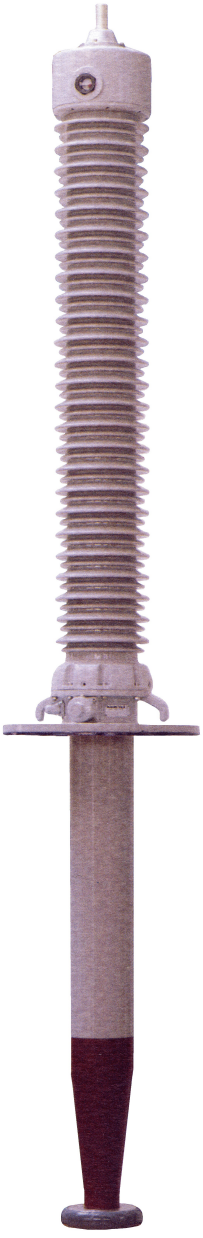
OIL TO AIR BUSHINGS SERIES PAO

VOLTAGE FROM 115 TO 765 kV



INSTRUCTION FOR STORAGE, TRANSPORTATION, INSTALLATION AND MANITENANCE

INDEX

First edition	June 2005
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1 DESCRIPTION

1.1 GENERAL

These instructions are applicable to the OIP (oil-paper) condenser bushings of series

"PAO" - Rated voltage 115 to 765 kV

according to Standards IEEE C57.19.00
IEEE C57.19.01

and give all general information to be followed from the receipt of bushings until their installation on the transformer. Other information is given regarding their service and maintenance.

Design, components and manufacturing technology guarantee an average lifetime longer than 30 years, in normal operation conditions.

The designation of the bushing is made as in the following example:

PAO.230.1050.1200

P	Condenser bushing ("P" from Italian word "Passante")
A	American Standard type
O	Oil paper insulation (OIP)
230	Rated voltage (in kV)
1050	BIL – Basic Insulation Level (in kV)
1200	Rated current (in A)

1.2 SAFETY

This manual must be available to the personnel responsible of the installation, operation and maintenance of the bushings.

Installation, operation and maintenance of the bushings, present conditions of no safety and it is necessary to follow carefully specific procedures and instructions. No compliance with these procedures and instructions can involve very severe and dangerous conditions for the personnel and the property.

Please follow carefully all the instructions of the manual and pay attention to the WARNING (severe hazard), and CAUTION (minor hazard) signs.

1.3 TECHNICAL CARACTERISTICS

These bushings are capacitance-graded type, oil impregnated type (OIP), provided for operation with the upper part in the open air (normally or highly polluted atmosphere) and with the lower part immersed in the transformer oil (fig. 1 and fig. 2).
The body of the bushing is a continuous sheet of pure Kraft paper, wound around a tube or conductor rod and oil impregnated, with aluminium foils inserted within the paper layers; this condenser execution improves radial and longitudinal distribution of electric gradients.

Every bushing is provided with an under-flange elongation – K – for CT accommodation in accordance with IEEE Standards. Other dimensions for CT accommodation are possible, upon request.

For rated voltage up to 230 kV bushings have an oil head reservoir, glass prismatic shape (fig. 1).

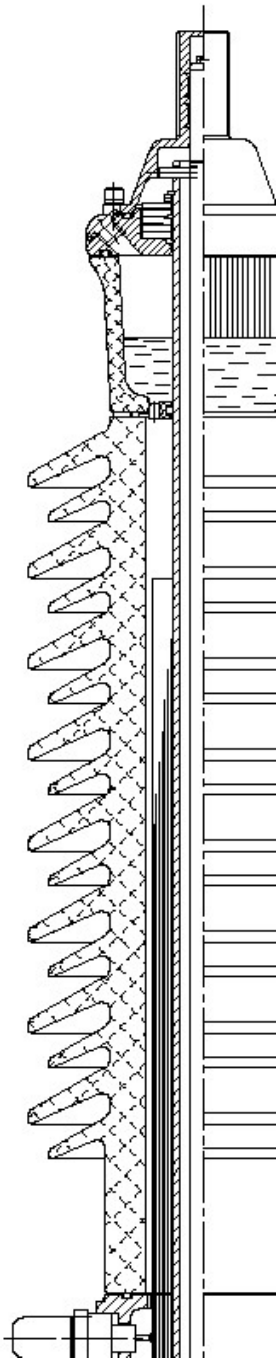


Fig. 1 - PAO 25 through 230 kV

For rated voltage from 345 kV up to 765 kV, bushings have a metal head reservoir (fig. 2).

