolerances of the outer insulator.

2. 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. 22 shows how the joints are locked by delivery.

3. The cord, pulled through the bushing with the compensating device (7), the washer (4), the nut (3), and the box spanner (2) in place, is used for lowering of the upper part of the draw rod to the correct position for jointing with the threaded sleeve to the lower end part.

4. 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.

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![Fig. 20. Example of suspension for inner terminals for draw rod during transport](image)

1) Smaller cover
2) Transport cover
3) Transformer cover
4) Draw rod
5) Spacer tube
6) Shield
7) Bottom contact
8) Connection to the winding
2 Installation

Fig. 21. Assembly of draw rod system
1) Flexible pull-through cord acc. to Fig. 6
2) Box spanner acc. to Fig. 7
3) Hexagon nut M16
4) Washer 17 x 45 x 3
5) Extension acc. to Fig. 6
6) Draw rod
7) Compensating device
8) Lifting gear acc. to Fig. 4
9) Hexagon head screw M10 x 50
10) Jointing sleeve, 2126 739-3
11) Washer, 2151 811-14
12) Conical spring washer 17 x 39 x 4 (Belleville spring)

Fig. 21b
Mount according to section "Draw rod"

Fig. 21c
5 washers
2 washers

Fig. 21d (Earlier design)

Depending on the length of the draw rod, one or two extra joints are sometimes needed. They are always locked in both parts with locking liquid 1269 0014-408 (Loctite 270).

Locked with locking liquid 1269 0014-408 (Loctite 270).

Unlocked at delivery.

Joint at flange level.

Locked with locking liquid 1269 0014-408 (Loctite 270).

Unlocked at delivery.

Additional joint upon request.

Fig. 22. Locking of draw rod.
5. Fix the bushing to the transformer cover. Ensure to tighten the bolts evenly cross-wise in order to avoid damages to the flange.

6. The washer and the nut are fastened according to Fig. 21b. Some smaller bushing sizes, which do not have the compensating device on the draw rod, are mounted according to Fig. 21c. Note that the belleville washers shall be placed as shown in the figures in order to function correctly.

The threads and the nut are treated with lubricant at delivery. If the nut can not 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. The torque is to be between 70 and 140 Nm.

**CAUTION:** To make sure that the right force is achieved in the draw rod the tightening of the nut shall be done according to the following procedure:

**A. Washer according to Fig. 21b and mounting according to Fig. 23.**

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) Tighten the nut and measure the distance (b).

3) Continue to tighten the nut until the difference between the second and the first measurement, (b-a) = the extension, is according to the value given in the information sheet. Each turn corresponds to an extension of 2 mm. To reach the requested extension, the tightening torque shall be between 70 and 140 Nm. Check with a dynamometric wrench.

**B. Conical spring washers according to Fig. 21c and mounting according to Fig. 24.**

1. Tighten the nut with a torque of 140 Nm.

2. Slack off the nut to 10 Nm and measure the distance (a) from the top of the nut to the top of the bolt, according to Fig. 24.

3. Tighten the nut and measure the distance (b).

4. Continue to tighten the nut until the difference between the second and the first measurement, (b-a) = the extension, is according to the value given in the information sheet. Each turn corresponds to an extension of 2 mm. To reach the requested extension, the tightening torque shall be between 70 and 140 Nm. Check with a dynamometric wrench.
C. Mounting fo draw rod using a jack according to Fig. 25.

1. Tighten the nut with a torque of 10 Nm.

2. Measure the distance from the top of the nut to the top of the bolt. If the free thread above the nut is less than 10 mm, tighten the nut with a wrench until the distance "a" is at least 10 mm.

3. The draw rod shall be pre-stressed with a jack.

4. Stress the draw rod with a force $F = 45$ kN and tighten the nut by hand.

5. Release and remove the jack.
2.8 Mounting of outer terminal

**CAUTION:** Before connection of conductor clamps, the outer terminals of aluminium must be carefully wire brushed and greased with a contact compound or vaseline. The inner contact surface on aluminium outer terminals are tin-zink plated, and wire brushing must thus not be carried out.

In order to obtain the correct pressure and a low contact resistance, the following must be carried out:

1. Clean the contact and gasket surfaces carefully.
2. Lubricate the O-ring with Mobilgrease 28.
3. Assemble the retainer ring, the O-ring, and the outer terminal stud and push them over the inner terminal. An extra O-ring intended for final installation is delivered with the bushing.
4. Grease all bolts on thread and underneath the head with Molykote 1000, or other suitable compound.
5. Insert and tighten the screws M10, with plane washer, which press the stud against the inner terminal. Tighten evenly crosswise to a final torque of 40 ±4 Nm.
6. Insert the M8 screws, with conical spring washer, which hold the tightening ring. Tighten them to press the gasket into place. Tighten evenly crosswise to a final torque of 20 ±2 Nm.

**CAUTION:** It is extremely important in both cases to tighten evenly. The bolts shall thus be tightened in steps, alternately on both sides.

**Fig. 26. Mounting of outer terminal**

1) Terminal stud  
2) Hexagon screw  
   GOE: M8 x 40  
   GOE(2): M8 x 30  
3) Hexagon screw M10 x 60  
4) Conical spring washer 8.4 x 18 x 1 (Belleville)  
5) Washer 10.5 x 22 x 2  
6) Gasket (O-ring)  
   GOE: 99.1 x 5.7  
   GOE(2): 59.2 x 5.7  
7) Retainer ring for gasket  
8) Top end of bushing
2.9 Flange earthing

**WARNING**

*Proper earthing is essential.*

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 under normal service conditions.

