Preface

These operating instructions show general procedures and guidelines that must be observed when installing and using the product. These operating instructions makes no claim for completeness and possibly does not cover all the activities that can occur during the installation, operation or maintenance, as there can be special variations of this product. It is highly recommended that all the necessary information and drawings are obtained before the installation and use. If in doubt or in need of additional information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner for further information.

General Information

Micafil bushings are designed specifically for mineral oil-filled IEC 60296 transformers and chokes for oil-outdoor applications. Our bushings comply with the standards IEC 60137, IEEE C57.19.00 and C57.19.01. Additionally, they must be qualified according to strict internal guidelines. Micafil bushings are produced exclusively at the ABB industrial site in Zurich, Switzerland.
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Safety information</td>
<td>4</td>
</tr>
<tr>
<td>1.1</td>
<td>Symbols and notes</td>
<td>4</td>
</tr>
<tr>
<td>1.2</td>
<td>Product safety</td>
<td>4</td>
</tr>
<tr>
<td>1.3</td>
<td>Personnel-related measures</td>
<td>4</td>
</tr>
<tr>
<td>1.4</td>
<td>Organizational measures</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Structure of the bushing</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>General structure</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>Packaging and delivery</td>
<td>6</td>
</tr>
<tr>
<td>3.1</td>
<td>Delivered state and reloading</td>
<td>6</td>
</tr>
<tr>
<td>3.2</td>
<td>Reference measurement No. 1</td>
<td>6</td>
</tr>
<tr>
<td>3.3</td>
<td>Repackaging</td>
<td>6</td>
</tr>
<tr>
<td>3.4</td>
<td>Transport box</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Storage</td>
<td>7</td>
</tr>
<tr>
<td>4.1</td>
<td>Storage</td>
<td>7</td>
</tr>
<tr>
<td>5.</td>
<td>Assembling</td>
<td>8</td>
</tr>
<tr>
<td>5.1</td>
<td>Recommended distance from the transformer wall</td>
<td>8</td>
</tr>
<tr>
<td>5.2</td>
<td>Lifting the bushing</td>
<td>8</td>
</tr>
<tr>
<td>5.3</td>
<td>Reference measurement N°1</td>
<td>9</td>
</tr>
<tr>
<td>5.4</td>
<td>Conductor and terminal (A, B, C)</td>
<td>9</td>
</tr>
<tr>
<td>5.5</td>
<td>Dismounting the cable bolt (A) or conductor rod (B)</td>
<td>9</td>
</tr>
<tr>
<td>5.6</td>
<td>Connection cable bolt/conductor rope (A)</td>
<td>10</td>
</tr>
<tr>
<td>5.7</td>
<td>Split conductor rod</td>
<td>11</td>
</tr>
<tr>
<td>5.8</td>
<td>Rope conductor insulation (A)</td>
<td>11</td>
</tr>
<tr>
<td>5.9</td>
<td>Insulation for the dismountable conductor rod (B), (D)</td>
<td>11</td>
</tr>
<tr>
<td>5.10</td>
<td>Fastening the shield</td>
<td>11</td>
</tr>
<tr>
<td>5.11</td>
<td>Bushing without shield</td>
<td>12</td>
</tr>
<tr>
<td>5.12</td>
<td>Shield for rope or conductor rod applications</td>
<td>12</td>
</tr>
<tr>
<td>5.13</td>
<td>Shield with spring-loaded thrust piece</td>
<td>12</td>
</tr>
<tr>
<td>5.14</td>
<td>Fixed conductor (C)</td>
<td>12</td>
</tr>
<tr>
<td>5.15</td>
<td>Preparation of the terminal surface (A, B, C).</td>
<td>13</td>
</tr>
<tr>
<td>5.16</td>
<td>Cleaning of the bushing surface and the interface</td>
<td>13</td>
</tr>
<tr>
<td>5.17</td>
<td>Installing of the bushing</td>
<td>13</td>
</tr>
<tr>
<td>5.18</td>
<td>Damage during installation</td>
<td>13</td>
</tr>
<tr>
<td>5.19</td>
<td>Assembly of cable bolt (A) or dismountable conductor rod (B)</td>
<td>13</td>
</tr>
<tr>
<td>5.20</td>
<td>Flat seal system</td>
<td>14</td>
</tr>
<tr>
<td>5.21</td>
<td>Ring seal system</td>
<td>15</td>
</tr>
<tr>
<td>5.22</td>
<td>Flange installation</td>
<td>15</td>
</tr>
<tr>
<td>5.23</td>
<td>Tightening sequence</td>
<td>15</td>
</tr>
<tr>
<td>5.24</td>
<td>Fastening sequence</td>
<td>16</td>
</tr>
<tr>
<td>5.25</td>
<td>Flange earthing</td>
<td>16</td>
</tr>
<tr>
<td>6.</td>
<td>Assembling</td>
<td>17</td>
</tr>
<tr>
<td>6.1</td>
<td>Evacuation of the transformer</td>
<td>17</td>
</tr>
<tr>
<td>6.2</td>
<td>Ventilation and downtimes</td>
<td>17</td>
</tr>
<tr>
<td>6.3</td>
<td>Reference measurement No. 2</td>
<td>17</td>
</tr>
<tr>
<td>6.4</td>
<td>Voltage connection</td>
<td>17</td>
</tr>
</tbody>
</table>
7. Test tape and voltage tap.............................................................................................................. 18
   7.1. Measuring connection structure (3 kV).................................................................................. 18
   7.2. Measurement terminal purpose of use .................................................................................. 19
8. Measurements of $C_1$, $C_2$, $\tan \delta_1$, $\tan \delta_2$ (reference n°1)................................................................. 21
   8.1. Reference measurements No. 1............................................................................................ 21
   8.2. $C_1$ and $\tan \delta_1$ measurement (reference n°1) ...................................................................... 21
   8.3. $C_2$ and $\tan \delta_2$ measurement (reference n°1) ................................................................. 21
   8.4. Reference measurement No. 1 overview .............................................................................. 22
   8.4.1. Capacity $C_1$ and loss factor $\tan \delta_1$ ........................................................................... 22
   8.4.2. $C_2$ & $\tan \delta_2$ (bushing with measurement terminal) ..................................................... 22
   8.5. Temperature-dependent correction factors for $\tan \delta_1$ & $\tan \delta_2$ ...................................... 22
   8.6. Temperature-dependent correction factors for $C_1$ and $C_2$ .............................................. 22
   8.7. Permissible tolerances .......................................................................................................... 23
   8.7.1. For bushings $\leq$ 145 kV................................................................................................. 23
   8.7.2. For bushings $> 145$ kV ................................................................................................. 23
9. Measurements of $C_1$, $C_2$, $\tan \delta_1$, $\tan \delta_2$ (reference n°2)................................................................. 24
   9.1. Reference measurements No. 2............................................................................................ 24
   9.2. $C_1$ et $\tan \delta_1$ measurement (reference n°2) ...................................................................... 24
   9.3. $C_2$ and $\tan \delta_2$ measurement (reference No. 2) ................................................................. 25
   9.4. Reference measurement No. 2 overview .............................................................................. 25
   9.4.1. Capacity $C_1$ and loss factor $\tan \delta_1$ ........................................................................... 25
   9.4.2. $C_2$ and $\tan \delta_2$ (bushing fitted with measurement terminal) ........................................ 25
   9.5. Temperature-dependent correction factors for $\tan \delta_1$ and $\tan \delta_2$ ................................. 25
   9.6. Temperature-dependent correction factors for $C_1$ and $C_2$ .............................................. 26
   9.7. Site-dependent correction for $C_1$.......................................................................................... 26
   9.8.1. For bushings $\leq 145$ kV ............................................................................................... 26
   9.8.2. For bushings $> 145$ kV ............................................................................................... 26
10. Maintenance........................................................................................................................................ 27
   10.1. Maintenance schedule ........................................................................................................ 27
   10.2. Bushing maintenance ....................................................................................................... 28
   10.3. Testing the connections with a thermal imaging camera..................................................... 28
   10.4. Cleaning the silicone insulator ........................................................................................ 28
   10.5. Capacity and $\tan \delta$ loss factor checks ........................................................................... 28
   10.6. Spare parts ....................................................................................................................... 28
   10.7. Replacement of bushings .................................................................................................. 28
11. Dismounting (transport, repairs or disposal)..................................................................................... 29
   11.1. Dismounting the bushing for transport, repairs or disposal .............................................. 29
12. Repair.............................................................................................................................................. 30
   12.1. Bushing repairs ................................................................................................................. 30
   12.2. Silicone insulator repairs .................................................................................................. 30
13. Disposal ........................................................................................................................................... 31
   13.1. Special hazards during disposal ....................................................................................... 31
14. Type designation .......................................................................................................................... 32
   14.1. Rating plate ....................................................................................................................... 32
1. Safety information