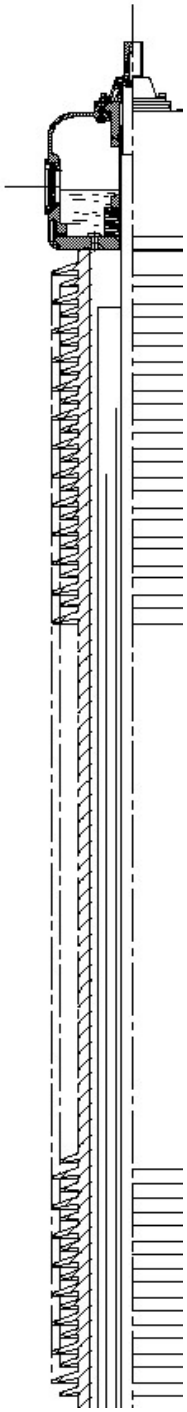


Fig. 2 - PAO 345 through 765 kV

The air side housing is made of grey porcelain and can be provided upon request with a resin fibreglass envelope covered by silicone sheds.

1.3.1 INSULATION

The main electrical insulation is given by a condenser body, made of a continuous sheet of pure Kraft paper, wound around a tube.
Heated cylinders and infrared rays dry the paper during winding, to reduce the water content in the paper to 1% maximum.
During winding a sequence of aluminium foils, cylindrical shape and coaxial disposition, is inserted between the layers of paper. These foils grade the best possible distribution of the radial and longitudinal electrical gradient between the conductor and the fixing flange, which is grounded.
Winding is made by computer-controlled machines, with simultaneous machining to the final shape.
After the winding the bushing is assembled and placed into an oven at 105 °C, treated under vacuum (each bushing individually), kept at $4 \cdot 10^{-2}$ mm Hg for some days and impregnated with oil (having max. humidity content of 3 ppm and suitably degassed). The impregnation is made under pressure in order to obtain the best impregnation and to test the perfect tightness. After impregnation the head of bushing is filled with a nitrogen cushion. All this process is automatic, and computer controlled.

1.3.2 AIR SIDE

The air side envelope is made of grey porcelain, (upon request resin fibreglass envelope covered by silicone sheds) with a creepage distance for very high-polluted atmosphere (VHP): 31 mm/kV.

The shed configuration is alternated type (small-large sheds). This is the most effective solution as proved by salt tests and the profile of sheds complies with the recommendations of IEC Standards.

1.3.3 OIL SIDE

The oil side envelope is made of molded epoxy resin. This type of housing has been employed by Passoni & Villa for the first time in 1963, for the manufacturing of the transformer side envelope in the re-entrant type bushing. The epoxy resins are bi-components type, i.e. consist of a resin base and a hardener, the charge material is quartz sand. The epoxy resin envelopes have shapes, thickness and dimension tolerances not possible to be achieved by porcelains.
The under flange grounded elongation for CT accommodation is obtained with a metallic tube.
Not standard dimensions for CT accommodation are possible, under request.

1.3.4 HV TERMINAL

The HV terminal is made of copper silver plated. Bushings rated 800 and 1200 A have a removable HV terminal; it is coupled to the inner terminal lug by means of multi-blades contact and it is fixed on the head by means of four screws.

1.3.5 HEAD AND OIL LEVEL INDICATION

The metal components of the head are made of aluminium alloy casting. Bushings up to 230 kV have an oil head reservoir, cylindrical prismatic shape, made of borosilicate glass, UV filter, which allows an easy check of the level also at distance, from any sight angle and in all the range of operating temperatures. Bushings from 345 kV up to 765 kV have a metallic head with a glass oil level indicator, prismatic type.

1.3.6 OIL SIDE SHIELD

The oil side ends with a suitable aluminium plate, according to IEEE Standards dimensions.
Under request it is available a suitable aluminium shield, varnished or covered by a layer of epoxy resin, to screen the bushing connection

1.3.7 FLANGE

The flange is made of aluminium casting, equipped with voltage tap (tested at 20 kV 50 Hz for 72 s) for the measurement of the dielectric characteristics, lifting holes and oil sampling plug.

1.3.8 GASKETS

Made of fluorocarbon rubber elastomer, O-ring type. They are compatible with impregnating oil of bushing and hot mineral oil of the transformer.
Flat gaskets are fitted concentrically to O-rings, to prevent a direct contact from the metal parts and the porcelain envelope.
For special requirements regarding low ambient temperatures (up to -55°C) special O-rings are foreseen, made of nitrile mixtures.

