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1 Safety

1.1 Levels of safety risks

Throughout the manual, various types of safety risks are indicated. The most serious level on this scale provides a warning about serious personal injury or possible death, or major damage to a product, if the instructions are not observed.

Symbols and their meanings

The following describes the symbols that appear in the manual, along with their meaning.

DANGER!
The yellow, filled warning triangle warns that an accident will occur if the instructions are not complied with and that it will result in serious personal injury or death and/or major damage to the product.

It is used, for example, to warn of such dangers as: contact with high voltage, explosion or fire risk, risk for toxic gases, risk of crushing, impacts, falls from high places, etc.

CAUTION!
The round warning symbol warns that an accident could occur if the instructions are not observed, and that this could result in personal injury and/or damage to the product.

It is also used to warn of risks that entail burns, eye or skin injuries, impaired hearing, crushing or slipping injuries, tripping, impacts, falls from high places, etc.

NOTE!
The comment symbol identifies important information and conditions. Also used to indicate any danger that could lead to property damage.

1.2 Hazardous working situations

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working close to high voltage.</td>
<td>Disconnect all plant power. Ground all objects at the workplace. If work must be done close to live plant components, make sure that the safety distance is in compliance with the applicable safety regulations.</td>
</tr>
<tr>
<td>Working on ladders and platforms.</td>
<td>Work must be done in accordance with the applicable safety regulations. Do not use ladders or platforms in poor weather conditions.</td>
</tr>
<tr>
<td>Working with heavy objects.</td>
<td>Do not walk under lifted objects. Make sure that heavy objects are stable before starting work.</td>
</tr>
</tbody>
</table>
1.3 Safety precautions

<table>
<thead>
<tr>
<th>Precaution</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer oil</td>
<td>Collect used transformer oil in drums.</td>
</tr>
<tr>
<td></td>
<td>Transformer oil is dangerous. Fumes from hot oil can cause irritation to the respiratory organs and the eyes. Long and repeated contact with transformer oil can cause damage to your skin.</td>
</tr>
<tr>
<td>Waste and cleaning up</td>
<td>Clean up liquid waste with an adsorbent.</td>
</tr>
<tr>
<td></td>
<td>Treat waste as hazardous to the environment.</td>
</tr>
<tr>
<td>Fire</td>
<td>Extinguish fires with powder, foam or carbon dioxide.</td>
</tr>
</tbody>
</table>

1.4 Competence level

Installation of the bushing should only be performed by authorized personnel.

**CAUTION!**

Incorrect installation can lead to catastrophic failure of the transformer.
2 Product description

2.1 Design

Overview
The TOE is a capacitance graded oil impregnated paper bushing made for immersed oil/air service. For a detailed description, please refer to the Technical guide, 1ZK3718019.

General schematics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top housing</td>
</tr>
<tr>
<td>2</td>
<td>Porcelain insulator, air side</td>
</tr>
<tr>
<td>3</td>
<td>Test tap</td>
</tr>
<tr>
<td>4</td>
<td>Extension for current transformer</td>
</tr>
<tr>
<td>5</td>
<td>Porcelain insulator, oil side</td>
</tr>
<tr>
<td>6</td>
<td>Bottom nut</td>
</tr>
<tr>
<td>7</td>
<td>Mounting flange</td>
</tr>
<tr>
<td>8</td>
<td>Oil sampling valve</td>
</tr>
<tr>
<td>9</td>
<td>Oil plug</td>
</tr>
<tr>
<td>10</td>
<td>Oil-level gauge</td>
</tr>
<tr>
<td>11</td>
<td>Lifting eye</td>
</tr>
</tbody>
</table>
**Test tap**

The bushing has a test tap that is connected to the outermost conductive layer of the condenser core. The test tap is used to measure the bushing insulation by capacitance and dissipation factor. The cover connects the outermost conductive layer to ground, and must always be installed when the bushing is energized.

The maximum one minute test voltage for this test tap is 20 kV rms. The test tap can be used as a power source, if it is connected to an external capacitance. The operating voltage is limited to 6 kV.

---

**CAUTION!**

Do not energize the bushing without a test adapter or the cover installed. The bushing is grounded through the cover to prevent damage to the bushing.

---

**Test adapter, 2769 522-C, optional equipment**

The test adapter 2769 522-C is available for permanent connection to measuring circuits.
2.2 Technical specification

2.2.1 General specifications
Refer to the table for the standard technical specifications of the bushing. For conditions exceeding the specifications, please contact ABB.

