HVDC transformer bushing, type GGF
Installation and maintenance guide

Applicable for bushings:
- LF 141 001-E, GGF 1950
- LF 141 001-H, GGF 1550
- LF 141 001-M, GGF 1675
- LF 141 001-F, GGF 1675
- LF 141 001-K, GGF 823-1050
- LF 141 001-N, GGF 1675
- LF 141 001-G, GGF 1950
- LF 141 001-L, GGF 1675
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 safety conditions are headed by one of the three hazard intensity levels which are defined as follows:

**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 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.
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1. Description

1.1 Design
The dimensions of bushing type GGF are given in the project specific dimension drawings. The design principle is shown in Fig. 1.

The GGF bushing is designed in two parts, one inner part and one outer part.

The inner part is built as a normal oil insulated bushing with an oil insulated condenser core. The bushing has no insulator on the oil side, which means that the bushing is connected to, and sharing the transformer oil system. The installation is similar to the GOF type of bushings and it has the same type of draw rod connection. The inner part of the bushing has to be completely oil filled. The oil conservator of the transformer shall be placed so that the oil level in the conservator always is above the top end of the bushing.

The outerinsulator, a glass fibre reinforced epoxy tube with silicone sheds, has to be properly filled with pressurized SF$_6$ gas before energizing.

The GGF bushing is equipped with a tap in the mounting flange, connected to the outer layer of the condenser core. The maximum test voltage for this tap is 20 kV, one minute at 50 or 60 Hz. It serves as a test tap, and in connection with an external impedance, it can be used as a voltage tap. The operation voltage is limited to 6 kV. The tap has dimensions according to IEEE, Potential tap type A, see Fig. 2a. For continuous measuring it can be furnished with a terminal box according to Fig. 2b.

![Fig. 1. Bushing design.](image-url)
The voltage tap must always be earthed or connected to an impedance.

The voltage tap is shown in Fig. 2a.

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. Bushing, 2769 522-N
6. Press screw, 2129 713-3
7. Disc spring, 2195 703-1
8. Gasket (O-ring), 24.2 x 3
9. Cable
10. Stud, 2769 517-6
11. Stud, 2769 517-7
12. Sealing washer, 4.5 x 7
13. Stud, 2769 517-7

1) Locking liquid 1269 0014-410 (Loctite 242)

Fig. 2a. Test tap, 2769 522-T, and test tap cover, 2769 522-M. The test tap cover automatically connects the tap to earth by the earthing spring.

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.

The cover does not function as an earthing device in this configuration.

Fig. 2b. Terminal box for permanent connection to measuring circuits, 2769 522-C.
### 1.2 Operating conditions

The table below shows the standard technical specifications for the GGF HVDC bushing. For conditions exceeding the values below, please contact ABB.

**Common specifications:**

<table>
<thead>
<tr>
<th>Application</th>
<th>Converter transformers and DC smoothing reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification</td>
<td>Inner part: Oil impregnated paper, capacitance graded completely oil immersed bushing</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>0 to +60 °C for use in valve halls</td>
</tr>
<tr>
<td>Altitude of site</td>
<td>&lt; 1.000 m</td>
</tr>
<tr>
<td>Type of immersion medium, inner part</td>
<td>Transformer oil. Maximum daily mean oil temperature is current dependent and project specific.</td>
</tr>
<tr>
<td>Type of immersion medium, outer part</td>
<td>SF₆ gas at 2.7 bar gauge at 20°C</td>
</tr>
<tr>
<td>Oil level below top housing of the inner insulator</td>
<td>Completely oil filled</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>

#### 1.2.1 Comments on denominations of gas pressure

This document makes use of two methods to state gas pressure, and these methods are introduced and described below:

**Pressure gauge**

Pressure gauge is atmospheric pressure, which may be approximated to 100 kPa at sea level. Most common gas pressure gauges are calibrated to show overpressure, that is the pressure of the enclosed gas volume that exceeds the surrounding atmospheric pressure. Such pressure is stated as "kPa overpressure" or "kPa gauge". A pressure gauge with this presentation reads "0 kPa" when not connected to the gas valve.

