

O Plus C™ condenser bushing instructions

Scope

This document describes the application recommendations as well as installation and maintenance guidelines for the O Plus C™ and O Plus C II™ family of condenser bushings. This information does not cover all possible contingencies which may arise during application, installation, operation, or maintenance nor all details and variations of this equipment. The bushing outline drawings contain pertinent information for a specific bushing, which is required for safe and proper installation and application. Review the outline drawing thoroughly before applying, installing or energizing a bushing. If you require further information, contact your ABB representative.

Type O Plus C and O Plus C II condenser bushings, which will be referred to as O Plus C bushings within this document, are available in voltage classes from 25 kV through 550 kV. Type O Plus C bushings meet all applicable dimensional requirements of the IEEE Standard C57.19.01-2000 and meet or exceed all applicable electrical and mechanical requirements of the IEEE Standard C57.19.00-2000 and/or IEC Standard 60137. In many cases, type O Plus C condenser bushings are also manufactured to meet the thermal requirements of the Canadian CSA Standard CAN/CSA-C88.1-96. These bushings are manufactured exclusively at the ABB facility in Alamo, Tennessee.

General Information

Type O Plus C bushings consist of an oil-impregnated, multi layered, paper condenser wound on a central tube. The condenser is housed in a sealed cavity formed by the upper and lower porcelain insulators, high strength flange, and oil expansion chamber. The assembly is sealed and clamped by a spring loaded center clamping assembly. This cavity along with the condenser is evacuated and then filled with highly processed insulating oil. The result of this design and process is a very low moisture content and low bushing power factor. A nitrogen gas cushion above the oil allows thermal expansion of the oil in the cavity. The low moisture content and low power factor are maintained throughout the life of the bushing by sealing the bushing cavity.



Safety Information

Keep this instruction book available to those responsible for the installation, operation, and maintenance of the bushing. The installation, maintenance, and operation of a bushing presents numerous unsafe conditions, including, but not limited to, the following:

- High pressures
- Lethal voltages
- Moving machinery
- Heavy components

Specialized procedures and instructions are required, and must be adhered to when working with bushings. Failure to follow instructions could result in severe personal injury, death, and/or property damage. Additionally, all applicable safety procedures such as OSHA requirements, regional and local safety requirements, safe working practices, and good judgment must be used by personnel when installing, operating, and maintaining bushings.

Safety as defined in this document, involves two conditions:

- Personal injury or death
- Product or property damage (including damage to the bushing or other property, and reduced bushing life)

Safety notations are intended to alert personnel of possible personal injury, death or property damage. The safety notations are headed by one of three hazard intensity levels which are defined as follows:

- Danger - immediate hazard which will result in severe personal injury, death, or property damage
- Warning - hazard or unsafe practice which could result in severe personal injury, death, or property damage
- Caution - hazard or unsafe practice which could result in minor personal injury, or property damage

Shipping methods

Condenser bushings are shipped from the factory with the upper end elevated a minimum of seven degrees above the lower end or in an upright position. ABB recommends that these bushings be shipped or stored in their own crates or shipped at a seven degree or higher angle (upper end being above the lower end) to prevent any entrapment of gas in the insulation, which could compromise the insulation life.

! Warning

Failure to follow these guidelines may result in damage to the bushing and cause an electrical failure. Failure to follow these guidelines will also void the warranty on the bushing.

Bushings must have the top end elevated during shipment and storage. Bushings should be shipped in their own individual crates. Generally, two supports are necessary for the horizontal shipment of bushings. One support is under the flange and the other is under the upper porcelain for bushings with a sight glass or under the expansion chamber for bushings equipped with a metal expansion chamber.

If it is not possible to ship the bushings at an angle or in the upright position, then bushings with a voltage rating up to and including 72.5 kV can be shipped in a horizontal position when the following guidelines are observed:

- The bushings can be shipped in a horizontal position if the maximum period in transit does not exceed 15 days.
- The bushings can be stored in a horizontal position for a maximum period of 30 days (including 15 days of transit).
- Bushings that have been in a horizontal position for a total period of 30 days or less must be placed in a vertical position for a minimum of 48 hours prior to the application of voltage. This applies to any time period 30 days or less. After the bushing is upright, gently rock it to release any nitrogen gas that may be trapped in the insulation.
- If the bushings are in transit or are stored in a horizontal position exceeding the time in these guidelines, contact ABB for recommendations. Re-impregnation of the condenser at the factory will be required if the specified time periods are exceeded.