1.3.9 ASSEMBLING

Mechanical coupling among all the components is obtained by compression springs placed at the head of the bushing. Furthermore the air side porcelain is cemented to the flange, in order to have a stronger mechanical resistance.

1.3.10 TYPE OF DIELECTRIC

The impregnation is made with a top quality inhibited super grade mineral oil, fully complying to Standards IEC 60296 and ASTM D3487, with the following outstanding characteristics:

- High dielectric strength (>70 kV/2,5mm);
- Very good low temperature properties (pour point typically <-60°C);
- Low viscosity even at the lowest temperatures;
- Very good oxidation stability;
- Extremely good heat transfer.

1.3.11 CURRENT RATINGS

There are two connection alternatives for the central conductor:

- Draw lead connection for 800 A.
- Bottom connection for upper currents.

See below (par. 4) for further explanations.

1.3.12 NAME PLATE

Each bushing is provided of a double name plate, with serial number and all the electrical data, in accordance with the prescription of IEEE Standards. The plate (fig. 3) is made of aluminium, is placed on the flange by rivets and includes the following information:

1 – Identification number
2 – Bushing code
3 – Insulation class
4 – Rated maximum line to ground voltage
5 – Rated impulse withstand voltage
6 – Rated continuous current for draw lead type
7 – Rated continuous current for fixed conductor, bottom connection type
8 – Serial number
9 – Month and year of final test
10 – Standard reference
11 – Length below mounting surface
12 – Weight
13 – Capacitance C1
14 – Capacitance C2
15 – Power factor value of C1 at 20°C

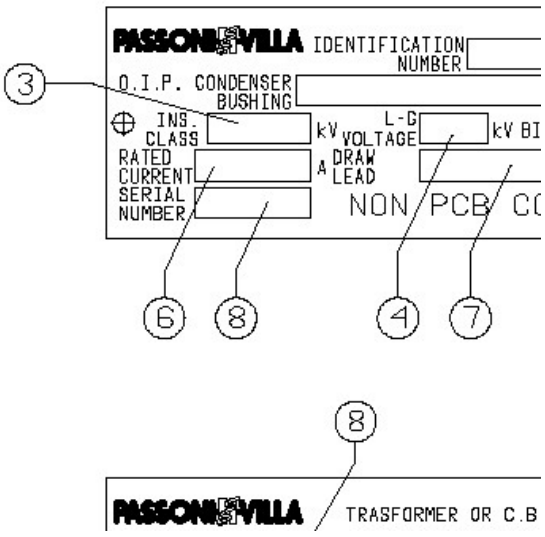


Fig. 3

The month is indicated by a code, as follows:

A = January	E = May	P = September
B = February	H = June	R = October
C = March	L = July	S = November
D = April	M = August	T = December

PACKING AND STORAGE

After the tests, before packing, the lower part of the bushing is cleaned from the oil and the porcelain from the dust. Thanks to a special device to prevent the diffusion of the nitrogen cushion of the head into the bottom part, bushings can be packed in horizontal position.

Remember to lay down the bushing following carefully the indication of the yellow label stickled in the bushing's head.

The possibility of positioning bushings in horizontal grants that the dimensions of cases are smaller and the transportation less costly.

CAUTION

It is necessary that the bushing with glass head is laid down with the PD tap placed downwards, as indicated in fig. 4a, and bushing with metallic head is laid down with oil level indicator placed downwards, as indicated in fig. 4b.

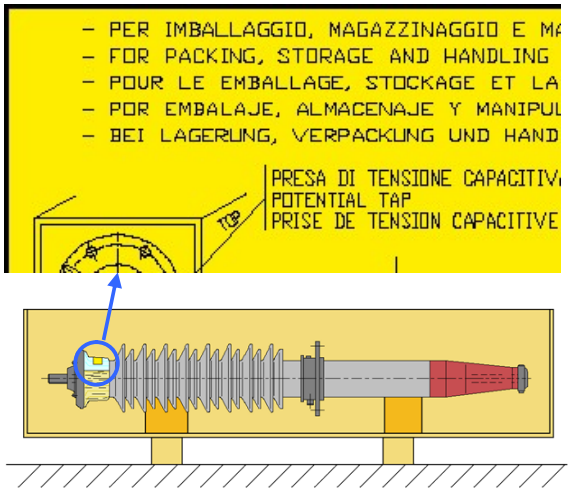


Fig. 4a – Bushings with glass head

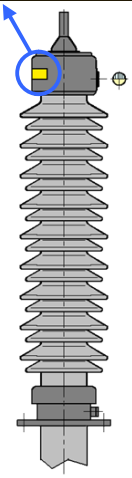


Fig. 4b – Bushings with metallic head

CAUTION

Be sure to follow the indication on the head-stickled yellow label in the operation of the bushings in horizontal position (fig. 4a and 4b).