**Absolute pressure**

Absolute pressure is any pressure above absolute zero, a theoretical condition that would occur in empty space. Pressure values used in vacuum technology are absolute pressure, not gauge pressure. When filling a gas insulated bushing for the first time at the ABB assembly line, the air is evacuated to a low level prior to adding SF₆. For simplicity, we may approximate the low pressure level as vacuum. The pressure after filling may then be stated as absolute pressure, a pressure level above the vacuum condition. A pressure gauge calibrated in "pressure absolute" would show a pressure of 100 kPa, or 1 bar, when not connected to the gas valve. The density guards supplied with the bushings are calibrated in "absolute pressure".

**Summary**

The discussion above explains that the nominal SF₆ pressure for the bushing at 20 °C is 270 kPa gauge, which is the same as 370 kPa absolute.

$$270 \text{ kPa gauge} = 370 \text{ kPa absolute}$$

### 1.3 Mechanical loading

The bushing is designed for the following cantilever load applied to the midpoint of the top end terminal perpendicularly to the bushing axis. The bushing mounting angle can be from 0° to 75° from vertical.

In axial direction, the GGF bushings can be loaded with 3.6 kN continuously.

The bushing can withstand 250 Nm torque on the outer terminal.

**Table 1. Mechanical loading perpendicular to the bushing axis.**

<table>
<thead>
<tr>
<th>Bushing</th>
<th>Type test load 1 minute</th>
<th>Max. service load</th>
</tr>
</thead>
<tbody>
<tr>
<td>LF 141 001-E</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.0 kN</td>
</tr>
<tr>
<td>LF 141 001-F</td>
<td>5 kN</td>
<td>1.5 kN</td>
</tr>
<tr>
<td>LF 141 001-G</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.0 kN</td>
</tr>
<tr>
<td>LF 141 001-H</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.5 kN</td>
</tr>
<tr>
<td>LF 141 001-K</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.5 kN</td>
</tr>
<tr>
<td>LF 141 001-L</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.5 kN</td>
</tr>
<tr>
<td>LF 141 001-M</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.5 kN</td>
</tr>
<tr>
<td>LF 141 001-N</td>
<td>&gt; 5 kN ¹⁾</td>
<td>1.5 kN</td>
</tr>
</tbody>
</table>

¹⁾ 3.15 kN + load contribution approx. 4 kN from weight of bushing.
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 transportation or installation, can be ordered from ABB.

1.5 Description of the sealing system
For bushings installed indoors in transformer turrets going through the valve hall wall, a sealing system is provided to prevent oil from flowing out from the transformer into the valve hall. The sealing system is installed into the space between a housing, connected to the intermediate flange, and the condenser core. Pressure valves are mounted through the sealing gaskets. The valve that allows oil from the transformer to flow into the bushing remains closed in case of damage to the insulators. Rapid changes in temperature cause the valves to open in the following manner:

As the oil conservator of the transformer is exposed to open air via a silica gel breather, large increase of pressure in the transformer tank due to temperature differences is not possible.

1. The temperature rise in the air side of the bushing increases until it reaches a pre-set value. Valve 2 opens and oil flows from the bushing into the transformer. The direction of the oil flow is shown by the arrows in Fig. 3.

2. The temperature goes down in the air side of the bushing. The pressure in the air side of the bushing decreases until it reaches a pre-set value. Valve 1 opens and oil flows from the transformer into the bushing.

3. The air side conical insulator as well as the outer insulator are both damaged. The valves remain closed and no oil can flow from the transformer into the valve hall. The oil volume enclosed in the air side of the bushing is about 108 litres.

Fig. 3. Sealing system.
2. Installation

2.1 Tools
- Soft slings
- Pull-through cord with M8 swivel 9760 669-A, see Fig. 4b
- Lifting gear, 9760 667-A, see Fig. 4a
- Jack (12 tons) with accessories (Manometer class 2.5) 9769 897-A, shown in Fig. 8
- Box spanner 9760 699-B, see Fig. 4c

Fig. 4a. Lifting gear, 9760 667-A. (Mass 14 kg)

Fig. 4b. Flexible pull-through cord, 9760 669-A.

Fig. 4c. Box spanner, 9760 669-B.
2.2 Consumables
- Mobilgrease 28 to protect the bottom flange O-ring
- Molykote 1000 or other suitable compound to lubricate the screws
- Loctite 242
- Activator T747

2.3 Transport, storage and handling

The bushing may be transported and stored horizontally up to 6 months. For long term storage exceeding 6 months, the bushing should be stored with the transport vessel tilted upwards about 5°. 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. If possible, store the bushing in its transport crate to keep it protected.