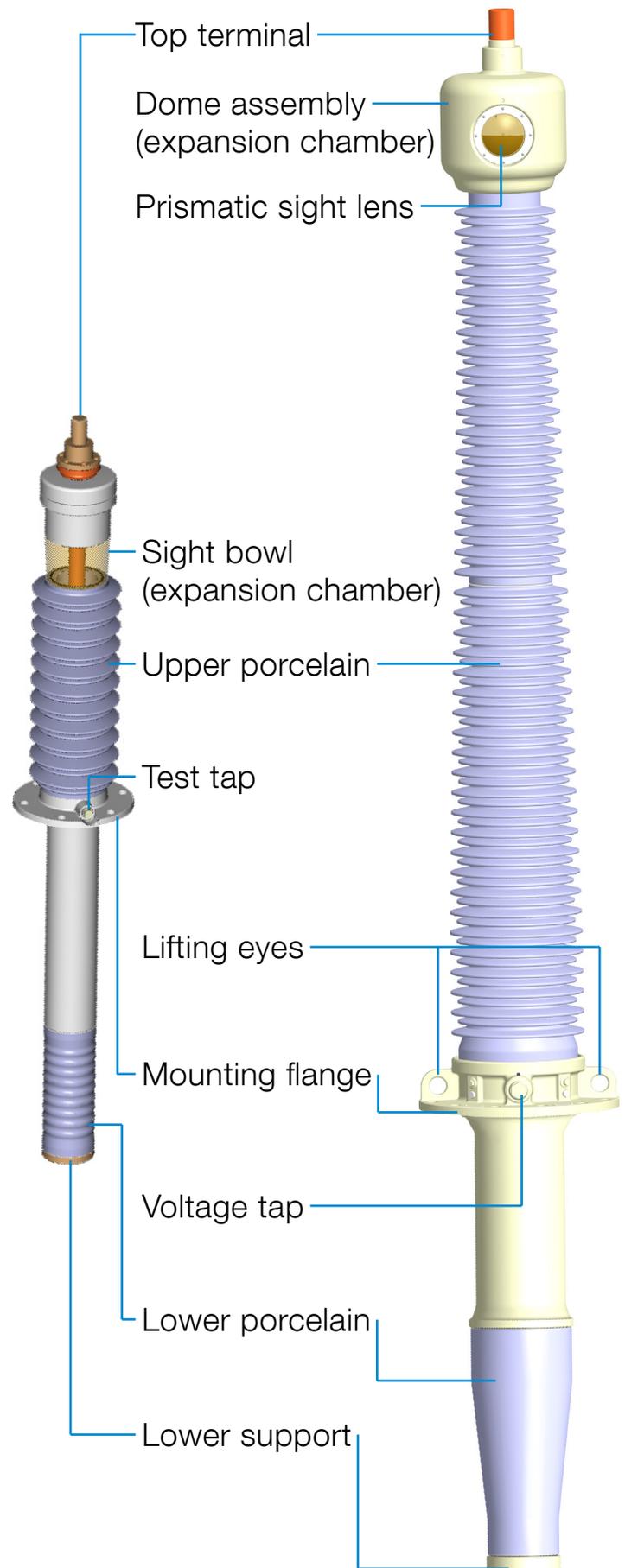


Figure 1 - Bushings overview

Handling

When a bushing is received, examine it for any damage incurred during shipment. Inspect the surface of the porcelain for small breaks or cracks. If damage or rough handling is evident, file a claim with the transportation company and immediately notify ABB.

Before lifting the bushing, remove any banding iron, clamps or mounting flange bolts holding the bushing to the shipping crate. Bushings with a voltage rating higher than 72.5 kV have lifting eyes in the flange. Always attach the main lifting tackle to the lifting eyes. Bushings with a voltage rating up to and including 72.5 kV do not have lifting eyes. Instead, these bushings can be lifted using a rope sling placed under the top shed of the upper porcelain.

Due to the weight and dimensions of bushings, lifting can be hazardous and should only be attempted by trained professionals using properly rated equipment and components. Be sure to maintain a seven degree or greater angle during the lift to prevent any entrapment of gas in the insulation of the bushing.

! Warning

Before lifting the bushing from the crate, the porcelain should be inspected thoroughly for cracks and damage as personal injury or property damage may occur if the porcelain breaks during the lifting process.

Unpacking

When a bushing is received, examine it for any damage incurred during shipment. Inspect the surface of the porcelain for small breaks or cracks. If damage or rough handling is evident, file a claim with the transportation company and immediately notify ABB.

Note the oil level as explained in the section titled *Liquid level indication* and examine the surface of the porcelain and sight lenses/bowls for small breaks or cracks. Though breaks or cracks may not immediately affect the oil level, they are cause for concern. If breaks or cracks are found contact ABB for further instruction.

Type O Plus C bushings are oil pressure tested at 40 psig during manufacture. The presence of an oil film on the surfaces or joints of a bushing may be residual oil remaining after the factory electrical testing. Though a leak is unlikely, the presence of an oil film should be investigated.

To inspect for residual oil versus an actual leak, the bushing surface should be thoroughly cleaned with isopropyl alcohol and a clean, dry cloth. Observe for leaks during a 48 hour period and check for the correct oil level. If the bushing is found to leak, contact ABB for further instructions.