<table>
<thead>
<tr>
<th>Application:</th>
<th>Transformers/reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification:</td>
<td>Transformer bushing</td>
</tr>
<tr>
<td></td>
<td>• Oil impregnated paper, capacitance graded, oil immersed.</td>
</tr>
<tr>
<td></td>
<td>• For outdoor and indoor use.</td>
</tr>
<tr>
<td>Working on ladders and platforms:</td>
<td>Work must be done in accordance with the applicable safety regulations.</td>
</tr>
<tr>
<td></td>
<td>Do not use ladders or platforms in poor weather conditions.</td>
</tr>
<tr>
<td>Ambient temperature limits:</td>
<td>-40 °C to +40 °C, limit temperatures, according to temperature class 2 of IEC 60137.</td>
</tr>
<tr>
<td>Maximum altitude of site:</td>
<td>1000 m (Bushings for other altitudes can be provided on request.)</td>
</tr>
<tr>
<td>Level of rain and humidity:</td>
<td>1-2 mm rain/minute horizontally and vertically, according to IEC 60060-1.</td>
</tr>
<tr>
<td>Pollution level:</td>
<td>III or IV, according to IEC 60815.</td>
</tr>
<tr>
<td>Immersion medium:</td>
<td>Transformer oil.</td>
</tr>
<tr>
<td></td>
<td>• Maximum daily mean oil temperature: +90 °C.</td>
</tr>
<tr>
<td></td>
<td>• Maximum temporary oil temperature, at short time overload: +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>Maximum pressure of medium:</td>
<td>$p_{1}$ 100 kPa (p$_1$ = relative to ambient pressure).</td>
</tr>
<tr>
<td>Angle of installation:</td>
<td>0 to 30° from vertical.</td>
</tr>
<tr>
<td>Test tap:</td>
<td>Test tap with 8 mm male contact pin.</td>
</tr>
<tr>
<td></td>
<td>According to IEEE type A.</td>
</tr>
<tr>
<td>Conductor:</td>
<td>Center-tube conductor.</td>
</tr>
</tbody>
</table>

2.2.2 Mechanical loading

Maximum permitted static load on the outer terminal
The load must be applied below the midpoint of the outer terminal. The total cantilever load must be perpendicular to the bushing axis. The bushing installation angle can be 0° – 30° from vertical.

In the axial direction, the bushing can withstand a static load of 20 kN.

NOTE!
The loads described in this section are static loads, for dynamic loads such as earthquakes and extreme weather conditions, please contact your ABB sales representative.
2.2 Technical specification

2.2.1 General specifications

Refer to the table for the standard technical specifications of the bushing. For conditions exceeding the specifications, please contact ABB.

**Application:**
- Transformers/reactors
- Transformer bushing
  - Oil impregnated paper, capacitance graded, oil immersed.
  - For outdoor and indoor use.
  - Work must be done in accordance with the applicable safety regulations.
  - Do not use ladders or platforms in poor weather conditions.
  - -40 °C to +40 °C, limit temperatures, according to temperature class 2 of IEC 60137.
  - 1000 m (Bushings for other altitudes can be provided on request.)
  - 1-2 mm rain/minute horizontally and vertically, according to IEC 60060-1.
  - III or IV, according to IEC 60815.
- Transformer oil.
  - Maximum daily mean oil temperature: +90 °C.
  - Maximum temporary oil temperature, at short time overload: +115 °C.

**Classification:**

<table>
<thead>
<tr>
<th>Working on ladders and platforms:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature limits:</td>
</tr>
<tr>
<td>Maximum altitude of site:</td>
</tr>
<tr>
<td>Level of rain and humidity:</td>
</tr>
<tr>
<td>Pollution level:</td>
</tr>
<tr>
<td>Immersion medium:</td>
</tr>
<tr>
<td>Oil-level in transformer:</td>
</tr>
<tr>
<td>Maximum pressure of medium:</td>
</tr>
<tr>
<td>Angle of installation:</td>
</tr>
<tr>
<td>Test tap:</td>
</tr>
<tr>
<td>Conductor:</td>
</tr>
</tbody>
</table>

**Mechanical loading**

Maximum permitted static load on the outer terminal

The load must be applied below the midpoint of the outer terminal. The total cantilever load must be perpendicular to the bushing axis. The bushing installation angle can be 0° – 30° from vertical.

In the axial direction, the bushing can withstand a static load of 20 kN.

**NOTE!**

The loads described in this section are static loads, for dynamic loads such as earthquakes and extreme weather conditions, please contact your ABB sales representative.