1.1. Symbols and notes

Warnings in these operating instructions point at particular hazards and specify measures for avoiding them. There are three levels of warnings:

**DANGER**

This safety sign warns of immediate danger. If such notices are not observed, it can lead to heavy injuries and even death. Additionally, material damage can occur.

Examples of hazards: electric shock, fire hazard, explosion, poisonous gasses, slipping, working at height, impacts...

**CAUTION**

This safety sign warns of possible danger. If such notices are not observed, it can lead to injury and/or material damage.

Examples of hazards: burning, skin, eye or hearing injury, tripping hazards...

**NOTE**

This symbol identifies important information or points at risks that can result in material damage.

This notice suggest a particular course of action.

The structure of the warnings is as follows:

**SYMBOLS**

- **Type and source of hazard**
  - The possible results of not introducing the measures are put here.
  - Dangerous conditions or actions to be avoided are included here.
  - Measures for avoiding the hazards are located here.

1.2. Product safety

Micafil capacitor bushings of types RTKF, RTXF, RTZF, RTF, RTKG, RAKF, RTKK, DMB-OA, RAF, RTAK, RTIM, RMFF, RMF, RMI, ... are produced according to the state of the art and the recognized safety rules. Despite that, when handling the bushing and improperly using it, hazards to the health and life of the user or third persons, or damage to the bushing and other material assets can occur.

- The bushing must be used only in technically faultless state as well as in observance of the provisions and the operating instructions, and with awareness of safety and hazards.
- Damaged bushings must be decommissioned and replaced.

1.3. Personnel-related measures

- The executing personnel as well as those who supervise the work must have adequate training, have safety-related knowledge in connection with the various activities, and work accordingly.
- Personnel should trained and instructed concerning the planned works with the bushing based on the operating instructions.
- The personnel that must be trained, taught or instructed, or the personnel that is in the process of obtaining general training, must work with the bushing under the supervision of an experienced technical specialist in the field of high-voltage equipment.
- For working at height, the corresponding guidelines must be observed.
- Use compliant tools.
- Wear suitable PPE (personal protective equipment: helmet, working clothes, safety shoes, gloves, goggles).

1.4. Organizational measures

- Read the relevant chapters of the operating instructions carefully and observe all safety and hazard instructions.
- Keep the full and readable operating instructions ready, and provide all-time access to it to the operating personnel.
- Observe the safety rules of the operator of the high and medium voltage system and all the relevant provisions of the national and international safety authorities.
- Only authorize trained and instructed specialist personnel.
- Clearly determine, make known and observe the areas of responsibility for the works with the bushing.
- Only the personnel that before the beginning of the work have read and understood the relevant chapters of the operating instructions may be assigned for activities with bushings.
- Safety and hazard-conscious work must be inspected regularly observing the operating instructions. Observing the 5 rules for voltage-free work: Switch off, secure, test, earth/close-circuit, protect.
2. Structure of the bushing

2.1. General structure

The EasyDry type series are dry, oil-free and capacitive-controlled bushings. The main insulation body of the bushing comprises a resin-impregnated synthetic material, also called RIS Resin Impregnated Synthetics. The aluminum layers in the insulating body are used for capacitive field control.

The outdoor side is directly molded in silicone. A vent screw is brought to the flange of the bushing to be able to ventilate the transformer. The possible central pipe can also be ventilated with a vent screw mounted in the conductor. Threads located on the flange can be used for mounting crane eyes or pushing the bushing away from the transformer flange. A self-earthing measuring connection is integrated in the flange, making possible the final measurement of the capacity and the loss factor of the bushing in the installed state.

Depending on the design, EasyDry bushings can be equipped with a fixed conductor, dismountable conductor rod or a cable bolt for rope conductors.

The bushings can be operated in any post-assembly position. The data in the dimension sheet are binding.

NOTE

Micafil bushings are dimensioned and designed for applications in mineral oil. For organic oils, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner for further information.

Fig. 1: Structure of an EasyDry bushing with cable bolt for rope conductors
3. Packaging and delivery

### DANGER

**Prevention of reloading hazards, cutting injuries, electric shock, slipping and tripping accidents**

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- The personnel should be trained for the reloading activities.
- The personnel should have appropriate training for work with dangerous voltages (reference measurement No. 1).
- Observe weight data and markings for the center of gravity.
- Wear appropriate PPE

#### 3.1. Delivered state and reloading

The bushings are sent in wooden transport boxes for protecting them against damage. The lower part of the bushing is packaged in a plastic bag, provided with a desiccant and possibly a humidity indicator to protect it from humidity.

In the delivery, the cable bolt or conductor rod is installed in the bushing.

**NOTE**

- For every packaging type, it must be ensured that it is fully intact after transport.
- If the humidity indicator has turned pink => see Storage Recommendation Tab 1. (see Chapter 4.1).

**Fig. 1: Packaging, delivered state, reloading**

#### 3.2. Reference measurement No. 1

After the delivery, it is highly recommended that reference measurement No. 1 for main capacity C1, capacity C2 and loss factors $\tan \delta_1$ and $\tan \delta_2$ are used to determine is the bushing took up any humidity after transport (see Chapter 8).

#### 3.3. Repackaging

It must be made sure that the bushing and the blank insulating body of the bushing are packaged in the same way as for delivery with a plastic bag and a desiccant (incl. humidity indicator) to protect them against humidity.

For bushings that are repackaged without cable or conductor bolts, the opening of the conductor tube must be sealed on the air side of the bushing.

**NOTE**

- For further information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.

#### 3.4. Transport box

Gross and net weight as well as dimensions are included in the dispatch note.

The center of gravity is normally marked on the transport box if it is longer than 2 meters and if the center of gravity is not in the middle.
4. Storage

Prevention of reloading hazards, cutting injuries, electric shock, chemical hazards, slipping and tripping accidents

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- The personnel should be trained for the reloading activities.
- The personnel should have appropriate training for work with dangerous voltages (reference measurement No. 1).
- Observe weight data and markings for the center of gravity.
- Wear appropriate PPE.

4.1. Storage

Protection of the bushing depends on the storage location and the storage duration. In general, bushings must always be protected against humidity. For this reason, the recommendations specified in Tab. 1 must be observed.

- When stored, the bushing must be completely sealed in humidity-protective packaging.
- If the humidity indicator has turned pink, see Storage recommendations Tab. 1.