Figure 2
Standard method for lifting bushings rated through 72.5 kV

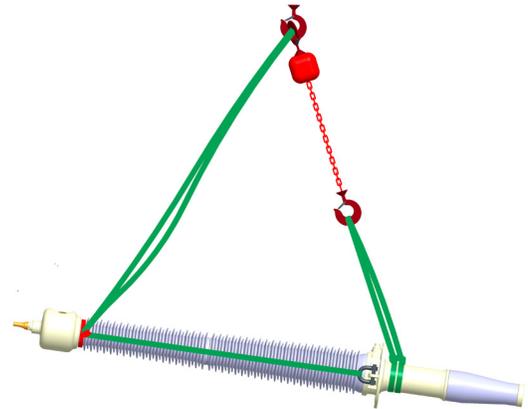


Figure 3
Standard method for lifting bushings rated above 72.5 kV with a single crane hook

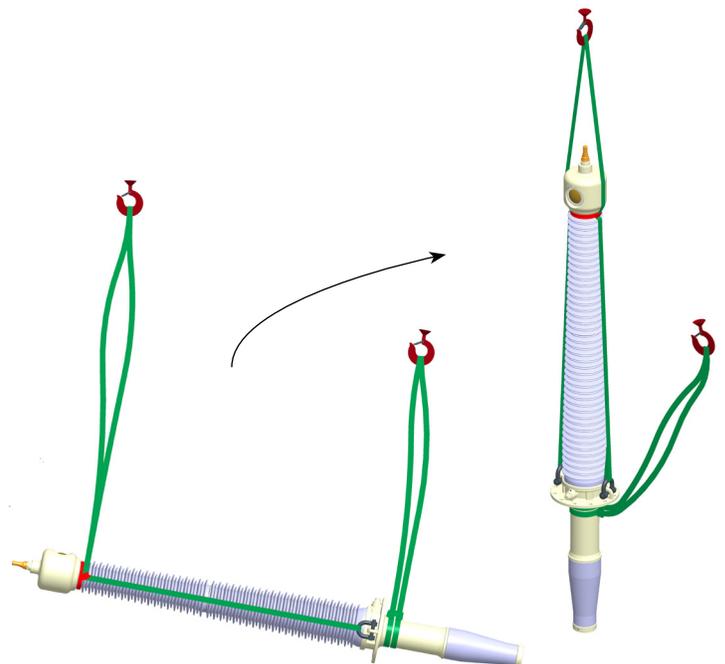


Figure 4
Standard method for lifting bushings rated above 72.5 kV with two crane hooks

Lifting

Bushings are shipped from the factory either in upright crates or horizontal crates with the upper end elevated a minimum of seven degrees above the lower end. It is critical to maintain at least seven degrees of elevation throughout the lifting and mounting process.

! Warning

Read, understand, and follow all instructions when lifting a bushing. Failure to use proper equipment or follow instructions could result in injury, property damage and/or loss of life.

The method for lifting bushings varies slightly since bushings rated 72.5 kV and below do not have lifting eyes. Instead, when lifting from an upright crate, these bushings can be lifted by the use of a rope sling placed under the top shed of the upper porcelain as illustrated in figure 2.

For lifting bushings from a horizontal crate, ABB recommends using two crane hooks.

- For bushings rated above 72.5 kV tie two choker ropes or slings to the bushing between the dome lower end and the first shed of the porcelain. Slings/ropes should be tied in a manner that an eye is formed in line with the lifting lugs on the bushing flange.
- For bushings less than 72.5 kV a single rope sling can be secured under the top shed of the upper porcelain and attached to one crane hook.
- Next, for bushings rated above 72.5 kV attach two slings to one crane hook. Pass the other end of these slings through the eye of each choker rope/sling that is tied around the top of the bushing. Then, attach a clevis to the end of each of these slings. Without crossing the slings, attach the clevises to the lifting lugs on the mounting flange.
- For all bushing ratings, choke a sling around the flange barrel and then attach the other end of the sling to the second crane hook.
- For all bushing ratings, lift the bushing from the crate by raising both of the crane hooks simultaneously. Be sure to maintain an angle of seven degrees or more.
- Once clear of the crate, the bushing can be shifted to vertical by continuing to raise the hook attached to the upper end of the bushing.
- For proper oil level indication on bushings provided with a prismatic sight lens, the indicator should be oriented so that the sight lens faces sideways when the bushing is mounted at an angle (Figure 5).

ABB recommends using two crane hooks while lifting or mounting a bushing. However, if two crane hooks are not available then a single crane hook with a hoist can be used.

- Begin by attaching the chain hoist to the crane hook.
- For bushings rated above 72.5 kV tie two choker ropes or slings to the bushing between the dome lower end and the first shed of the porcelain. Slings/ropes should be tied in a manner that an eye is formed in line with the lifting lugs on the bushing flange.