<table>
<thead>
<tr>
<th>Type</th>
<th>Test load 1 minute (N)</th>
<th>Maximum cantilever load in operation at installation angle (N)</th>
<th>Maximum axial static load (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOE 1675, 1800</td>
<td>17500</td>
<td>8750</td>
<td>5200</td>
</tr>
</tbody>
</table>

**Maximum permitted torque on the outer terminal**

The maximum torque that is permitted on the terminal stud is 250 Nm.
3 Delivery

3.1 Incoming inspection

- Make sure that all items have been delivered, refer to the packing list.
- Carefully inspect the bushings for shipping damage.

**NOTE!**
The bushing has been routine tested in oil, and there can be small quantities of oil remaining on the oil-side of the bushing. Vaseline is used for lubrication of threads, and at some temperatures Vaseline can appear as oil.

**NOTE!**
The oil-level is not shown correctly when the bushing is in the horizontal position.

3.2 Transportation

- The bushing must be transported in the transport box.
- The bushing must be transported in the horizontal position.
- Carefully inspect the bushing for damage after transportation.

3.3 Storage

**Short term storage, less than 6 months**

- The bushing can be stored outdoors, if it is in the transport box.
  Keep the transport box protected from water, when the bushing is stored outdoors.
- Keep the bushing dry, clean and protected against mechanical damage.
- The bushing can be stored in both the vertical, and horizontal positions.

**NOTE!**
The oil-level is not shown correctly when the bushing is in the horizontal position.

**Long term storage, more than 6 months**

- The bushing can be stored outdoors, if it is in the transport box.
- Keep the transport box protected from water, when the bushing is stored outdoors.
- Keep the bushing dry, clean and protected against mechanical damage.
- Lift the bushing to the vertical position with the top end upwards, and put it in a safe stand.
- As an alternative: keep the bushing in the transport box and lift it to an inclined position, with the top end upwards and at an angle of at least 7°.

The bushing is delivered from ABB in a transport box, and the bushing is held in place by support blocks and fiberboard in the box.

The transport box is marked with Top end, this identifies the end to lift when the bushing is in storage.
3.4 Lifting

3.4.1 Lifting the transport box

Overview

Procedure

1. Make sure that the crane and the soft lifting slings are approved for the total weight of the transport box and bushing. Refer to the weight in the packing list.

2. Attach soft lifting slings (2).

3. Make sure that the angle of the soft lifting sling is not more than 20°.

4. Carefully lift the transport box.

5. Set down the transport box on a flat surface.

End of instruction
3.4.2 Lifting the bushing out of the transport box

Overview

![Diagram of the bushing]

1 Top end of air side insulator

Procedure

1 Make sure that the crane is approved for lifting the weight of the bushing. Refer to the net weight on the packing list.

2 Open the transport box.

   **NOTE!**
   The cover is attached with bolts.

3 Remove the support blocks from the transport box and put them on the ground.

   **CAUTION!**
   Make sure that the ground is flat.

4 Attach a soft lifting sling to the lower part of the flange and then to the crane hook.
5 Attach a soft lifting sling to the top end of air side insulator (1) and then to the crane hook.

CAUTION!
Attach the soft lifting sling as close to the top housing as possible, or damage will occur.

6 Carefully lift the bushing.

7 Make sure that the support blocks are in the same positions as the support blocks in the transport box.

CAUTION!
Do not apply force to the ceramic insulator, it will break.

8 Lower the bushing onto the support blocks.

End of instruction
4 Installation

4.1 Tools

<table>
<thead>
<tr>
<th>Tool</th>
<th>Part number</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifting tool</td>
<td>1ZK190020-A</td>
<td>-</td>
</tr>
<tr>
<td>Soft bedding</td>
<td></td>
<td>E.g. rubber mat or wood board</td>
</tr>
<tr>
<td>Soft lifting slings</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Torque wrench key for hex socket screws</td>
<td></td>
<td>18 mm (M12), 16 mm (M10) and 13 mm (M8), torque 20 to 60 Nm.</td>
</tr>
<tr>
<td>Wrench for hex socket screws</td>
<td></td>
<td>45 mm or adjustable wrench for 45 mm bolts or larger.</td>
</tr>
<tr>
<td>Shackles</td>
<td></td>
<td>To fit Ф28 mm holes, for connection of the soft lifting slings to the bushing flange.</td>
</tr>
<tr>
<td>Tackle</td>
<td></td>
<td>For installation of the bushing at a specific angle.</td>
</tr>
</tbody>
</table>

4.2 Consumables

<table>
<thead>
<tr>
<th>Item</th>
<th>Brand</th>
<th>Part number</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil based Vaseline</td>
<td>Fuchs</td>
<td>1171 5011-102</td>
<td>For treatment of contact surfaces. Does not react with transformer oil.</td>
</tr>
<tr>
<td>Mobilgrease 28</td>
<td>MOBIL</td>
<td>1171 4014-407</td>
<td>Lubricates and protects metals against corrosion. Protects rubber. Does not react with transformer oil.</td>
</tr>
</tbody>
</table>

4.3 Lifting

Overview

1  Lifting tool
2  Soft bedding, e.g. rubber mat or wood board
3  Shackle
### Procedure

1. Make sure that the crane can lift the bushing. Refer to net weight in the packing list.

2. Remove the plugs (1) and gaskets (2).

   **NOTE!**
   Keep the plugs (1) and gaskets (2), they may be used again.

3. Install the lifting tool (3), align the side of lifting tool with oil-level gauge(6). Install the M8 x 50 (4) bolts and the washers (5).