NOTE

- When stored, the bushing must be completely sealed in humidity-protective packaging.
- If the humidity indicator has turned pink, see Storage recommendations Tab. 1.

<table>
<thead>
<tr>
<th>Storage duration</th>
<th>Outdoor, protected against rain</th>
<th>Indoor space, dry (not condensing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 2 years</td>
<td>In original box, packed with PE tubular film.</td>
<td>In original box and original packaging.</td>
</tr>
<tr>
<td>Long-term storage,</td>
<td>No possible =&gt; Risk of irreparable damage</td>
<td>In original box and original packaging.</td>
</tr>
<tr>
<td>more than 2 years</td>
<td></td>
<td>Only in dry rooms (relative air humidity &lt;50%) at a temperature that is as constant as possible.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conduct regular inspections (at least once a year)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Desiccant amount/air conditioning: 2½ TME/m² (moderate) and 25 TME/m² (extreme)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- TME/m²: Desiccant units per m² of the barrier layer surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Desiccant according to the standard:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 Unit (DIN 55473A) = 1 Unit (MILD 3464 E) = 1/16 Unit (NF H-320 &amp; 321)</td>
</tr>
</tbody>
</table>

Tab. 1: Storage recommendations

NOTE

- For further information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.
5. Assembling

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**Prevention of reloading hazards, cutting injuries, electric shock, chemical hazards, falling, slipping and tripping accidents**

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- The personnel should be trained for the reloading activities.
- Appropriate climbing aids and supporting structures should be used.
- The personnel should be authorized to work at height.
- The personnel should have appropriate training for work with dangerous voltages (reference measurement No. 1).
- Wear appropriate PPE.

---

**NOTE**

- The protective cover of the silicone insulator should be laid out until the commissioning in order to avoid partial discharges through fingerprints.

---

**5.1. Recommended distance from the transformer wall**

The bushings are developed and tested for mineral oil applications. The field strengths in oil in the lower part of the bushing depend on the form of the surrounding parts as well as on the transformer oil.

The corresponding gaps (A) to the earthed structures under standard conditions are listed as a guideline in the following Tab. 2. This concerns the oil-side ends of the bushings according to the data of the dimension sheet for the bushing. Due to framework conditions, additional insulation measures and/or greater distances can be necessary. If necessary, the distance can also be reduced.

Non-insulated edges may only appear in the permitted area and should have a \( R_{\text{min}} = 5 \text{ mm} \).

---

**CAUTION**

- A possible current transformer must not be longer than L6 (see Fig. 5 and dimension sheet of the bushing), as the field is disrupted and a destruction of the bushing is possible.

---

<table>
<thead>
<tr>
<th>( U_{\text{r}} ) [kV]</th>
<th>( U_{\text{Ac test}} ) [kV]</th>
<th>Diameter of the shields ( \Phi ) [mm]</th>
<th>Recommended minimal distances A to the earthed parts of the transformer [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \leq 52 )</td>
<td>80</td>
<td>( \leq 105 )</td>
<td>-</td>
</tr>
<tr>
<td>72.5</td>
<td>90</td>
<td>140</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>160</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>123</td>
<td>-</td>
<td>115</td>
<td>130</td>
</tr>
<tr>
<td>230</td>
<td>-</td>
<td>145</td>
<td>145</td>
</tr>
<tr>
<td>145</td>
<td>-</td>
<td>170</td>
<td>170</td>
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<td></td>
<td>-</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>170</td>
<td>-</td>
<td>210</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>230</td>
<td>230</td>
</tr>
</tbody>
</table>

---

**Fig. 3: Recommended distance A from earthed parts (e.g. transformer wall)**

---

**5.2. Lifting the bushing**

Smaller types (<20 kg) can be picked up manually; larger types require a textile rope and lifting gear (crane, hoist etc.).

The lifting of the bushing from the transport box can take place with the use of two lifting gears and two suspension ropes. One of the suspension ropes is fastened with a textile rope sling directly onto the flange or on the crane eyes mounted on the flange, which then can be hung onto the tow hook of the first lifting gear. The other suspension rope can hang on the crane eye that can be screwed in the conductor at the top.
5.3. Reference measurement N°1

Before the installation, reference measurement No. 1 for main capacity C1, capacity C2 and loss factors tan δ1 and tan δ2 should be obtained (see Chapter 8) to establish a reference point for later measurements and also to determine if the bushing took up any humidity after transport and/or storage.

5.4. Conductor and terminal (A, B, C)

When connecting the bushing a solid conductive contact surface should be taken into account to minimize the influence of possible contact resistance (see Chapter 5.15).

Three different conductor types are available. All with a cable bolt for conductor rope, with dismountable conductor rod or fixed conductor variant, depending on the order.

![Diagram of conductor types]

Fig. 5: Details of the lower part of a bushing (schematic)

If any, future conductors and contact terminals on the winding side of the transformer should be oversized to avoid overheating in the area of terminal connections.

5.5. Dismounting the cable bolt (A) or conductor rod (B)

Depending on the order, the bushing is delivered with a cable bolt or a conductor rod. Before the bushing can be installed on a transformer, it is necessary to solder a conductor wire in the cable bolt or conductor rod. In order to be able to solder the conductor rope, the cable bolt or conductor rod must be dismounted and

In order to maintain sufficient and prolonged contact pressure, strong spring washer should be placed under the screws. In order to avoid disengagement through constant vibrations, a screw lock should be used.

In order to maintain sufficient and prolonged contact pressure, strong spring washer should be placed under the screws. In order to avoid disengagement through constant vibrations, a screw lock should be used.

The connection details can be found in the dimension sheet for the bushing.

![NOTE]

- Avoid magnetic screws here.
- The surfaces of the terminals may not be damaged.

![NOTE]

- Future conductors must not be made rigid (above and below), as the bushing must not pick up or transmit any movements or vibrations.
- The use of flexible terminal connections makes it also possible to avoid vibrations and movements of the transformer affecting nearby parts.

![NOTE]

- The feed and discharge lines, including their connection elements, such as terminal lugs, terminals or additional connectors, must be dimensioned in a way that no heat is brought to the connections of the bushing.
- The connective surfaces should be flat, even, clean and not unprocessed.

Tab. 3: Recommended tightening torques

<table>
<thead>
<tr>
<th>Strength class and Tightening torque [Nm]</th>
<th>A2-70</th>
<th>A4-70</th>
<th>8.8</th>
<th>10.9</th>
<th>12.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 6</td>
<td>8.5</td>
<td>8.5</td>
<td>10</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>M 8</td>
<td>21</td>
<td>21</td>
<td>25</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>M 10</td>
<td>41</td>
<td>41</td>
<td>49</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>M 12</td>
<td>72</td>
<td>72</td>
<td>86</td>
<td>120</td>
<td>145</td>
</tr>
</tbody>
</table>

Fig. 4: Fastening the suspension rope

NOTE

- The connections or control covers must not be used as a suspension point for protection against damage.
processed. Bushings with a conductor rod that, oil-side, has a flat terminal, need not be processed.

In order to remove the cable bolt or conductor rod, it is recommended that the vent screw is replaced with an eyebolt. A rope is attached to the eyebolt, preventing the slipping out of the cable bolt or conductor rod during the dismounting.

As is shown in Fig. 6, first, the clamp screw (3) is loosened and the clamp halves (4) are removed to the side. The cable bolt or conductor rod can be fully pulled out with the sealing sleeve from the central tube by loosening the clamp halves.