- For bushings less than 72.5 kV a single rope sling can be secured under the top shed of the upper porcelain and attached to the crane hook.
- Next, for bushings rated above 72.5 kV attach two slings to the crane hook. Pass the other end of these slings through the eye of each choker rope/sling that is tied around the top of the bushing. Then, attach a clevis to the end of each of these slings. Without crossing the slings, attach the clevises to the lifting lugs on the mounting flange.
- For all bushings regardless of the kV class, choke a sling around the flange barrel and then attach the other end of the sling to the chain hoist.
- Mount the bushing by raising the crane hook and lowering the chain hoist. Be sure to maintain an angle of seven degrees or more.
- For proper oil level indication on bushings provided with a prismatic sight lens, the indicator should be oriented so that the sight lens faces sideways when the bushing is mounted at an angle (Figure 5).

Storing

A type O Plus C bushing can be stored in the shipping crate. However, for long term storage, ABB recommends storing the bushing in a vertical position in a clean, dry place. If a bushing must be stored in a position other than vertical, you must elevate the top end at an angle of at least seven degrees from horizontal. This ensures that there is adequate oil coverage of the condenser. All type O Plus C bushings are shipped with the top end elevated to assure coverage of the condenser.

For long term storage, suitable protections must be provided for terminals and mounting hardware. You must coat terminal contact surfaces and the gasket surface on the underside of the flange with grease. Greasing these surfaces will help prevent oxidation.

Additionally, if your bushing has a voltage tap you should fill the voltage tap housing with clean, dry transformer oil. This will prevent condensation and corrosion. Remove the fill plug located on the top of the voltage tap. Fill the tap cavity leaving a space of one quarter of an inch in the chamber for oil

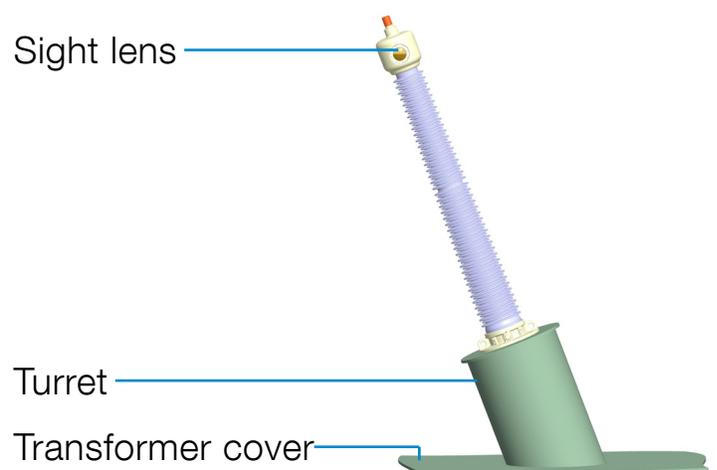


Figure 5 - Angular mounting

expansion. Next, coat the threads on the fill plug with PTFE tape or PTFE based pipe sealant. Finally, replace the plug and ensure that the plug is tight. No additional action is required for a bushing with a test tap.

Installation

Prior to installation, wipe the bushing clean of all dust, grease, oil or particles of packing materials using a clean dry cloth. If necessary, an ammonia based glass cleaner can be used to clean the bushing surfaces. Care should be taken to avoid getting the ammonia based cleaner on any gasket materials. Clean the inside of the conductor tube (if open at the oil end) with a denatured alcohol soaked swab to remove any contaminants that may have entered the tube during shipping or storage.

The capacitance and power factor of the bushing should be measured in accordance with the sections titled *Field measurements* and *Measurement guidelines* prior to energizing. After placing the bushing upright (orienting vertically), check to ensure that the internal bushing oil is at the proper level. Before energizing keep the bushing upright (vertically oriented) for a minimum of 48 hours. Always allow the bushing to equalize to the temperature of the equipment on which it is being installed prior to energizing. For final mounting, it is important to ensure the mounting angle does not exceed that of the design. Please refer to the outline drawing for specific mounting details.

! Warning

The installation of a bushing involves the use of heavy equipment as well as high voltages. Do not attempt to move or install a bushing unless you are qualified to do so and have fully read and understood the instructions in this document.

Bolting

Tighten the mounting bolts a fraction of a turn at a time, working in a crisscross or star pattern until all bolts are uniformly tight. Tighten sufficiently to seal the bushing to the equipment. Normally, the torque values listed below will provide adequate gasket compression for sealing and fastening to the equipment. Please note, that in some cases the indicated torque values may require grade 5 or higher mounting hardware.

Bolt diameter in inches	Threads per inch	Torque in ft-lbs (N-m)	
		72.5 kV and below	Above 72.5 kV
1/2	13	25 (34)	50 (68)
5/8	11	30 (41)	62 (84)
3/4	10	35 (48)	75 (102)
1	8	N/A	100 (136)



Figure 6 - Test tap



Figure 7 - Voltage tap

Liquid level indication

The factory adjusts the oil level in the bushing to the normal level at approximately 25 °C. Unless there is subsequent mechanical damage to the bushing, which results in loss of oil, the fill level should be satisfactory for the life of the bushing. Since fluctuations in oil level will occur with changing temperatures, there is a nitrogen gas blanket above the oil column to provide a cushion for this expansion.