Carefully inspect the bushing on receiving with regard to shipping damage.

The bushing is supplied with the gas volume filled with N₂ gas 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”.

2.4 Lifting from the box

CAUTION

For lifting of the bushing from the box, apply two clean lifting slings as shown in Fig. 5. Slings shall not be applied around the insulator as the silicon sheds may be damaged. When placed on the ground, it shall be blocked under the mounting flange and top cover. It may not be supported by the silicone sheds.

![Fig. 5. Lifting the bushing from the box.](image)
2.5 Mounting

The bushing is delivered as a complete unit.

1. The bushing has a housing on the oil side that encloses the clamping device. The housing also contains the sealing system as described in section 1.5. Inside this housing and inside the inner insulator, there is oil left when the bushing is lifted out from the transport container. This oil quantity, approx. 108 litres, shall be drained before mounting in the transformer.

Regarding the shield system of the transformer, see the installation guide for the transformer.

When the bushing is placed on the ground, the oil has to be drained from the bushing. To fully drain the bushing:

- Connect a hose through the drain hole in the transport container (max. diameter 30), so that the oil can be pumped out from the transport container.
- From horizontal position, lower the top end so that the top cover is leaning slightly downwards, and one oil valve is facing straight down.
- Open the oil valves on the flange and empty the bushing from oil.
- When the oil flow stops, lift the bushing to horizontal position to completely drain it.

Always use clean and undamaged hoses.

2. Dismount the transport container.
3. Remove the outer terminal acc. to section 2.6 Mounting of outer terminal. Place the box spanner over the flexible pull through lead after which the lead is connected to the upper part of the draw rod. Insert the draw rod in the bushing centre tube. Apply the lifting gear, shown in Fig. 4a, on the top end fitting and mount slings or a tackle in order to get the right mounting angle. Arrange the bushing into the correct mounting angle, as illustrated in Fig. 6.
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.

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

The lower part of the draw rod, that shall be mounted in the bushing turret, is usually mounted inside the transformer and is held during transportation by a special bracket in the transport cover. Before mounting of the bushing, this cover shall be opened and the bracket loosened after which the bracket and the cover are removed.

Lower the draw rod so that the connection of upper and lower parts can be done. Mount the draw rod. Clean the threads in the rods and lock the joint with locking fluid (Loctite) and activator Loctite T 747. When the draw rod is assembled, insert the bushing in the transformer. Approx. 120 mm before the final position, the guiding cone at the bottom contact enters the bushing tube.

Be careful so that the connection in the transformer is not damaged.

Instructions for assembling the shielding system of the transformer is given in the installation guide for the transformer.

5. After bolting the bushing to the transformer, mount the draw rod according to the description on the next page.

The threads and the nut shall be lightly oiled before assembly. Try the nut on the rod to be sure that it can be threaded easily.

Connect the jack and apply a tensile force of 40 kN. Tighten the nut by hand with the box spanner. Release and remove the jack.

Fig. 7. Bushing before mounting into the transformer.
Flexible pull-through lead, 9750 669-A
Hexagon nut M16
Box spanner, 9760 669-B
Conical washer 17x39x4
Washer 17x45x3
Washer of insulating material 16x76x3
Draw rod, upper part

Draw rod, lower part
Guide cone

Bottom contact
Clean the threads from oil and lock the joint with Loctite 242 and activator T 747.

Fig. 8.
Jack (12 tons) with accessories (Manometer class 2.5), 9769 897-A
The applied tensile force on the draw rod with the jack shall be 40 kN. Tighten the nut just by hand with the box spanner. Release and remove the the jack.
Note that the sealing plug, as shown in Fig. 10, shall be mounted.

Fig. 9. Mounting of draw rod.
2.6 Mounting of outer terminal

First mount the sealing plug LF 170 049-B according Fig. 10.

Before connection of the conductor clamps to the outdoor side of the bushing, the outer terminal made of aluminium or copper must be carefully brushed and greased with a contact compound or vaseline. The inner contact surface on aluminium outer terminals and the contact surface on the bushing cap are tin-zink plated, and wire brushing must thus not be carried out.

Fig. 10 shows a standard current connection.