- Bushings with a conductor rod (B) that, oil-side, has a flat terminal, need not be processed.
- Before the bushing can be installed on a transformer, it is necessary to solder a conductor wire in the cable bolt. In order to be able to solder the conductor rope, the cable bolt must be dismounted and processed.

A slipping out of the cable bolt or conductor rod is possible.
- Secure with eyebolt and wire.

Fig. 6: Steps for dismounting the cable bolt/conductor rod.
1 Vent screw | 2 Eyebolt | 3 Clamp screw
4 Clamp halves | 5 Sealing sleeve | 6 Groove

The grooves (6) on the cable bolt/conductor rod help shifting the conductor several millimeters in the vertical direction.

5.6. Connection cable bolt/conductor rope (A)
Standard EasyDry bushings with conductor rod have an oil-side flat terminal and, thus, need no processing.

The conductor rope may be soft soldered or brazed to the cable bolt. The temperature necessary for the soft soldering must not exceed 450 °C, to avoid possible annealing of the cable bolt. The soldering must be performed carefully in order to ensure optimal contact. For brazing, the sealing and the terminal must be sufficiently cooled. Silver solders with melting temperatures of under 700 °C must be used here.

- Before the soldering, the vent screw and all the seals must be removed from the cable bolt.

Damage to the seal system can lead to malfunctions in the bushing or the transformer.

With an appropriate tool and an adjustment of the cable bolt, a pressing of the cable bolt is possible as an alternative.

The bolt is delivered unprocessed. For this reason, a hole suitable for soldering the conductor rope must be drilled in the bolt. The diameter of the drilled hole must be adjust to the diameter of the rope. Whenever possible, the bore design without a peak is recommended. The recommended maximum drilling depths and hole diameters for the standard cable bolt are provided in Fig. 7 and Tab. 4.

- Do not drill in the ventilation channel.

ATTENTION
- The cable bolt or conductor rod must not be scratched.

NOTE
- Do not drill in the ventilation channel.
Fig. 7: Processing on cable bolt.

Turned (left) and drilled (right) hole.
1 max. hole diameter | 2 cable bolt diameter
3 max. drilling depth | 4 cable bolt lower part length
5 ventilation channel | 6 diameter d3 (see bushing dimension sheet)

<table>
<thead>
<tr>
<th>Tube diameter d3 (6) [mm]</th>
<th>Max. hole diameter (1) [mm]</th>
<th>Cable bolt diameter (2) [mm]</th>
<th>Max. drilling depth (3) [mm]</th>
<th>Max. drilling depth (4)-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>38</td>
<td>33</td>
<td>36</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>40</td>
<td>45</td>
<td>45</td>
<td>20</td>
</tr>
</tbody>
</table>

Tab. 4: Recommended maximum drilling depth and hole diameter for a standard cable bolt

In order to make sure that the drilling is not performed too deeply, the following rules are recommended: Maximum drilling depth (3) is the same as the length of the cable bolt (4) minus 20 mm. The diameter of the power conductor should be at least a half of the tube diameter Ø d3 (6). The oil supply may not be impaired in the central bushing opening and in the open area of the shield.

5.7. Split conductor rod

If the bushing is equipped with a split conductor rod (see Fig. 12), the lower part of the conductor rod must be screwed to the upper part of the conductor rod after soldering. When installing, make sure that the screw are alternately tightened.

Fig. 8: Split conductor rod screw joint

1 screws and spring washers | 2 upper conductor rod | 3 lower conductor rod

The mounting screws can vary depending on the size of the conductor rod. Recommended tightening torques are:

<table>
<thead>
<tr>
<th>Thread</th>
<th>Tightening torque [Nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>M8</td>
<td>12</td>
</tr>
<tr>
<td>M10</td>
<td>25</td>
</tr>
<tr>
<td>M12</td>
<td>45</td>
</tr>
</tbody>
</table>

Tab. 5: Recommended tightening torques for the screws of the divided conductor rod (non-greased)

5.8. Rope conductor insulation (A)

To prevent partial discharges caused e.g. by switching transients between the rope conductor and the central tube of the bushing, the rope conductor must be wrapped in at least 1 mm of insulation material. The use of aramide paper (heat-resistant) is recommended.

Fig. 9: Rope conductor insulation. At least 1 mm insulation material thickness

If the insulation material thickness is too high, the bushing can overheat.

CAUTION

5.9. Insulation for the dismountable conductor rod (B), (D)

For a dismountable conductor rod, spark formation is avoided through insulating centering rings that separate the conductor rod from the central tube.

Fig. 10: Insulation for the dismountable conductor rod

1 insulating body | 2 tube | 3 centering ring | 4 conductor rod | 5 oil-air gap

5.10. Fastening the shield

Depending on the execution of the bushing, fixed or dismountable shields are used and mounted on the end of the bushing. These prevent the excessive stress on the transformer oil and simplify the structure of the power conductor insulation under the bushing.

The originally delivered shields are dimensioned with the help of modern methods and have a high-value, solid insulation layer on the surface.

Please observe installation recommendations (see Tab. 2).
5.11. Bushing without shield
Due to the resulting field strengths, bushings up to and including 72.5 kV do not need any shielding. For this reason, no further measures are needed on the bushing.

5.12. Shield for rope or conductor rod applications
This shield is dimensioned for rope and conductor rod applications (not only for conductor rod with flat terminal), because of which it is considerably shorter than the other types of shields.

![Fig. 11: Shield for rope or conductor rod application](image)
The shielding is available for voltages ranging from 24 kV. The shield is caulked with the supporting tube at the factory, and cannot be dismounted.

![NOTE](image)
- The rope conductor must not touch the shield not even due to vibration or other displacements.
- The shield for rope applications must not be dismounted.

5.13. Shield with spring-loaded thrust piece
This shield is longer compared to shields only for rope applications, for covering exposed edges at the terminal inside the shield.

The shielding is available for voltages ranging from 123 kV (optional, depending on the bushing type). The shielding can be mounted on the mounting ring and dismounted from it at the factory.

- In order to dismount the shield, the 3 spring-loaded pressure pieces must be loosened with a suitable wrench (not completely: unscrew it enough to keep them mounted on the shield).
- The shield can be shifted upwards or downwards.
- The terminal is then freely accessible and can be connected to the connection pieces. It must be in any case made sure that the contact resistance is kept as low as possible.
- Shift the shield back to its original position and place it to match the three threaded holes. The spring pressure pieces can be screwed on again.
- Finally, the screws must be tightened back with the specified torque (see Table 6).

![Fig. 12: Shield with spring-loaded thrust piece](image)

<table>
<thead>
<tr>
<th>Strength class and torque [Nm]</th>
<th>Tightening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread</td>
<td>A2-70</td>
</tr>
<tr>
<td>M 6</td>
<td>8.5</td>
</tr>
<tr>
<td>M 8</td>
<td>21</td>
</tr>
<tr>
<td>M 10</td>
<td>41</td>
</tr>
<tr>
<td>M 12</td>
<td>72</td>
</tr>
</tbody>
</table>

Tab. 6: Recommended tightening torques (greased and non-greased)

![NOTE](image)
- Do not let parts fall into the transformer tank.
- The fastening ring (3) at the connections must not be dismounted.

5.14. Fixed conductor (C)
The connection details can be found in the dimension sheet for this bushing. These bushings need no additional installation work and can be connected directly to the oil-side terminals.

![Fig. 13: Lower part of the bushing](image)
1 base terminal (according to IEEE C57.19.01)
5.15. Preparation of the terminal surface (A, B, C)
The connecting to the bushing should always be made with special care with respect to the reduced contact resistance.

Before the connection to the silver-plated contact surface, the protective film (grease) must be removed with a cloth. No cleaning agents/solvents may be used.