The oil level should be visible during normal operation. When a low oil level is indicated, examine the bushing for possible loss of oil, which could result in electrical failure. A low level typically exists when the level has disappeared below the prismatic sight lens or sight bowl. Please see figures 8 and 9 for typical liquid levels. However, note that at extremely low temperature the oil level may not be visible. If the bushing has a liquid level gauge, the gauge face will indicate "LOW" should the liquid level ever drop below the normal level.

! Warning

Do not operate or test a bushing which does not have a visible oil level. This could result in serious damage to the bushing, equipment on which the bushing is mounted, and/or the testing equipment being used. Operation could result in severe personal injury, death or property damage.

Gas bubble evolution

Because of the complexity and the many variations of transformer processing, we cannot provide specific advice. It is left to each transformer manufacturer to evaluate these recommendations and adjust their processes and procedures to suit their specific needs. Any closed, fixed volume vessel containing oil and a gas space will generate bubbles when exposed to rapid heating and cooling. Since the vast majority of oil insulated paper (OIP) bushings fit this description virtually all are candidates for gas bubble evolution (GBE). Many variables can contribute to the severity of GBE. The most significant are the amount of heating, the ultimate maximum temperature of the bushing, the ratio of gas to oil, the length of the heating/cooling cycle and the cooling characteristics of the transformer/bushing combination.



Figure 8 - Sight bowl liquid level

The common issue, when it occurs, is partial discharge (pd) created within the temporary bubbles generated by GBE during transformer factory testing. This pd is problematic because it interferes with determining the level and acceptability of pd produced by the transformer being tested. There is no evidence that this pd is a risk to the bushing or to the transformer once the bubbles have dissipated. Venting the bushing accelerates this bubble dissipation. If the bushings are vented during the entire heating/cooling process of transformer thermal testing, the GBE can be prevented completely. Only the transformer manufacturer can evaluate the risk of contamination of the bushing during this cycle because the risk varies based on the duration of the exposure as well as the environmental conditions at the test site.

Our default recommendation is not to open a bushing because this can compromise the integrity of the bushing's internal environment. Opening the bushing adds the risk of contamination and the possibility of failure to reseal the bushing properly. However, we recognize that there are circumstances which mandate breaking the bushing seal. Venting is done on a relatively frequent basis by transformer manufacturers and bushing users without unsatisfactory results.

Do not vent bushings unless:

- History has indicated that during your specific processing/testing process you have experienced GBE in the past with similar applications of the same style bushing or
- When a specific bushing is believed to be experiencing GBE and a remedial action, other than extended waiting, is required.



Figure 9 - Sight lens liquid level

Additionally, under the following special cases ABB recommends that the bushings be vented during the thermal testing and not resealed until the dielectric testing is complete. Extreme care should be taken to prevent contamination and to reestablish a robust seal of the bushing with the gas space purged with dehydrated Nitrogen.

- An exception to the general recommendation previously noted is in the case of extreme thermal performance testing such as for overloads.
- If the nameplate value of a bushing rated 3000 A or above is to be exceeded for more than 10 minutes
- If the heating cycle is to exceed 36 hours
- If the top oil temperature of the transformer is expected to exceeded 100 °C

Internal electrical connections

The method used to make connections between a bushing and the equipment on which it is mounted will depend on the type of connection used during the manufacture of the equipment.

Bottom connected bushings

Bushings rated 1200 amperes and higher carry the current through the center conductor. Depending on the rating, a circuit breaker interrupter or transformer terminal maybe connected to the lower end. There are a variety of lower end options to coordinate with IEEE C57.19.01-2001. Please refer to the specific outline drawing for details.