   **NOTE!**
   The bolts (4) with property of class 6.8 or above and washers (5) shall be prepared before the installation.

   **Torque**
   20 Nm

4. Attach soft lifting slings (8) from the lifting holes through the lifting tool to the crane hook.

   **NOTE!**
   The diameter of the holes for the lifting-slings in the lifting tool is Ø70 mm.
5 For installation at a specific angle: attach soft lifting slings with a shackle (9) from the flange to the crane hook.

6 Align the crane hook with the lifting tool on the bushing.

7 Carefully lift the bushing.

**CAUTION!**
Make sure that the bushing does not rotate.

8 Adjust the shackle (9) until the bushing flange has the same angle as the transformer flange.

9 Continue with Install the bushing on transformer

---

4.4 Install the bushing on transformer

4.4.1 Installation the bushing on the transformer

**Procedure**

1 Move the bushing on to the transformer.
2  If the bushing is installed in a non vertical position, the oil-gauge (10) must point down.

3  Install the nuts and washers. Tighten the nuts in a crosswise sequence.

   **CAUTION!**
   Make sure that the nuts are tightened evenly. First tighten all nuts to half the torque, then to the full torque.

4  Remove the M8 bolts (4), the washers (5), and the lifting tool (1).

5  Continue with Installation the bottom contact on the bushing, page 18.
4.4.2 Installation the bottom contact on the bushing

Overview
The step can be done before Installation the bushing on the transformer.

Procedure

1. Install the bottom contact (12), the washers (13) and the bolts (14) to the bottom nut (11).

Align the narrow side of panel of the bottom contact with the test tap on mounting flange of the bushing.

NOTE!
Install the bottom contact, refer to the drawing 1ZKJ173010-AD.

End of instruction

4.4.3 Installation the end shield on the bushing

Procedure

1. Install the springs (15), the guiding sleeves (16), the pressing ring (17), and the hex screws (18) to the bottom nut (11).

Install the winding cables through the end-shield.

CAUTION!
Make sure that there is no tension in the winding cables. Tension in the winding cables will cause damage to the bottom contact.

Install the end shield:
1. Push the end shield carefully against the pressing ring (17), until the hex screw heads come through the holes in the end shield.
2. Turn the end shield clockwise approximately 20°, to its locked position.

Torque
40 Nm

60 Nm
2. Put the winding cables through the end-shield.

3. Install the winding cables to the bottom contact.

**CAUTION!**
Make sure that there is no tension in the winding cables. Tension in the winding cables will cause damage to the bottom contact.

4. Install the end shield:
   1. Push the end shield carefully against the pressing ring (17), until the hex screw heads come through the holes in the end shield.
   2. Turn the end shield clockwise approximately 20°, to its locked position.

*End of instruction*
4.4.4 Installation the corona ring on the bushing

Procedure

1. Remove the plugs (1) and the gaskets (2).

2. Remove the nuts (21) and the washers (22).

3. Install the support ring (23), the corona ring (24), the washers (25) and the bolts (26).

**CAUTION!** Install the support ring (23) keep the notches downward.

**End of instruction**
4.4.5 Grounding of the bushing flange

Overview
The bushing flange must be grounded to the transformer tank. This prevents electrical discharge between the bushing flange and the transformer tank under normal service conditions. There are two alternatives.

DANGER!
Make sure that the grounding is correct. An unsatisfactory grounding can cause damage to equipment, or death to personnel.

Procedure with a cone point set screw

1. Apply a large quantity of Mobilgrease 28 to the cone point set screw (13).
   
   CAUTION!
   The quality of the cone point set screw is important, stainless steel of A4-80 quality is recommended.

   NOTE!
   Or use a lubricant similar to Mobilgrease 28.

2. Install the cone point set screw (13).
   
   NOTE!
   The cone point of the set screw penetrates the paint(if any). This makes an electrical connection between the bushing and the transformer tank, keeping them at the same potential.

   Torque
   M12, 40 Nm

End of instruction

Procedure with a cone point set screw

1. Clean the contact surfaces.

2. Put a flexible cable (14) between the grounding hole in the bushing flange and a grounding point on the transformer.
3  Apply a large quantity of Mobilgrease 28 to the bolt (13).