Contact surfaces without painting must first be treated to remove the layer of oxidation. A fine steel brush, abrasive paper or similar can be used for this purpose. The contact grease for electric connection surfaces is applied onto the entire surface; the surface is then brushed cross-wise until the entire oxide layer is removed. The oxide-free surface must then be cleaned with a cloth, and fresh contact grease is applied.

5.16. Cleaning of the bushing surface and the interface
The sealing surfaces on the impregnation of the transformers and on the bushing flange must be free of corrosion and dirt, and have a high surface texture (max. Ra 3.2). The cleaning of these surfaces takes place by soaking a lint-free cotton cloth in the cleaning liquid and wiping the sealing surfaces.

5.17. Installing of the bushing
The bushing should reach the ambient temperature before the installation to avoid condensation on its surface.

Only now, the bushing can be brought to the final position. First, the bushing is lifted with lifting gear and then slowly lowered on the flange side until the desired position is reached.

- The use of the possible thread for the lifting eye is always the best option to lift the bushing and install it.
- After the installation, the possibly used lifting eyes must be removed again.
- It is recommended that the corresponding threads for the lifting eyes are closed, e.g. with blind plugs.

5.18. Damage during installation
The insulator, whether a porcelain or a silicone variant, is recommended for avoiding impacts and stress concentration. Any use of tools that can cause such damage (e.g. chains, hooks) should be in any case avoided. For this reason, textile ropes must be used.
After the insertion, the cable bolt and conductor rod is fastened to the head of the bushing, and a possible head shield is mounted using the clamp system. The torques provided below must be observed (see Tab. 7).

<table>
<thead>
<tr>
<th>Thread</th>
<th>A2-70</th>
<th>A4-70</th>
<th>8.8</th>
<th>10.9</th>
<th>12.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>M 6</td>
<td>8.5</td>
<td>8.5</td>
<td>10</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>M 8</td>
<td>21</td>
<td>21</td>
<td>25</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>M 10</td>
<td>41</td>
<td>41</td>
<td>49</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>M 12</td>
<td>72</td>
<td>72</td>
<td>86</td>
<td>120</td>
<td>145</td>
</tr>
<tr>
<td>M 14</td>
<td>115</td>
<td>115</td>
<td>135</td>
<td>190</td>
<td>230</td>
</tr>
<tr>
<td>M 16</td>
<td>180</td>
<td>180</td>
<td>219</td>
<td>295</td>
<td>355</td>
</tr>
<tr>
<td>M 18</td>
<td>245</td>
<td>245</td>
<td>290</td>
<td>400</td>
<td>485</td>
</tr>
<tr>
<td>M 20</td>
<td>345</td>
<td>345</td>
<td>410</td>
<td>580</td>
<td>690</td>
</tr>
</tbody>
</table>

Tab. 7: Recommended tightening torques (greased and non-greased)

After dismounting the eye screw, the vent screw must be mounted back again. The recommended tightening torque is as follows: non-lubricated 30 Nm, lubricated 25 Nm.

**NOTE**

If the vent screw is not mounted correctly, water can get into the transformer.

---

5.20. Flat seal system

The central position of the flat seal is located directly under the hole circle of the flange plate and must be on both sides of the pitch circle to avoid flange deformation. The flat seal must be provided with the appropriate hole pattern for the flange. During installation, the flat seal must be put through the mounting bolts without tensile or compressive stress. If the flat seal is warped by the mounting bolt, the holes must be drilled out to avoid any stress on the flat seal (see Fig. 15).

---

**Note**

- If available, it must be made sure that the ventilation hole is not blocked by the flat seal.
- The flat seal (1) must be installed over the hole circle until the flange external side (2) (Ø D4), avoiding any shearing forces or damage (see Fig. 15).
5.21. Ring seal system

The position of the O-ring gasket is inside the hole circle of the flange plate, and inside the specified sealing surface (shown on the dimension sheet of the bushing).

![Diagram of O-ring gasket system](image)

Fig. 16: O-ring gasket system
1  O-ring gasket | 2  flange | 3  transformer / switchgear
4  hole circle diameter 4  hole circle diameter | 5  sealing surface
6  washer and nut

**NOTE**
- For systems that must be operated under pressure, an O-ring gasket system must be provided.
- The contact area of the flange plate (5) as well as the surface (3) should have no steps to avoid shearing forces or damage (see Fig. 16).

5.22. Flange installation

**Not damaging the sealing surface**
- When installing the flange, make sure that the sealing surface is not damaged.
- If the lifting eyes are on the lower side of the flange, these must be dismounted before the flange is tightened.
- For transformers, the contact area must have a flatness tolerance of no more than 0.3 mm.

**NOTE**

5.23. Tightening sequence

When the bushing flange is put in place, the screws/nuts must be first screwed as far as possible by hand. The flange fastening must be performed according to the following tightening sequence and Fig. 17:

1. Light fastening with wrench.
2. Fastening with 25% of the recommended torque.
3. Fastening with 75% of the recommended torque.
4. Fastening with 100% of the recommended torque.
5. Additional turn for control, with 100% of the recommended torque.

6. If possible, repeat steps 4 and 5 after 24 hours, as the clamp force can decrease in the first 24 hours.
- In order not to overlook any screws/nuts, the tightened screws/nuts must be marked with a felt pen.
5.24. Fastening sequence

The sequence to be maintained is defined in the following sectional drawings for the different hole patterns:

![Diagram of fastening sequence for different flange models]

Fig. 17: Fastening sequence for different flange models

5.25. Flange earthing

The bushings have one or two threads on the flange for its earthing.

- The flange of the bushing must always be earthed via a secure connection after installation.

NOTE
6. Assembling

6.1. Evacuation of the transformer

The use of a vacuum when filling the transformer is not problematic for the installed bushing. If the transformer oil is drawn in under vacuum, a following ventilation for the bushing or the transformer dome is normally not necessary. However, there is an exception in the bushings that protrude over the expansion vessel. For these, ventilation via the screw provided frontally on the cable bolt/conductor rod is recommended.

6.2. Ventilation and downtimes

Before each first-time commissioning, the central bushing tube must be ventilated via the screw located frontally on the cable bolt/conductor rod. As a result, the transformer oil in the central tube rises to the corresponding elevation of the transformer expansion vessel. If the bushing is not mounted vertically, the transformer dome should be ventilated with the vent screws on the flange of the bushing. The M12 vent screws are tightened on the cable bolt/conductor rod and on the flange as follows: 30 Nm unlubricated and 25 Nm lubricated. Bushings with a fixed conductor can only be ventilated at the flange. During the installation of the bushing, it must already be made sure that the flange ventilation and the terminal of the Buchholz relay is at the highest position as possible.

6.3. Reference measurement No. 2

After the installation and before the voltage is fed, reference measurement No. 2 for main capacity C1, capacity C2 and loss factors tan δ1 and tan δ2 should be obtained (see Chapter 9). These can serve as a good basis for condition assessment for later measurements. In order to make a more precise condition diagnosis, perform the measurement using Dielectric Frequency Response (DFR).

6.4. Voltage connection

- After the ventilation and before the commissioning of the bushing, it must be checked that all the vent screws are tightened.
- Furthermore, the indentation the vent screw in the cable bolt/conductor rod should be filled with a flexible silicone paste.
- An initial set-up of the phase-earth voltage must take place after operating for at least 12 hours after completing the filling of the transformer with oil.

- An initial set-up of the phase-earth voltage must take place after operating for at least 12 hours after completing the filling of the transformer with oil.