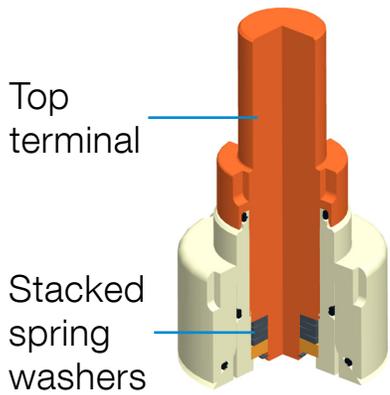


Figure 10 - Bottom connected

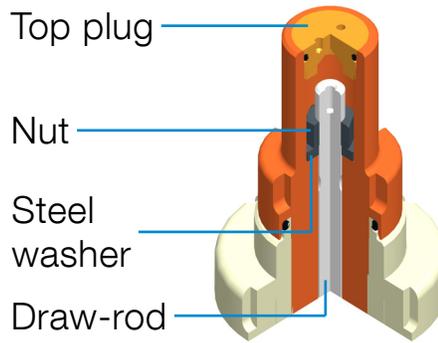


Figure 11 - Draw-rod connected

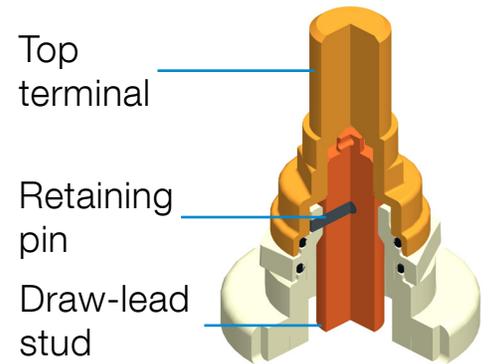


Figure 12 - Draw-lead connected

Draw-rod connected bushings

Draw-rod connected bushings allow a manufacturer to disconnect a bushing and/or its turret for shipment of the equipment. To install a bushing which utilizes a draw-rod connection please contact ABB for supplementary instructions.

Draw-lead connected bushings

Draw-lead bushings have a hollow conductor through which a current carrying cable can be passed and attached to the draw-lead stud of a bushing. Please note, the cable is part of the equipment on which the bushing is being installed and is not supplied with the bushing. Generally bushings rated above 72.5 kV with current ratings of 800 amperes or less have a conductor tube through which an insulated, flexible cable is pulled. Bushings rated at or below 72.5 kV with a current rating of 400 amperes are also designed with this type of hollow conductor. Additionally, bushings rated at or below 72.5 kV with a current rating of 400/1200 amperes are convertible from draw-lead (400 amperes) to bottom connected (1200 amperes).

To install a draw-lead connected bushing, remove the top terminal, the retaining pin, and the draw-lead stud. Additionally on bushings rated 72.5 kV and below the draw-lead nut must also be removed. Ensure that the draw-lead cap is screwed tightly into the center conductor. Pass a cable or cord through the bushing center conductor. Attach it to the hole at the top end of the draw-lead stud connected to the equipment manufacturer's flexible cable. Lower the bushing into the mounting hole while simultaneously pulling the cable up through the center conductor of the bushing. Secure the draw-lead

stud to the draw-lead cap by inserting the retaining pin. Be sure that the retaining pin is fully inserted and flush with the draw-lead cap. For bushings rated 72.5 kV and below install the draw-lead nut and tighten. Do not over tighten as it will bend the retaining pin. The top terminal will need to be installed next. Refer to the section titled *Top terminal tightness* for assembly and tightening of the top terminal.

Top terminal tightness

All bushings leave the factory with a threaded top terminal in place that is tightened to the proper torque. Generally, the top terminal on bottom connected and draw-rod connected bushings is not removable and should not need tightened. However, tightness of the top terminal is essential for trouble free operation and should be monitored as instructed in the section titled *Top terminal inspection*. If a loose top terminal is suspected on a bottom or draw-rod connected bushing contact ABB for further assistance.

For draw-lead connected bushings, the top terminal is removable and must be torqued to 35 ft·lbs (48 N·m) for bushings with 1.125 inch terminals and 100 ft·lbs (136 N·m) for larger terminals. Before assembling the top terminal, make sure that the threads on the mating parts are clean. If not, clean the threads with a wire brush. Apply petroleum jelly to the top terminal threads and coat the gasket with a thin film of transformer oil or petroleum jelly. Make sure that the retaining pin is flush with the draw-lead cap. Then, screw the top terminal onto the draw lead stud and tighten to the recommended torque.

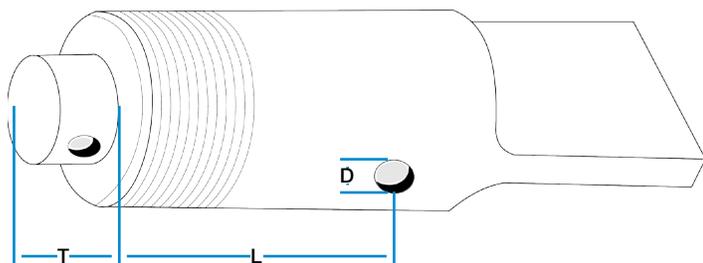


Figure 13 - Draw-lead stud critical dimensions

Draw-lead stud

The draw-lead stud (Figure 13) is of the same general type used throughout the industry for many years. Unfortunately, not all such studs are identical in length. Due to the limited clearances of this line of bushings, the length of the threaded draw-lead stud is critical. The critical dimensions of the stud furnished with the bushing are included in the table below. Crimp type studs are available for purchase. However, any suitable copper stud that complies with these dimensions can be used.