In order to obtain the correct contact 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 tightening ring, the O-ring and the outer terminal stud and push them over the inner terminal.
4. Grease all bolts on the thread and underneath the head with Molykote 1000, or other suitable compound.
5. Insert and tighten the M10 screws with plane washers, which press the stud against the inner terminal. Tighten stepwise to a final torque of 40±4 Nm.
6. Insert the M8 screws with conical spring washers and plane washers, which hold the tightening ring. Tighten them to press the gasket into place. Tighten cross-wise to a final torque of 20±2 Nm.

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

Fig. 10. Mounting of outer terminal.
2.7 Flange earthing
The bushing flange is provided with a tapped hole M12. After tightening the bolts fixing the bushing to the bushing turret, the flange should be earthed. This prevents electrical discharges between bushing flange and transformer turret 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 bushing turret 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.

Fig. 11. Tapped hole M12 for flange earthing.
2.8 Pressure gauge and density monitor

The pressure gauge is normally supplied separately from the bushing and is fitted as follows: Unscrew the protective cap from the valve. Check that the valve and the pressure gauge orifice are clean. Introduce the pressure gauge orifice into the valve and screw down the clamping nut. Torque at 20 Nm.

The fitting sequence for the density monitor is the same as for the pressure gauge, but add the following: Connect signal cables to the terminals of the relays.

The gas density is monitored by a density guard, which activates a switching relay for each of the three alarm levels. The circuit diagram shows the position of the switches when the gas pressure is nominal for operation, and above all three alarm levels. Pressure levels are given as absolute pressure.

Alarm level 1 (350 kPa): Switch number D1 is activated, circuit 11-13 is opened and 11-12 is closed.

Alarm level 2 (330 kPa): Switch number D2 is activated, circuit 21-23 is opened and 21-22 is closed.

Alarm level 3 (310 kPa): Switch number D3 is activated, circuit 31-33 is opened and 31-32 is closed. At gas densities below 310 kPa the type test levels for dielectric strength do not apply. The ability of the bushing to conduct current and withstand voltage declines progressively with falling gas density.

Fig. 12 shows the circuit diagram for the connections to the density monitor.

Fig. 12. Terminal marking and circuit diagram for density guard.
2.9 Oil filling

Before oil filling of bushings and transformer, connect a hose between one of the oil filling valves on the mounting flange (small valves with handles) and the vacuum equipment. In order to assure proper vacuum on both sides of the sealing gaskets, a vacuum hose also has to be connected to the transformer turret. When both the transformer and the bushings are at vacuum, the bushings will be filled with oil from the transformer, through the pressure valves mounted in the flange extension.

The minimum oil level \( h \) is calculated according to

\[
h = 3590 \times \sin \alpha,
\]

where \( \alpha \) is the mounting angle of the bushing. \( h \) is measured from the top side of the mounting flange.

**Example:**
The mounting angle is 20º. \( h = 3590 \times \sin 20º = 1230 \text{ mm} \)

---

**Fig. 13. Oil filling.**
2.10 Gas filling

The purpose of the compressed SF₆ 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 N₂ gas at a transport pressure of 25 kPa (gauge). The SF₆ filling procedure starts with evacuating all of the N₂ gas to a vacuum of 20 Pa. The SF₆ nominal filling pressure at 20 °C is 370 kPa absolute (270 kPa gauge).

For filling gas at other temperatures, Table 2 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 bursting disc, mounted on the flange. The disc is mounted under a protective cover and is indicated in Fig. 3. In order not to damage the pressure sensitive disc, the cover may not be removed. The disc is designed to withstand maximum operating pressure of the bushing.

2.10.1 Description of SF₆ gas

Sulfur hexafluoride (SF₆) 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 SF₆ 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 N₂