**Alternative 1**

Insert a heavily greased (Mobilgrease 28 recommended) pointed set screw M12 (stainless steel A4-80 preferably). 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.

2.10 Waiting time before energizing

**CAUTION:** When a bushing has been stored horizontally, it must be raised with the top up for at least 12 hours before service voltage is applied and 24 hours before test voltage is applied. If, by mistake, the bushing has been stored horizontally more than one year, it must be placed in the vertical position for at least one week before energizing. Some waiting time may be necessary before energizing in order to avoid flashovers or partial discharges due to airbubbles 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, the oil should be allowed to enter the centre tube to at least flange height by releasing the outer terminal sealing system and allowing air to escape this way.
2.11 **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 outer terminal of the bushing to the rest of the switchyard power circuit.

1. Tightness test between transformer and bushing flange.
2. Tightness test of bushing outer terminal.
4. Check of through-resistance.

2.11.1 **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.

2.11.2 **Tightness test of bushing outer terminal**

Since the top terminal is often situated above the oil level of the transformer expansion system, a leak at this point is extremely serious, because water could enter directly into the transformer insulation this way. It is thus recommended to make a tightness test after assembly, preferably both with vacuum and over-pressure. Several different methods may be used and we refer to instructions given by the firm responsible for the field erection.

One possible method is the tracer gas method:

1. Put a tracer gas into the centre tube before mounting the outer terminal. The oil level of the transformer must be above the bottom end of the bushing but below the bushing flange.
2. Increase the pressure in the center tube by increasing the oil level as much as possible.
3. Search with a gas detector (sniffer) for leaking gas at the gasket.
2.12.3 Measurement of capacitance and tan δ

**WARNING**
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-energised 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 capacitances $C_1$ between the bushing conductor and the tap, and the capacitance $C_2$, between the test tap and earth are marked on the nameplate. $C_2$ 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.

The dissipation factor varies with the temperature of the bushing body and the measured value should thus be multiplied with the correction factor (multiplier) given below.

*Table 1. Dissipation factor variations as a function of temperature.*

<table>
<thead>
<tr>
<th>Bushing body temperature °C</th>
<th>Multiplier to 20 °C (IEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-7</td>
<td>0.85</td>
</tr>
<tr>
<td>8-12</td>
<td>0.90</td>
</tr>
<tr>
<td>13-17</td>
<td>0.95</td>
</tr>
<tr>
<td>18-22</td>
<td>1.00</td>
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<tr>
<td>23-27</td>
<td>1.05</td>
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<td>28-32</td>
<td>1.10</td>
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<td>33-37</td>
<td>1.15</td>
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<td>38-42</td>
<td>1.20</td>
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<td>43-47</td>
<td>1.25</td>
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<td>48-52</td>
<td>1.30</td>
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</table>
2.12.4 Check of through resistance

This method can be used to detect very large faults in the current path, such as disruptions, and is not a tool for diagnostic of the bushing.

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 150 $\mu\Omega$. Since the through resistance of the HV winding of a typical power transformer is in the order of 0.1 ..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 GOF bushings are maintenance-free. For bushings with oil-level indicator, it is recommended to note the oil level during normal routine inspections in the plant.

**DANGER**

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

3.1 Recommended maintenance and supervision

1. Cleaning of insulator surface
2. Measurement of capacitance and $\tan \delta$
3. Thermovision (infrared camera) check for local overheating on connectors
4. Check for leakage
5. Checking and adjustment of the oil level

3.1.1 Cleaning of insulator surface

*CAUTION:* Avoid having solvent on the bushing gasket and porcelain joints.

Under conditions of extreme pollution it may be necessary to clean the porcelain insulator surface. This should be done by water-jet or by wiping with a moist cloth. If necessary, ethyl-alcohol or ethyl-acetate may be used.

3.1.2 Measurement of capacitance and $\tan \delta$

Please refer to Chapter 2 Installation.

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

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

Make a visual inspection for oil leakage during normal station supervision.

3.1.5 Checking and adjustment of the oil level

For bushings with two oil level glasses, the oil level at 20 °C is to be between the two glasses. Bushings with magnetic oil level indication have the indication arranged to show that the oil level does not reach the minimum level. The oil level at normal and high temperatures should always be above the red area on the indicator. If the oil level is too low, clean and dry transformer oil must be added. For the correct oil level A, according to Fig. 1a, please contact ABB. Adjustment of oil level is allowed only when the temperature of the bushing is +5 °C to +35 °C. It is recommended that the sealing plug be provided with a new gasket after the check. The sealing plug is to be tightened with 20 Nm.

**CAUTION:** Normally we do not recommend taking oil samples or opening our bushings. The bushing is sealed and tightness tested at the time of manufacturing. An oil sampling means that the bushing has to be opened. Thus, there is also a risk of improper sealing after the sampling is finished. However, when a problem is known, for example high power factor over C, or visible leakage, there might be a need for oil sampling and gas analysis or oil level check. In this case, ask for product information 2750 515-142 "Bushing diagnostics and conditioning".

![Fig. 27. Checking of the oil level.](image)
3.2 Disposal after end of service life

The bushing consists of the following material:

- Conductor tube of copper or low-alloy aluminium.
- Terminals of copper, brass or low-alloy aluminium may be plated with for instance silver, tin, gold or nickel in layer thickness up to 20 µm.
- Transformer oil as per IEC 60296.
- Transformer oil impregnated condenser body consists of paper and 1 % Al foils.
- Top housing, top end nut, test tap and flexible connection consist of Al alloys.
- Flange may be designed of aluminium or welded steel.
- Press ring for oil level glass consists of plated brass.
- Prism glass consists of glass.
- Insulators consist of quartz or alumino silicate based porcelain.
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