CAUTION!
The quality of the bolt is important, stainless steel of A4-80 quality is recommended.

NOTE!
Or use a lubricant similar to Mobilgrease 28.

4  Install the bolt (13).

Torque
M12, 40 Nm

5  Connect the other end of the flexible cable (14) to the transformer.

NOTE!
This makes an electrical connection between the bushing and transformer tank, keeping them at the same potential.

End of instruction
5 Commissioning

5.1 Waiting time before energization

General requirements for the bushing

- If the bushing has been stored in the vertical position with the top end upwards, then no waiting time is required.
- If the bushing has been stored in the horizontal position, or in an inclined position of 7°, then air bubbles must be removed from the oil before it can be energized. Refer to the table.
- The waiting times can be met with the bushing installed on the transformer.

When the bushing is in the vertical position, air bubbles that are trapped in the oil collects at the top.

<table>
<thead>
<tr>
<th>Storage time in the horizontal position</th>
<th>Minimum required waiting time in the vertical position</th>
<th>Before test voltage application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than one year</td>
<td>48 hours</td>
<td>72 hours</td>
</tr>
<tr>
<td>More than one year</td>
<td>7 days</td>
<td>7 days and 12 hours</td>
</tr>
</tbody>
</table>

CAUTION! If you do not obey this procedure, flashovers or partial discharges can occur inside the bushing.

Waiting times after oil-filling of the transformer

Some waiting time is necessary after the transformer has been oil-filled, before the bushing is energized. The reason for this is that air bubbles stick to the bushings surface when the transformer is filled with oil, and flashovers and partial discharges can form in the bubbles. Thus, it is important to let the necessary waiting time pass, to make sure that all the air bubbles have risen to the surface of the oil before the bushing is energized. Refer to the table.

<table>
<thead>
<tr>
<th>The transformer is oil-filled with</th>
<th>Necessary waiting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>The vacuum process</td>
<td>No waiting time is necessary, air bubbles does not form in vacuum. Refer to the transformer manufacturers instructions.</td>
</tr>
<tr>
<td>Gas-saturated transformer oil</td>
<td>After the oil-filling process has been completed, wait for 24 hours before energizing the transformer.</td>
</tr>
<tr>
<td>De-gassed transformer oil</td>
<td>After the oil-filling process has been completed, wait for 6 hours before energizing the transformer.</td>
</tr>
<tr>
<td>A reduced oil-level</td>
<td>After the oil-level has been restored, wait 24 hours before energizing the transformer.</td>
</tr>
</tbody>
</table>

5.2 Recommended test before energization

5.2.1 Overview

The tests should be done to check the insulation, sealing and current path of the bushing.

NOTE! The tests should be done after installation, but before connecting the outer terminal of the bushing to the power circuit.
5.2.2 Tightness test between transformer and bushing flange
Several different methods can be used and we thus refer to the instructions given by the company responsible for field erection. As an example, the tightness of the seal between the transformer and the bushing flange can be checked when the transformer is oil-filled by using chalk or, perhaps easier, with paper strips.

5.2.3 Measurement of capacitance and dissipation factor

Overview
After installation of the bushing, it is recommended to measure the capacitance values for future reference, such as repairs, service etc. This can be done on an installed bushing because it has an insulated test tap.

Refer to 2750 515-142, ”Bushing diagnostics and conditioning”.
- C1 is the capacitance between the test tap and the outer terminal.
- C2 is the capacitance between the test tap and ground.

Nominal capacitance
The capacitance (C2) depends on the transformer, and it is not possible to give a nominal value that is valid for all service conditions. Thus, it is important to measure and record the capacitance (C2) for future reference, such as repairs, service etc.

<table>
<thead>
<tr>
<th>Type</th>
<th>Space for CT = 305 mm</th>
<th>Space for CT = 605 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C1 (pF)</td>
<td>C2 (pF)</td>
</tr>
<tr>
<td>TOE 1675-1300</td>
<td>486</td>
<td>870</td>
</tr>
<tr>
<td>TOE 1800-1360</td>
<td>486</td>
<td>870</td>
</tr>
</tbody>
</table>

* Reference values from ABB Hefei Transformer Co., Ltd.

Dissipation factor, tan δ
The dissipation factor varies with the temperature of the bushing body, and thus the measured dissipation factor must be multiplied with the correction factor given below.