Climate-effecting CO₂ equivalent: 22,800

Lifetime in the atmosphere: 3,200 years

2.10.2 Quantity of pure SF₆ gas for filling of bushing

<table>
<thead>
<tr>
<th>Bushing</th>
<th>Catalogue number</th>
<th>Amount of SF₆</th>
<th>CO₂ gas equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGF 1675</td>
<td>LF 141 001-F</td>
<td>19 kg</td>
<td>433.2 tonne</td>
</tr>
<tr>
<td>GGF 1950</td>
<td>LF 141 001-E</td>
<td>21 kg</td>
<td>478.8 tonne</td>
</tr>
<tr>
<td>GGF 1950</td>
<td>LF 141 001-G</td>
<td>21 kg</td>
<td>478.8 tonne</td>
</tr>
<tr>
<td>GGF 1550</td>
<td>LF 141 001-H</td>
<td>19 kg</td>
<td>433.2 tonne</td>
</tr>
<tr>
<td>GGF 825-1050</td>
<td>LF 141 001-K</td>
<td>16 kg</td>
<td>364.8 tonne</td>
</tr>
<tr>
<td>GGF 1675</td>
<td>LF 141 001-L</td>
<td>19 kg</td>
<td>433.2 tonne</td>
</tr>
<tr>
<td>GGF 1675</td>
<td>LF 141 001-M</td>
<td>19 kg</td>
<td>433.2 tonne</td>
</tr>
<tr>
<td>GGF 1675</td>
<td>LF 141 001-N</td>
<td>19 kg</td>
<td>433.2 tonne</td>
</tr>
</tbody>
</table>

Fig. 7. Nozzle for connection to gas valve.
2.10.3 Quality and type of gas
The quality of the SF₆ gas should adhere to standards IEC 60376 and 60796b "Specifications and acceptance of new sulphur hexaflouride".

For additional information regarding gas filling, please contact ABB.

2.11 Dismounting of bushing from transformer
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.

2.11.1 Removal of SF₆ gas

**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:

1. Connect the SF₆ gas to a service unit.
2. 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.

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

2.11.2 Mounting the transport container
After dismounting of the bushing from the transformer the transport container shall be mounted. The bushing and the transport container are then filled with dry clean transformer oil after which the expansion volume (approximately 50 litres) is removed from the transport container.

To make certain the complete oil volume is filled, the filling should be made both at the flange and at the filling plug on the transport container. If connecting at both positions at the same time, the oil pressure and flow at the filling plug on the container should be reduced to the same level as at the flange.

If the bushing has not been drained at the flange, it is sufficient to verify the oil level by checking through one of the oil valves after arranging the valve upwards. If this shows a high oil level, oil may be filled directly into the transport container until it is filled. Finish the procedure by removing oil (approximately 50 litres).

The bushing should then be stored with the transport vessel leaning upwards at an angle >5°, as described in section 2.3. If the bushing is not in the table below, contact ABB for correct information.
2.12 Recommended tests before energizing
The following tests may be performed to check the sealing and capacitance of the bushing.

2.12.1 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.

2.12.2 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 the 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 $C_1$ between the bushing conductor and the tap is shown on the nameplate.

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<table>
<thead>
<tr>
<th>Bushing body temperature °C</th>
<th>Multiplier to 20 °C (IEC)</th>
<th>Multiplier to 25 °C (USA and Canada)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-7</td>
<td>0.85</td>
<td>0.80</td>
</tr>
<tr>
<td>8-12</td>
<td>0.90</td>
<td>0.85</td>
</tr>
<tr>
<td>13-17</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>18-22</td>
<td>1.00</td>
<td>0.95</td>
</tr>
<tr>
<td>23-27</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>28-32</td>
<td>1.10</td>
<td>1.05</td>
</tr>
<tr>
<td>33-37</td>
<td>1.15</td>
<td>1.10</td>
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<tr>
<td>38-42</td>
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</tr>
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<td>43-47</td>
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<td>1.20</td>
</tr>
<tr>
<td>48-52</td>
<td>1.30</td>
<td>1.25</td>
</tr>
</tbody>
</table>
3. Maintenance and supervision

WARNING

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

GGF 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 Gas
The gas density should not be allowed to fall below 3.5 bar absolute pressure. Gas moisture content may be checked according to IEC 60376 B "Specification of Dew Point Measuring". Checking of gas characteristics may be carried out according to IEC 60480 "Guide for checking SF\textsubscript{6} taken from electrical equipment".

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 Hydrophobicity check
The hydrophobicity of the silicone rubber may be checked as directed in product information \textbf{2750 515-142, Bushing diagnostics and conditioning}. This check is less relevant for indoor applications.