	Rated 72.5 kV and below	Above 72.5 kV
Bolt diameter in inches	0.75	1.25
Threads per inch	12	12
T in inches (mm)	0.25 (6.35)	0.375 (9.53)
L in inches (mm)	1.625 (41.28)	1.5 (38.1)
D in inches (mm)	0.228 (7.11)	0.323 (8.20)

External electrical connections

The external connection to the bushing must be sufficiently supported or flexible to avoid putting a mechanical strain on the bushing parts.

External terminal connectors should be selected of the appropriate size and materials to keep the bushing upper terminal temperature below 70 °C at rated current. Additional conditions such as overloads should be considered during the selection of the terminal connector. This will minimize the risk of overheating and possible damage to the bushing.

! Warning

Before applying vacuum to a transformer, be certain there is sufficient slack in the external line connections to the bushing allowing for bushing movement caused by flexing of the transformer cover and/or walls. Failure to relieve this stress at the bushing connection may result in damage to the bushing seals and loss of oil. Loss of oil will cause an electrical failure.

Tap connections

O Plus C bushings have a small housing containing either a voltage tap or test tap as part of the mounting flange. Bushings rated 72.5 kV and below have a test tap while bushings with a rating greater than 72.5 kV have a voltage tap (see figures 6 and 7). Both taps provide a convenient means for making power factor and capacitance measurements by the ungrounded specimen test (UST) method.

! Caution

Do not apply voltage to the bushing with the test or voltage tap cap removed, except when measuring power factor. If the tap connection is not grounded, the tap voltage will exceed the insulation dielectric strength, resulting in a flashover. The voltage on the tap must not exceed 8 kV when measuring power factor. The voltage on the test tap must be limited to one kV for reverse UST tests.

In order to connect to the test tap on bushings rated 72.5 kV and below remove the threaded cap and connect the UST lead of the power factor measuring equipment to the terminal spring. After testing has been completed, replacing the test tap cover will ground the test tap for service operation of the bushing. Tighten the tap cover to a torque of 10 ft·lbs (13.55 N·m).

Bushings with a voltage tap, rated above 72.5 kV, can also be tested as described above. After testing has been completed, replacing the tap cover will ground the voltage tap for service operation of the bushing by means of a spring clip in the cover. A layer of petroleum jelly should be applied to the sealing gasket. Tighten the tap cover to a torque of 15 ft·lbs (20 N·m).

Additionally, a bushing potential device maybe connected to a voltage tap. If you are connecting a bushing potential device, the voltage tap must be filled with transformer oil prior to energizing. To do this, remove the fill plug and fill the chamber with clean, dry transformer oil. Leave an expansion space of approximately 1/4 inch (6 mm) air space at the top of the chamber when you fill it. Coat the threads on the fill plug with PTFE tape or PTFE based pipe sealant and replace the plug in the fill hole. Be certain the plug is tight.

! Warning

Do not remove the voltage tap fill plug when the bushing is at an elevated temperature, because the oil inside the bushing may be very hot and under high pressure. Make sure the bushing temperature is in the 15 °C to 35 °C range. Failure to follow these guidelines could result in severe personal injury.

Nameplate data

Nameplate data is of special importance in answering questions about bushings. All requests will be expedited if the factory is furnished with the serial number, the functional style number, version number, and the year of manufacture as indicated on the bushing nameplate. At a minimum, the factory should be provided with the serial number of the bushing in question.

Preventative maintenance

Many users have programs for planned preventative maintenance of bushings. ABB strongly endorses and recommends such programs. The following sections should be considered at a minimum when organizing such a program.

Maintenance

Little maintenance is required other than periodic checking of the fluid level via the sight lens. Periodic measurement of the power factor and capacitance should be taken, as well as periodic checking of the condition and tightness of the top terminal. Bushings exposed to salt spray, cement dust and other abnormal deposits are subject to special contamination related hazards and must be cleaned regularly to prevent flashover and corrosion of parts. ABB recommends heavy or extra heavy creep for this type of environment.

Fluid level adjustment

O Plus C bushings are filled to the proper level and sealed at the factory. The fluid level of a bushing should not be adjusted without first contacting ABB.

! Caution

Each bushing is carefully designed to allow for thermal expansion. The addition/subtraction of fluid to a bushing could exceed design tolerances. Failure to follow these guidelines may void the warranty on a bushing.

In the unlikely event it becomes necessary to add oil to a bushing, the fill plug in the spring assembly or dome assembly can be removed. Insertion of a clean standpipe, with an outside diameter of slightly less than the diameter of the hole, will provide a means of adding small quantities (one quart or less) of fluid to the bushing. This should return the oil to the proper level. If not, the bushing must be removed from service and returned for repair and processing.

Obtain the necessary oil from the factory in Alamo, Tennessee or provide oil that meets the transformer oil standard PDS 55822AG processed to have additional requirements of:

- Moisture content less than 5 ppm
- Neutralization less than 0.02 Mg KOH/g
- Dielectric breakdown min. 45 kV ASTM D 877
- Power factor less than 0.05%

! Warning

Do not remove the fill plug when the bushing is at an elevated temperature as the oil inside the bushing may be very hot and under high pressure. Make sure the bushing temperature is in the 15 °C to 35 °C range. Failure to follow these guidelines could result in severe personal injury.