- The voltage connection should take place only after the nominal values for C1 and tan δ1 are successfully confirmed as implemented.
- During the initial switch-on, as well as when switching back on after a revision, all personnel should be removed from the site of the installation for at least 2 h.

- Whenever possible, a measurement of C1 and tan δ should take place with the high-voltage conductor suspended, especially if other transformer load the network with harmonics.
- The tan δ values must always be calculated for the reference value at 20 °C.
7. Test tape and voltage tap

7.1. Measuring connection structure (3 kV)

The measuring connection at capacitance-graded bushings gives access to the outermost control layer of the bushing. With it, the characteristic values of a busing (C & tanδ) can be measured using a suitable measuring device, e.g., Omicron CPC 100, Tettex 28xx or Doble. In operation, this covering must be connected to the flange via the spring contact available in the measurement terminal, and thus be earthed, or be connected to earth via an accordingly large capacity, to avoid voltage of more than 350 V or 1.5 kV (see Chapter 7.2).

Fig. 18: Measurement terminal in operating state, earthed with protective cover

The structure of the measurement terminal provides automatic earthing of the measurement covering via the flange. This earthing can be opened by full insertion of a 4 mm connecting coupling (see Fig. 19) or by connecting a transition coupler (see Fig. 20). If there is no measurement performed at the measurement terminal, it must be closed with the provided protective cover and an intact seal, to avoid weather effects.

Fig. 19: Measurement terminal. Connecting coupling

Fig. 20: Measurement terminal. Transition coupler (N or UHF connector)

<table>
<thead>
<tr>
<th>Transition coupler N or UHF (online measurement)</th>
</tr>
</thead>
<tbody>
<tr>
<td>▶ Cable wiring must be controlled regularly for correct contact: cable oxidation and cable breakage lead to bushing failure. For this reason, permanent reliance on online measurements is not preferable.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurement terminal tampering</th>
</tr>
</thead>
<tbody>
<tr>
<td>◉ Using screwdrivers or other tools to tamper with and push away the earthing spring is strictly forbidden (see Fig. 21).</td>
</tr>
<tr>
<td>▶ Use a connecting coupling or the transition coupling for measurement (see Fig. 19 and 20).</td>
</tr>
</tbody>
</table>

Fig. 21: Measurement terminal. Any manipulation prohibited

<table>
<thead>
<tr>
<th>Protective cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>◉ The bushing must never be commissioned without installing the protective cover on the measurement terminal or connecting a monitoring system.</td>
</tr>
<tr>
<td>▶ The correct function of the spring contact in the measurement terminal must always be tested before locking the bushing.</td>
</tr>
<tr>
<td>If this is not observed, the bushing or the transformer can suffer severe damage. Under unfavorable conditions, heavy personal injuries are also not out of the question.</td>
</tr>
</tbody>
</table>

Sealing
Spring
Protective cover

DANGER

CAUTION
7.2. Measurement terminal purpose of use

The measuring connection serves for the measurement of the main capacity $C_1$ of the bushing and the loss factor $\tan \delta$. The most common test circuit is shown below.

![Measuring setup diagram]

$C_z = C_1 \left( \frac{U_N}{\sqrt{3} \cdot U_2} - 1 \right) - C_2 \geq C_{z_{min}}$

To remove active power $P$ from the bushing, an ohm resistance $R_z$ must be switched on in parallel to $C_2$. The $P$ power is produced as a result of:

$$P = \frac{(U_N / \sqrt{3})^2}{R_z} \cdot \frac{1}{a^2 + b^2}$$

with:

$$a = 1 + \frac{C_z}{C_1}$$

and

$$b = \frac{1}{\omega C_1 \cdot R_z}$$

A condition in this case, however, is that $U \leq U_2$. This can be controlled with:

$$U = \frac{U_N / \sqrt{3}}{a^2 + b^2} \cdot \sqrt{a^2 + b^2} \leq U_2$$

**Secondary voltage $U_2$ (350 V or 1.5 kV)**

- When using the transition plug type N or type UHF by ABB, the secondary voltage must be limited to 350 V.
- When using an external transition plug, the secondary voltage must be limited to 1.5 kV.

**Primary voltage $U_1$ (12 kV)**

- The measurement voltage must not exceed the phase/earth voltage of the bushing.
**Voltage at the measurement terminal**

Without a connection of additional impedance, the voltage at the measurement terminal is always higher than 350 V or 1.5 kV for the C1 and C2 values.

⚠️ For this reason, for a bushing under voltage, the measurement terminal must be conductively connected to the flange (protective plug installed) or through a connected additional impedance, to limit the voltage to 350 V or 1.5 kV.

The achievable measurement precision during the voltage measurement depends on the changes in the C1 and C2 capacities, as well as in the connected impedance. As the capacities are temperature-dependent, a measurement precision of about 5% must be taken into account.
8. Measurements of C1, C2, tan δ1, tan δ2 (reference n°1)

**Prevention of reloading hazards, electric shock, slipping and tripping accidents**
- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- The personnel should be trained for the reloading activities.
- The personnel should have appropriate training for work with dangerous voltages.
- Wear appropriate PPE.

**Danger**

**Hazardous voltage**
- The measurements are performed using high voltage. The local safety regulations of high voltage installation must be observed.

**Note**
- These measurements must be performed before the installation, after the delivery and after long (≥ 1 year) or incorrect storage.

8.1. Reference measurements No. 1
The lifting of the bushing from the transport box can take place with the use of lifting gear, as well as a crane, a hoist etc. and two suspension ropes. One of the suspension ropes is fastened with a textile rope sling directly onto the flange or on the crane eyes mounted on the flange. The other suspension rope is fastened with a textile rope sling to the insulator between the shields, near the head or using the crane eyes mounted on the head or on the special clamp (optional).

The bushing should be lifted at least 1.5 m above ground to reduce parasitic influences when measuring main capacity C1, capacity C2 and loss factors tan δ1 & tan δ2.

The purpose of the measurements is to test the condition of the bushing. The results must be compared with the ABB test report.

In order to make a more precise condition diagnosis, perform the measurement using Dielectric Frequency Response (DFR).

8.2. C1 and tan δ1 measurement (reference n°1)

8.3. C2 and tan δ2 measurement (reference n°1)
8.4. Reference measurement No. 1 overview

8.4.1. Capacity C1 and loss factor tanδ1

<table>
<thead>
<tr>
<th>Voltage [V]</th>
<th>On-site measurements</th>
<th>On-site measurement, correction for temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 [pF]</td>
<td>tan δ1 [%]</td>
<td>C1 [pF] tan δ1 [%]</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 8: C1 and tan δ1 measurement overview

- The values of the measurements shall be compared with those indicated in the ABB test report (for 10kV).

8.4.2. C2 & tan δ2 (bushing with measurement terminal)

<table>
<thead>
<tr>
<th>Voltage [V]</th>
<th>On-site measurements</th>
<th>On-site measurement, correction for temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2 [pF]</td>
<td>tan δ2 [%]</td>
<td>C2 [pF] tan δ2 [%]</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 9: C2 and tan δ2 measurement overview

- The voltage of 2 kV must not be exceeded during this test.

8.5. Temperature-dependent correction factors for tan δ1 & tan δ2

The tanδ values must be calculated for the reference value at 20 °C, see below:
1. During the measurement, the ambient temperature must be measured (T_{ambient} = T_{bushing}).
2. With the curve or the table specified below, the correction factor fc can be determined at the corresponding ambient temperature, with which tan δ relative can be calculated with the following formula:

\[
\text{tan δ relative} = \frac{\text{tan δ measured}}{\text{fc}}
\]

- DANGER - The voltage of 2 kV must not be exceeded during this test.