2.1. ACCEPTANCE

Upon receipt of the goods the Customer should operate as follows:

- Check the external surfaces of the packing cases:
  - No sign of damage shall be found;
  - The shock and tilt indicators, placed in the external part of each packing case (fig. 5 and 5A), must be NOT ACTIVATED.

Fig. 5

Fig. 5A

If the shock or tilt indicator is red (ACTIVATED) don't refuse shipment, make a notation on delivery receipt and inspect for damage as follow:

- Open the packing case by removing its cover;
- Make sure that the anchoring elements are in order and securely fixed;
- Make sure that there are no leaks from the bushings, especially in the joints between porcelain and metal parts and that there are no breaks or broken parts. Please consider that each bushing has been tested with the tail immersed in oil, therefore some oil traces can be found.

In case any damage is found, leave in original packaging and request an immediate inspection from carrier within 15 days of delivery. Moreover give the forwarding agent a written claim and notify the manufacturer with the details of the packing list, including the number of the case and the serial number of the bushing, to the following address:

GRID SOLUTIONS SpA - Unit RPV
Via Mario Villa, 210
20099- Sesto San Giovanni (ITALY)
PHONE: +39-02-24105001

2.2. STORAGE

Every bushing is protected with a polyethylene bag hermetically sealed and containing a silicagel bag; in such a way the bushing is protected in dry air against the humidity of the ambient.
Although there is no preclusions for the bushings remaining in the open air, it is better to store them in a closed room.
The bushings must be kept in their original packing, and in their original position, as indicated by the yellow label put on the head and reproduced in fig. 4a and 4b.

On request, for a long period storage (greater than one year) the bushings can also be shipped with the lower part protected by a rigid container, hermetic and containing silicagel salt, or by a metallic container, oil filled and hermetic: bushings so protected can be shipped and stored even in the most unfavourable weather conditions.

For bushing with rated voltage from 500 up to 765 kV the oil side envelope is made of porcelain, so there are not preclusions, regarding humidity absorption, for a long period storage.

The temperature range acceptable for the storage is from -25 to +50 °C.

For special requirements regarding low ambient temperatures (see paragraph 5), where special O-rings are foreseen, bushings can be stored at temperature up to – 55°C.

When the bushing is taken out from the storage is necessary to make a visual check to be sure about the good conditions of any part.

3. LIFTING AND TRANSPORTATION

The bushing type PAO is sturdy, nevertheless, in order to avoid dangerous movements, it is better to follow the suggested options.

CAUTION
During the period prior the final installation of the bushing on the transformer, special care must be taken in order to avoid that the lower part of the bushing remains outside and in very humid places for long periods. The lower part of the bushing is made with a epoxy resin-moulded envelope, which is not hygroscopic; nevertheless it is better to keep the bushing in a dry ambient. Until bushing is not installed on the transformer it has to be considered as an apparatus for indoor installation.

3.1. PACKED BUSHING

The case containing the bushings can be easily lifted with a tackle by applying the ropes on the points and with the inclination as indicated in fig.6.

Some indications appear also in the packing case.

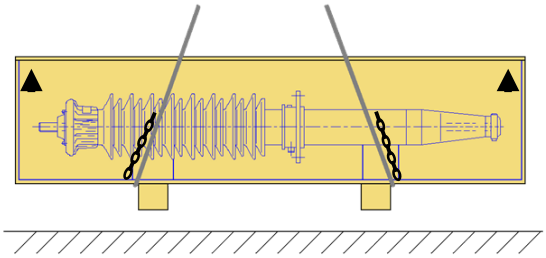


Fig. 6

3.2. UNPACKED BUSHING

3.2.1 Bushings with rated voltage up to 230 kV

To take out of the case the bushing up to 230 kV, operate as indicated in fig. 7 and 8.

The best way to transport the unpacked bushing is to keep it in vertical position; this can be done with a rope between the second and third shed (from the top) of the porcelain as indicated in Fig. 8.