<table>
<thead>
<tr>
<th>Bushing body temperature °C</th>
<th>Correction factor to 20 °C (IEC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-7</td>
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<tr>
<td>8-12</td>
<td>0.90</td>
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<tr>
<td>13-17</td>
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<td>18-22</td>
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<tr>
<td>23-27</td>
<td>1.05</td>
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<tr>
<td>28-32</td>
<td>1.10</td>
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<tr>
<td>33-37</td>
<td>1.15</td>
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<td>38-42</td>
<td>1.20</td>
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<tr>
<td>43-47</td>
<td>1.25</td>
</tr>
<tr>
<td>18-52</td>
<td>1.30</td>
</tr>
</tbody>
</table>
**Procedure**

1. De-energize the transformer.
2. Disconnect the external connections from the outer terminal of the bushing.
3. Remove the cover (2).

<table>
<thead>
<tr>
<th>Part</th>
<th>Article number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover</td>
<td>2769 522-M</td>
</tr>
<tr>
<td>O-ring</td>
<td>21522012-422</td>
</tr>
</tbody>
</table>

4. Connect the measuring equipment.
   1. Connect the low voltage cable to the stud (1).
   2. Connect the high voltage cable to the outer terminal.
   3. Connect the ground cable to the bushing flange (3).

5. Measure the capacitance (C1) between the outer terminal and the stud (1).

   **NOTE!**
   Refer to the table for the nominal capacitance (C1), Nominal capacitance, page 24.

6. Measure the capacitance (C2) between the stud (1) and the flange (3).
   • Record the capacitance (C2) for future reference.

7. Install the cover (2).

   **CAUTION!**
   The test tap is not self-grounding!
   The bushing can be destroyed if the test tap is not grounded. Because the capacitance (C2) is usually relatively small, the test tap must never be open-circuited when applying a voltage to the bushing. It must always be grounded or connected to an external impedance.

   **CAUTION!**
   Do not energize the bushing without the cover or a test adapter installed. The cover connects the outermost conductive foil to ground and will prevent damage to the bushing.

   **CAUTION!**
   Make sure that the cover is correctly installed with the O-ring in place, when the bushing is not in use. The purpose is to prevent dust and water from entering the tap.

8. Connect the outer terminal of the bushing to the external connections.

   **End of instruction**
5.2.4 Measurement of through-resistance

Overview
The method to use for measuring the through-resistance depends on the design of the transformer. In general, a current is applied from bushing to bushing. The voltage drop from the outer terminal to outer terminal is measured. The resistance is calculated with Ohm's law, \( R = \frac{U}{I} \).

(R: total circuit resistance, U: measured voltage drop, I: through-current).

The total through-resistance is the sum of the transformer winding, lead resistance, the bushing conductor, and contact resistance. The additional resistance from the bushing conductor should not be more than 150 \( \mu \Omega \). Because the through-resistance of the HV winding of a typical power transformer is in the order of 0.1 to 1 \( \Omega \), this is a very rough method that can only be used to detect very large faults in the current path, such as open circuits.

Small faults in the current path can only be detected by making sensitive measurements across each connection point, or by measuring the temperature increase during operation with an infrared sensitive camera (thermovision).

The through-resistance of an installed bushing can only be measured from the outer terminal of one bushing, to the outer terminal of the other bushing on the same transformer winding. The through-resistance will include the resistance of both bushings, all connections and the transformer winding.

Do the measurement of through-resistance before connecting any of the external circuits.

Because the result of the measurement depends on the temperature and the accuracy with which the temperature can be measured, this can be a source of errors.

Procedure

1. Record the temperature of the transformer winding.

   **NOTE!**
   The resistance of metals depends on their temperature. Because the transformer winding usually dominates the total resistance, the average winding temperature at the time of measurement must be recorded.

2. Measure the through-resistance from outer terminal to outer terminal.

3. Calculate the measured resistance to the reference temperature. Then compare the calculated resistance to the reference resistance. A difference of less than 2% is acceptable.

   **NOTE!**
   The transformer manufacturer gives the reference temperature for through-resistance measurements.

4. If the calculated difference of resistance is more than 2% from the reference resistance:
   1. Make sure that the external connections have low resistance, and make sure that the outer terminal and the internal connections are correctly installed.
   2. Measure the through-resistance again.

5. If the calculated difference of resistance again is more than 2%:
   - Wait 24 hours and do steps 1 through 5 again.

End of Instruction
6 Maintenance

6.1 Recommended maintenance

General
The bushings are maintenance free, no regular maintenance is necessary.

DANGER!
Risk of electrocution!
Do not go near the bushing while it is energized, or ungrounded. High voltages can kill you. Make sure that the bushing is de-energized, and grounded before you do work on it.

Cleaning of the insulator surface
If the insulator shed is exposed to very high pollution, it can be necessary to clean the surface. Remove the pollution with a moist cloth, or a low pressure water jet. If necessary, put isopropyl alcohol on the cloth.