Field measurements

Measure and record the power factor and capacitance at the time of installation and repeat the measurements annually. Field measurements of power factor and capacitance can differ from measurements made under the controlled conditions in the factory. Therefore, the power factor and capacitance measured at the time of installation should be used as a base to compare with future measurements as indicated in the section titled *Measurement guidelines*.

Use the following guidelines to minimize the effect of contamination and high humidity during power factor and capacitance measurements in the field:

- Clean the bushing thoroughly with a suitable cleaner to remove any contaminants that may have deposited on the porcelains and other parts during shipping or storage. An ammonia based glass cleaner is a suitable cleaning agent.
- After cleaning, wipe the surface dry to avoid moisture condensation.
- Clean and dry the voltage or test tap insulator to remove any contamination or condensation.
- Avoid taking power factor measurements in wooden crates to minimize the effect of surface leakage due to moist wood.
- Provide sufficient clearance between the bushing and other objects to minimize the effects of stray capacitance.

If you obtain unsatisfactory readings, repeat the cleaning process and re-measure. If the measurement improves but is still not in the satisfactory range, clean and measure again. Repeat this process as long as the measured values keep improving. Some forms of contamination are difficult to remove without vigorous cleaning.

For information on ground connections and other guidelines, please refer to the test equipment manufacturer's instruction manual.

Measurement guidelines

Measurements of power factor and capacitance when compared to appropriate factory values (or installed values as noted) are the best indicators of bushing health and suitability for continued service. It is always best to make these measurements on an annual basis so that trending can be observed. Trend analysis will readily show a bushing that is deteriorating in service and should be considered for replacement. If annual measurements are not available, these guidelines provide a means for determining if a bushing has deteriorated to the point where it should be considered for replacement.

For all O Plus C bushings, the C1 capacitance is always controlled by the bushing's construction and is not significantly influenced by installed conditions. The C2 capacitance in bushings rated 72.5 kV and below is not well controlled by the nature of its construction. Field measurements will be influenced by the environmental conditions at or near the bushing.

The C2 capacitance in bushings rated above 72.5 kV is controlled by its construction and is not significantly influenced by environmental conditions.

For bushings rated at or below 72.5 kV, consider replacement if:

- The measured C1 capacitance differs by 10 percent from the nameplate value
- The measured C1 power factor is 2-times the nameplate value

Because the C2 capacitance in bushings rated 72.5 kV and below is not a controlled capacitance, field measurements should be compared to the installed reference value. The reference value is established when the bushing is first installed on the transformer by measuring both the C2 capacitance and power factor. Consider the bushing for replacement if:

- The measured C2 capacitance differs by 10 percent from the reference value
- The measured C2 power factor is 2-times the reference value

For bushings rated above 72.5 kV, the C2 capacitance is controlled by the nature of their construction. As such, measured values when compared to nameplate values provide an accurate assessment of a bushing's condition. Consider replacement if:

- The measured C1 or C2 capacitance differs by 10 percent from the nameplate value
- The measured C1 or C2 power factor is 2-times the nameplate value

Top terminal inspection

For satisfactory operation of a bushing, it is important that the top terminal is tight at all times. If any of the parts are loose, overheating of the current carrying joint can take place and result in damaged terminal joints. This type of overheating can deteriorate the bushing gasket seals. If the bushing seals are compromised, moisture could enter the bushing. Once compromised, contaminants can enter the bushing and compromise the insulation, which could lead to decreased performance and possible failure.

The preferred method for inspection is to perform an infrared scan of the top terminals. This should be performed at regular intervals during peak loading. Another method of inspection is to observe the bushing for discoloration of the top terminal, external terminal connector, bolts, and the draw-lead cap-nut. Additionally the casual observer can look for steam rising from the terminal during rain. Any of these conditions could be signs of a loose terminal or connection and require a more rigorous examination.

Inspect the terminal for signs of overheating and check the power factor and capacitance (see the sections titled *Field measurements* and *Measurement guidelines*). If any signs of overheating are present, take the bushing out of service. If the top end parts are discolored and the bushing has been installed using the draw-lead method, remove the top terminal and

examine for any damage. Be sure to inspect the gaskets for any signs of hardening. If the top terminal cannot be removed, it has most likely suffered overheating damage.

For specific recommendations, please contact ABB.

Field repairs

Any repair of O Plus C bushings should be done in the factory because of the danger of contamination to the insulation if the seal is broken. In addition, the very high clamping pressure requires the use of equipment not usually available in the field. Any damage to a bushing which might make repair either desirable or necessary, should be reported to the factory. Do not attempt to repair a type O Plus C bushing without specific recommendations from ABB.

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