Tab. 10: Correction factors

<table>
<thead>
<tr>
<th>RIS body temp. [°C]</th>
<th>tan δ Corr. Factor fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.43</td>
</tr>
<tr>
<td>10</td>
<td>1.19</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
</tr>
<tr>
<td>30</td>
<td>0.84</td>
</tr>
<tr>
<td>40</td>
<td>0.75</td>
</tr>
<tr>
<td>50</td>
<td>0.70</td>
</tr>
<tr>
<td>60</td>
<td>0.69</td>
</tr>
<tr>
<td>70</td>
<td>0.72</td>
</tr>
<tr>
<td>80</td>
<td>0.78</td>
</tr>
<tr>
<td>90</td>
<td>0.92</td>
</tr>
</tbody>
</table>

8.6. Temperature-dependent correction factors for C1 and C2

The C1 and C2 values must be calculated for the reference value at 20 °C as described below (the capacity increases by about 0.03% per °C):
1. During the measurement, the ambient temperature must be registered (T_{ambient} = T_{bushing}). The temperature difference should be calculated with the following formula:

\[
\Delta T = T_{bushing} - 20 \text{ [°C]}
\]

2. The measurement should be corrected with the following formula:

\[
C_{20°C} = C_{measured} \times (1 + \Delta T \times 0.0003)
\]
8.7. Permissible tolerances

8.7.1. For bushings ≤ 145kV

<table>
<thead>
<tr>
<th>C1</th>
<th>tan δ1</th>
<th>C2</th>
<th>tan δ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 5% (Relative)</td>
<td>+/- 0.05% (Absolute)</td>
<td>+/- 20% (Relative)</td>
<td>+/- 0.15% (Absolute)</td>
</tr>
</tbody>
</table>

8.7.2. For bushings > 145kV

<table>
<thead>
<tr>
<th>C1</th>
<th>tan δ1</th>
<th>C2</th>
<th>tan δ2</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 3% (Relative)</td>
<td>+/- 0.05% (Absolute)</td>
<td>+/- 20% (Relative)</td>
<td>+/- 0.15% (Absolute)</td>
</tr>
</tbody>
</table>

Tab. 11: Tolerances

NOTE

► If the measured values do not fit with the set tolerances, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.
9. Measurements of C1, C2, tan δ1, tan δ2 (reference n°2)

**DANGER**

- Prevention of falling accidents, electric shock, slipping and tripping accidents
  - The work area must be marked and kept clear.
  - All the activities must be supervised by a qualified person.
  - Appropriate climbing aids and supporting structures should be used.
  - The personnel should be authorized to work at height.
  - The personnel should have appropriate training for work with dangerous voltages.
  - The system is switched-off, secured and tested.
  - The primary and secondary side of the transformer or the switchgear is short-circuited and earthed.
  - The work can only be started after a complete electric discharge of the system.
  - Wear appropriate PPE.

**NOTE**

- When conducting the measurement, the surface must be cleaned and dry.
- In a humid environment, the measurement terminal should be dried — e.g. with a dryer.
- The measured tan δ and capacity must be calculated taking into account the reference value at 20 °C. It must be made sure that the transformer (for transformers) cools down very slowly and that the tan δ value of the bushing is heavily influenced by the transformer oil temperature in this period.
- The advantage of the DFR method is that it always gives the same curve of the tan δ value over the frequency independently from the temperature; this curve can be used with the Arrhenius equation to apply to any temperatures.

### 9.1. Reference measurements No. 2

After the installation of the bushings and before switching on the system or during the maintenance, main capacity C1, capacity C2 and the tan δ1 & tan δ2 loss factors must be measured. The results must be compared with the ABB test report. These measurements function as an important assessment basis during the entire service life of the bushings.

In order to make a more precise condition diagnosis, perform the measurement using Dielectric Frequency Response (DFR), as this method allows for a more precise condition assessment as a reference measurement of the bushing in the installed condition.

### 9.2. C1 et tan δ1 measurement (reference n°2)

Fig. 26: Typical measurements of C1 and tan δ1
9.3. C2 and tan δ2 measurement (reference No. 2)

9.4. Reference measurement No. 2 overview

9.4.1. Capacity C1 and loss factor tan δ1

<table>
<thead>
<tr>
<th>Voltage [V]</th>
<th>On-site measurement C1 [pF] tan δ1 [%]</th>
<th>On-site measurement, correction for temperature C1 [pF] tan δ1 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 12: C1 and tan δ1 measurement overview

**NOTE**

The measured values are regarded as the first measurement in the installed state, and cannot be compared with the test report.

9.4.2. C2 and tan δ2 (bushing fitted with measurement terminal)

<table>
<thead>
<tr>
<th>Voltage [V]</th>
<th>On-site measurement C2 [pF] tan δ2 [%]</th>
<th>On-site measurement, correction for temperature C2 [pF] tan δ2 [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tab. 13: C2 and tan δ2 measurement overview

**DANGER**

The voltage during this test must not exceed 2000 V.

9.5. Temperature-dependent correction factors for tan δ1 and tan δ2

The tan δ values must be calculated for the reference value at 20 °C, see below:

1. While the measurement, record ambient and oil temperature, and calculate the temperature of the condenser core:

   \[ T_{bushing} = \frac{2 \times T_{air} + T_{oil}}{3} \] [°C]

2. With the curve or the table specified below, the correction factor fc can be determined at the corresponding ambient temperature, with which tan δ relative can be calculated with the following formula:

   \[ \tan \delta_{relative} = \frac{\tan \delta_{measured}}{fc} \]
**Tab. 14: Correction factors**

<table>
<thead>
<tr>
<th>RIS body temp. [°C]</th>
<th>tan δ Corr. Factor fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.43</td>
</tr>
<tr>
<td>10</td>
<td>1.19</td>
</tr>
<tr>
<td>20</td>
<td>1.00</td>
</tr>
<tr>
<td>30</td>
<td>0.84</td>
</tr>
<tr>
<td>40</td>
<td>0.75</td>
</tr>
<tr>
<td>50</td>
<td>0.70</td>
</tr>
<tr>
<td>60</td>
<td>0.69</td>
</tr>
<tr>
<td>70</td>
<td>0.72</td>
</tr>
<tr>
<td>80</td>
<td>0.78</td>
</tr>
<tr>
<td>90</td>
<td>0.92</td>
</tr>
</tbody>
</table>

**9.7. Site-dependent correction for C1**

The measurement of the C1 capacity of installed bushings on site is always smaller than in the test area. Permissible tolerances

**9.8.1. For bushings ≤ 145kV**

<table>
<thead>
<tr>
<th>C1</th>
<th>tan δ 1</th>
<th>C2</th>
<th>tan δ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 5% (Relative)</td>
<td>+/- 0.05% (Absolute)</td>
<td>+/- 20% (Relative)</td>
<td>+/- 0.15% (Absolute)</td>
</tr>
</tbody>
</table>

**9.8.2. For bushings > 145kV**

<table>
<thead>
<tr>
<th>C1</th>
<th>tan δ 1</th>
<th>C2</th>
<th>tan δ 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 3% (Relative)</td>
<td>+/- 0.05% (Absolute)</td>
<td>+/- 20% (Relative)</td>
<td>+/- 0.15% (Absolute)</td>
</tr>
</tbody>
</table>

Tab. 15: Tolerances

> If the measured values do not fit with the set tolerances, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.

**NOTE**

**9.6. Temperature-dependent correction factors for C1 and C2**

The C1 and C2 values must be calculated for the reference value at 20 °C as described below (the capacity increases by about 0.03% per °C).