DANGER!
Trichloroethane or Methyl-chloride are not recommended as detergents, because they are dangerous to persons and the environment.

CAUTION!
Do not wash the insulator sheds with a high pressure water jet. This can cause damage to the joints in the insulator shed, and between the insulator shed and metal parts.
Measurement of capacitance and dissipation factor

Thermovision (infrared camera) check for local overheating on connectors
At the maximum rated current, the bushing outer terminal normally operates at a temperature of about +35 °C to +45 °C above the ambient temperature. Significantly higher temperatures can be a sign of bad connections, especially at lower current loading.

Checking of oil leakage
Make a visual inspection for oil leakage during regular station supervision.

Checking of oil-level
The oil-level at normal and high temperatures, must always be above the red area on the oil-level indicator.

If the oil-level is in the red area (10), clean and dry transformer oil must be added. For the correct oil-level, please contact ABB. Adding oil is only allowed when the temperature of the bushing is between +5 °C and +35 °C.

CAUTION!
Be careful when the oil plugs is removed, contamination can enter the bushing.

Use new gaskets for the oil plugs (9) and the cover (8). Tighten the oil plugs (8) and the cover (9) to 20 Nm.

CAUTION!
Make sure that the oil plug and the cover are correctly installed, and that there is no leakage.
Taking oil-samples
Taking oil samples is generally not recommended. Take an oil sample only if a problem is known, for example a high power factor over C1, or visible oil leakage. Please refer to product information 2750 515-142 "Bushing diagnostics and conditioning".

Take the oil sample from the oil valve (7) in the flange, and close the oil valve (7).

CAUTION!
Make sure that the oil valve (7) is correctly closed.

NOTE!
It is generally not necessary to add oil after an oil sample is taken. But it can be necessary to add oil when many oil samples have been taken.
7 Re-packing

7.1 Removal of the bushing from the transformer

Procedure

1. Remove the end shield from the bushing, disconnect the winding cables from the bottom contact, refer to Installation the end shield on the bushing, page 18.

2. Remove the bottom contact from the bushing, refer to Installation the bottom contact on the bushing, page 18.

3. Install the lifting tool, refer to Lifting the bushing, page 14.

4. Remove the nuts and washers.

5. Lift the bushing from the transformer.

6. Lower the bushing to the floor.

   **CAUTION!**
   Make sure that there is soft bedding, or support blocks on the floor.

7. Install the transport cover on the transformer turret.

End of instruction
7.2 Re-packing of the bushing

Overview

Procedure

1. Lift the bushing. Refer to Lifting the bushing out of the transport box, page 12.

2. Lower the bushing into the transport box.
   - CAUTION! Make sure that there are support blocks in the transport box.
   - CAUTION! Make sure that the oil valves and test tap does not make contact with the transport box, or other objects.

3. Attach the bushing to the transport box in the same way as when it was delivered.
   - CAUTION! Make sure that the bushing cannot move or rotate in the transport box.

4. Close the transport box.
   - NOTE! Refer to Lifting the transport box, page 11 and Transportation, page 10.

End of instruction
8  Spare parts and special tools

8.1 Summary

If the bushing is damaged, we recommend that it is returned to ABB for repairs and re-testing. Some parts that are damaged or lost during transportation or installation, can be ordered from ABB.

8.2 Spare parts

Cover
For the test tap.

<table>
<thead>
<tr>
<th>Position</th>
<th>Part</th>
<th>Article number</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-</td>
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<tr>
<td>2</td>
<td>O-ring</td>
<td>21522012-422</td>
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</table>

Oil-plug 1ZKJ173001-C

<table>
<thead>
<tr>
<th>Position</th>
<th>Part</th>
<th>Article number</th>
<th>Note</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Oil-plug</td>
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<tr>
<td>2</td>
<td>Gasket</td>
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</tbody>
</table>
Spare parts and special tools

8.1 Summary
If the bushing is damaged, we recommend that it is returned to ABB for repairs and re-testing. Some parts that are damaged or lost during transportation or installation, can be ordered from ABB.

8.2 Spare parts

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<tr>
<th>Position</th>
<th>Part</th>
<th>Article number</th>
<th>Note</th>
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<td>2</td>
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8.3 Special tools

Lifting tool

<table>
<thead>
<tr>
<th>Part</th>
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<th>Note</th>
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<tr>
<td>Lifting tool</td>
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</table>
9 Disposal and environmental information

9.1 Overview

This chapter specifies the materials used in the bushing. Comply with local environmental regulations on disposal of this product, the materials used are specified for this purpose.