3.2 Disposal after end of service life
The bushing consists of the following material:

- Conductor tube of copper.
- Terminals of copper or low-alloy aluminium may be plated with for instance silver, tin, gold or nickel.
- Transformer oil as per IEC 60296, class 2.
- Transformer oil impregnated condenser body consists of paper and 1 % Al foils.
- Test tap consist of Al alloys.
- Flanges, cover and gas filling valves are made of aluminium.
- Oil filling valves consist of plated steel, plastic and brass.
- Insulators consist of glass fibre reinforced epoxy.
- Outer insulator filled with sulphur hexafluoride (SF\textsubscript{6}).
A gas-insulated bushing for transformer or through-wall application has a closed volume of gas and is not communicating with other gas sources. Varying temperature will make the pressure vary, but the amount of gas molecules is constant within the constant volume, and thus the density is considered constant. The important properties of insulation depend on the gas density, and it is therefore important to assure the status of the gas volume.

The GGF bushing is equipped with a bursting disc and density monitors to supervise the pressure/density within the bushing. The bursting disc is built into the flange and limits the pressure if a situation with over-pressure would occur. The density monitors verify the gas condition to give alarm for a condition with leakage and a resulting reduction of pressure/density.

Below is a description of the density monitor used to supervise the gas, together with suggestions how to interpret and handle a situation of alarm.

4.1 Density monitor

The density monitor is delivered with a connection that fits directly into the gas valves installed in the flange of the bushings. When inserting the monitor, the valve opens, and if the monitor is removed the valve closes so that gas cannot escape during handling of the monitor.

The monitor is built into a housing with the active part sealed in a plastic protective box and connections to three switching relays through three terminal blocks. The function of the monitor is to activate the switches at preset density levels.

Fig. 14 shows the monitor with the top cover removed from the housing.

The density level at which the switches change position is ordered at purchase, and calibrated by the manufacturer. The maximum load on the contacts of the switches is 1 A at 250 V AC, or 2 A at 24 V DC.
The different steps and alarm levels are activated in the following way, where Fig. 15 shows the positions before filling gas. Initially the density is such that the corresponding pressure at 20 °C is below 310 kPa absolute. This is the situation when filling from vacuum and before reaching 310 kPa.

The sequence then proceeds as:

- when the pressure has exceeded 310 kPa, contact 31-32 is opened and 31-33 is closed
- continuing filling, at 330 kPa contact 21-22 is opened and 21-23 is closed
- finally when reaching 350 kPa, contact 11-12 is opened and 11-13 is closed

The positions of the switches are shown in Fig. 16 for normal operation, when the gas density is above the first (highest) alarm level of (350 kPa).

Gas is then added to exceed the first alarm level with 20 kPa (0.2 bar) up to 370 kPa absolute at 20 °C.

If a leakage occur with decreasing density, switch D1 is activated at the first alarm, D2 at the second and D3 at the third alarm level. For each of these levels the corresponding switch returns to its position for indication of low level.
4.2 Decoding of switch positions and alarm levels

The third alarm level on the density monitor represents the minimum condition at which the insulating and cooling capacity of the gas is type tested.

The bushing may be operating at its full capacity down to level 3, and there is therefore no need to discontinue operation before this level is reached.

The philosophy how to act for the different alarm stages may depend on local conditions and regulations.

A suggestion how to act for the different alarm stages is given in the following:

- For all three switches drawn in position as applicable for nominal gas pressure – normal operation and no action.
- At alarm level 1, 350 kPa, record the time the alarm occurs. Continue operation with attention to the next alarm, and in particular how long the time span is until the second alarm.
- At alarm level 2, 330 kPa, record the time for this alarm. Evaluate elapsed time since alarm 1 occurred. Continue operation but be prepared for the third alarm. If the time between alarm 1 and alarm 2 is longer than remaining time until the next scheduled maintenance stop, it may be decided to continue operation and plan a check of the bushing in question during the stop. If the time is shorter between alarm 1 and alarm 2 than until the next stop, it may be considered to make a shorter break at the best suitable time and check the bushing. One option at such a break could be to top up the gas to continue operation until the next scheduled stop, without risking an unplanned forced outage.

- At alarm level 3, 310 kPa, trip the converter and investigate the bushing. Also at this point, topping up of gas may be considered to continue operation until the next scheduled stop. However, if time between alarm 2 and 3 is considerably shorter than between 1 and 2, there is a risk a damage or other cause of leakage has occurred that is increasing in size, and care should be taken before continuing operation.

The two density monitors that are supplied with each bushing are independent units, both checking the same gas volume. They may be connected individually to the A and B alarm and monitoring systems, so that one unit is monitored by each respective system. There is for such case a redundancy in the supervision of the gas density, and together with the procedure outlined above, should give an ample safety margin against too low gas density.