1. After the measurement, the temperature ΔT difference should be calculated with the following formula:

   \[ ΔT = T_{bushing} - 20 \ [°C] \]

2. The measurement should be corrected with the following formula:

   \[ C_{20°C} = C_{measured} \times (1 + ΔT \times 0.0003) \]
10. Maintenance

10.1. Maintenance schedule

<table>
<thead>
<tr>
<th>Level</th>
<th>System under voltage</th>
<th>tan δ1 &amp; tan δ2</th>
<th>Capacitance C1 &amp; 2</th>
<th>Visual inspection</th>
<th>Thermal</th>
<th>Insulator cleaning</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level A</td>
<td>System under voltage</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X (all 5 years until replacement)</td>
<td>-</td>
<td>See Tab. 17</td>
</tr>
<tr>
<td>Level B</td>
<td>System switched off and earthed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>See Tab 18</td>
</tr>
</tbody>
</table>

Tab. 16: Maintenance schedule and maintenance intervals

DANGER

Prevention of falling accidents, chemical hazards, electric shock, slipping and tripping accidents
- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- Appropriate climbing aids and supporting structures should be used.
- The personnel should be authorized to work at height.
- The personnel should have appropriate training for work with dangerous voltages.
- The system is switched-off, secured and tested.
- The primary and secondary side of the transformer or the switchgear is short-circuited and earthed.
- The work can only be started after a complete electric discharge of the system.
- Wear appropriate PPE.

Tab. 17: Risk analysis level A

Prevention of electric shock, slipping and tripping accidents
- The work area must be marked and kept clear.
- The personnel should have appropriate training for work with dangerous voltages.
- Wear appropriate PPE.

Tab. 18: Risk analysis level B

NOTE

The maintenance schedule according to Tab. 16 shows the typical maintenance intervals recommended for rated loads of the bushing. The service life estimates are based on conservative empirical values and are as a rule higher.
10.2. Bushing maintenance
Tab. 16 provides a schedule for the expected service life as well as the maintenance intervals of the RIP product. This overview is only a recommendation.

10.3. Testing the connections with a thermal imaging camera
It is recommended during the inspection and after the first commissioning that the connections are tested with a thermal imaging camera (reasons: possible loose or oxidized connections, insufficient crimping).

**NOTE**
- Thermography is only useful after 24 hours under nominal load.

10.4. Cleaning the silicone insulator
Cleaning the silicone insulator is not normally necessary in operation, as silicone due to its hydrophobic nature and the transfer of the hydrophobia in the contaminated surface maintains its water-repellent properties even with high contamination and age.

However, if the silicone surface becomes dirty, it can be cleaned with water. If it is not enough, the following can be used for cleaning:
- Light contamination: 5% water solution of cleaning agents (e.g. soap).
- Medium to strong contamination: alcohol.

The cleaning of these surfaces takes place by soaking a lint-free cotton cloth in the cleaning liquid and wiping the silicone surface.

**DANGER**
- Cleaning of the bushing may only take place with the installation shut down.

**CAUTION**
- Clean only in well-ventilated rooms.
- Avoid skin and eye contact with the cleaning liquid, do not inhale the vapors.
- No open flames with volatile solvents.
- Work and protective measures must comply with the safety data sheet and local guidelines.
- Wait for 24 hours after the cleaning before commissioning.

10.5. Capacity and tan δ loss factor checks
Detailed information about measuring the capacity and tan δ can be found in Chapters 8 and 9.

10.6. Spare parts
When ordering spare parts, the production number from the rating plate on the flange of the bushing must always be provided.

10.7. Replacement of bushings
If a reserve bushing is needed, the production number from the rating plate on the flange of the bushing must always be provided if requested.
11. Dismounting (transport, repairs or disposal)

**Prevention of reloading hazards, cutting injuries, electric shock, chemical hazards, falling, slipping and tripping accidents**

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- Appropriate climbing aids and supporting structures should be used.
- The personnel should be authorized to work at height.
- The personnel should be trained for the reloading activities.
- The personnel should have appropriate training for work with dangerous voltages.
- The system is switched-off, secured and tested.
- The primary and secondary side of the transformer or the switchgear is short-circuited and earthed.
- The work can only be started after a complete electric discharge of the system.
- For transformers, the available current transformer must always be short-circuited and earthed at the transformer, preferably in the terminal box. This is to suppress the displaced earth potentials.
- Wear appropriate PPE.

**DANGER**

**11.1. Dismounting the bushing for transport, repairs or disposal**

The work steps described in Chapter 5 must be performed in reverse order.

To ensure safety for this activity, the above recommendations must be observed.

**NOTE**

- For further information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.
12. Repair

12.1. Bushing repairs
Extensive repairs should be conducted in consultation with High Voltage Components at ABB Switzerland Ltd. The production number as well as a precise description of the damage do be repaired are necessary for this.

12.2. Silicone insulator repairs
Damaged silicone insulators must be replaced or repaired.

As the manufacturers of the silicone insulators use different types of silicone for shielding, different repair compounds (LSR or HTV) must be used, and the corresponding vulcanization times must be observed. For this reason, in case of repairs please consult High Voltage Components at ABB Switzerland Ltd, providing them with photographs of the damaged area as well as the serial number of the bushing.

Depending on the damage case, a repairs kit can be provided. For this reason, in every case please consult High Voltage Components at ABB Switzerland Ltd before repairs.

In case of repairs, the surfaces of the interfaces and their environment must be cleaned with lint-free cloth soaked in acetone; alternatively, a narrow piece can be cut out from the damaged area with a knife to reach a clean surface.

> Apply the repair compound and vulcanize.

---

**Prevention of falling accidents, chemical hazards, cutting injuries, electric shock, slipping and tripping accidents**

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- Appropriate climbing aids and supporting structures should be used.
- The personnel should be authorized to work at height.
- The personnel should have appropriate training for work with dangerous voltages.
- The system is switched-off, secured and tested.
- The primary and secondary side of the transformer or the switchgear is short-circuited and earthed.
- The work can only be started after a complete electric discharge of the system.
- Wear appropriate PPE.

---

**NOTE**

For further information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.
13. Disposal

Prevention of reloading hazards, cutting injuries, chemical hazards, falling, slipping and tripping accidents

- The work area must be marked and kept clear.
- All the activities must be supervised by a qualified person.
- Appropriate climbing aids and supporting structures should be used.
- The personnel should be authorized to work at height.
- The personnel should be trained for the reloading activities.
- Wear appropriate PPE.

13.1. Special hazards during disposal

After the service life of the bushing expires, it should be disposed of in accordance with the local laws and regulations.

The disposal should be performed by a recycling company that specializes in these activities.

The product, including accessories, does not contain any toxic basic components

Special case for bushings equipped with spring assemblies

Depending on the type of the bushing, spring assemblies can be included on the air side. Due to the high mechanical tensioning, sawing the bushing apart is complex and dangerous.

- Danger from flying objects. The release of tension in the spring assembly must be performed with utmost caution.

For further information, please contact High Voltage Components at ABB Switzerland Ltd or your local ABB partner.
### 14. Type designation

#### 14.1. Rating plate

<table>
<thead>
<tr>
<th>Rating plate</th>
<th>DMB-OA 72.5 – 325 / 1600</th>
</tr>
</thead>
</table>

- **Rated current** [A]
- **Lightning impulse voltage** \(1.2/50 \mu s\) (BIL) [kV]
- **Maximum voltage** [kV]

D = dry / M = molded / B = bushing / O = oil / A = air
For further information, please contact

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