9.2 Disposal and recycling

ABB strives to minimize the product’s impact on the environment throughout its entire life cycle. Technical and product development focuses on environmental aspects. The ecocycle approach is striven for, and consideration is taken to the materials’ environmental impact and recycling alternatives. The manufacturing processes are selected to be as safe for the environment as possible.

Disposal of worn-out equipment

Worn-out equipment must be disposed of in an environmentally sound manner. Much of the material, or the energy content in the material, can be recycled if it is sorted and cleaned. The quantity of material that can be recycled varies depending on the technical resources and capabilities in each country. Non-recyclable components should be sent to an approved environmental waste treatment plant for destruction or disposal.

DANGER!

Be careful when dissembling the bushing. There is a large quantity of mechanical energy stored in the bushing from its assembly, disassembly of the bushing can cause it to break with explosive force.

The bushing has these parts and materials

• The conductor is made of low-alloy aluminum.
• The terminal stud and the bottom contact are made of copper. The terminal stud and bottom contact can be plated with silver or tin, with a thickness up to 20 μm.
• Transformer oil, refer to IEC 60296, class 2.
• The condenser core is made of paper and 1 % aluminum foil, impregnated with transformer oil.
• The top housing, mounting flange, flange extension, top end nut and test tap are made of aluminum alloys.
• The bottom nut is made of brass.
• The insulators are made of quartz-silicate or alumino-silicate based porcelain.

Porcelain

After cleaning, the porcelain can be sent for disposal or used for other purposes, such as for use as filling material.

Electronics

Electronics equipment should be sent to an approved recycling plant, or sorted into different component materials for correct processing.
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This chapter specifies the materials used in the bushing. Comply with local environmental regulations on disposal of this product, the materials used are specified for this purpose.

9.2 Disposal and recycling
ABB strives to minimize the product’s impact on the environment throughout its entire life cycle. Technical and product development focuses on environmental aspects. The ecocycle approach is strived for, and consideration is taken to the materials’ environmental impact and recycling alternatives. The manufacturing processes are selected to be as safe for the environment as possible.

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**DANGER!**
Be careful when dissembling the bushing. There is a large quantity of mechanical energy stored in the bushing from its assembly, disassembly of the bushing can cause it to break with explosive force.

The bushing has these parts and materials:
- The conductor is made of low-alloy aluminum.
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- The condenser core is made of paper and 1% aluminum foil, impregnated with transformer oil.
- The top housing, mounting flange, flange extension, top end nut and test tap are made of aluminum alloys.
- The bottom nut is made of brass.
- The insulators are made of quartz-silicate or alumino-silicate based porcelain.
- Porcelain:
  - After cleaning, the porcelain can be sent for disposal or used for other purposes, such as for use as filling material.
- Electronics:
  - Electronics equipment should be sent to an approved recycling plant, or sorted into different component materials for correct processing.
- Metals:
  - Metals should be sorted according to type and surface coating, and sent to an approved recycling plant. After the removal of paint or other surface coatings, clean metal can usually be melted down and used in new products. Many metal components of iron, steel and aluminum are large and easy to identify, e.g. support structures. ABB strives to reduce the use of precious metals and the release of environmentally hazardous metals.
  - The recycling of precious metals is particularly important. Metals such as copper and silver are expensive, and are only present in small quantities in the earth’s crust. Copper is primarily used in current conductors, contacts and cables. Some contacts are silver plated. Fumes from some metals can cause environmental damage, this applies to zinc and nickel, which are used sparingly as surface coatings.
- Plastics:
  - The different types of plastic should be separated and sent to an approved environmental waste treatment plant or recycling plant. The energy content in thermoplastics and thermosetting plastics can often be recovered through combustion at a plant built for the purpose. Thermoplastics can usually be melted down and reused without significant loss of quality. Composites can be fractioned and used as filling materials in other materials, or be disposed of.
- Oils and greases:
  - Before disposal of the bushing, oil, grease and similar products must be removed and sent to an approved environmental waste treatment plant or recycling plant. By utilizing gravimetric forces, oil waste can be separated into oil, water and a range of contaminants. In many cases, the oil can then be reused. As an alternative, the energy content in oil can be recovered through combustion at a plant designed for the purpose.
- Rubber:
  - Send rubber to an approved environmental waste treatment plant, either for disposal or reuse for different purposes.
  - Rubber is used in seals and gaskets.
- Other materials:
  - Sort other materials and send them to an approved environmental waste treatment plant.
10 References

10.1 Summary

- Bushing diagnostics and conditioning, 2750 515-142.
- Test adapter, Installation and maintenance guide, 1ZSC000563-ACD.
- Transformer oil, IEC 60296, class 2.
Note
Note