If the sheds are in silicone, the rope has not to be fixed between them, because there is the risk of damage. So place the rope between the head and the first shed.

On the flange of bushings two holes are foreseen. They can be used for the connection to earth or, if necessary, to apply two eyebolts for lifting, or to tighten two screws working as extractors during the dismounting from transformer, in case of difficulties.

CAUTION
This is a delicate operation. Before starting the handling, be sure that the ropes are well fixed. Make all these operations only with expert people.

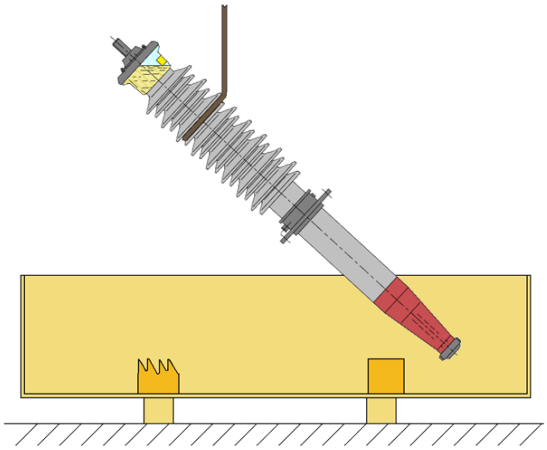


Fig .7

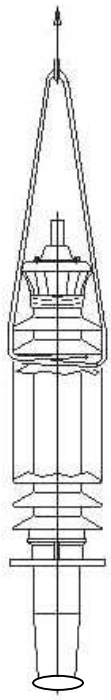


Fig. 8

Inclined Mounting

If the bushing is to be mounted in inclined position, it will be necessary to apply the rope as in Fig. 9 and manually adjust the inclination.

CAUTION
In all operations of handling it will be necessary to avoid putting the bushing with the head lower than the tail (fig. 10), in order to be sure that no nitrogen goes in the lower part of the bushing.

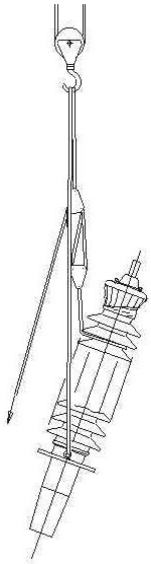


Fig 9

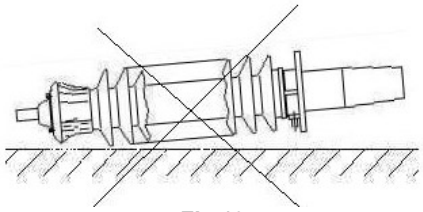


Fig 10

3.2.2. Bushings with rated voltage greater than 230 kV

To take the bushing out of the case, operate according to the following suggestions:

- Considering the weight and the dimensions it is advisable to use two tackles or two equivalent lifting systems.
- Apply a rope at the two lifting holes (screwed eyebolts) on the flange and fasten it with a string around the upper sheds of the porcelain (from second and third) (fig. 11a).
- Apply a second rope at the same two lifting holes (fig. 11a).
- Lift with the two tackles and hold the bushing in horizontal position (fig. 11b).

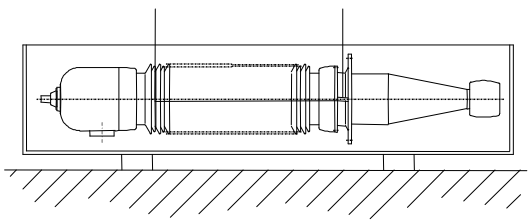


Fig. 11a

CAUTION

This is a delicate operation. Before starting the handling, be sure that the ropes are well fixed. Make all these operations only with expert people.

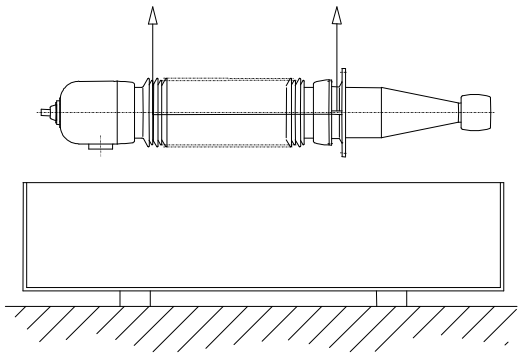


Fig. 11b

- Handle with the two tackles in order to bring the bushing to the vertical position (fig. 11c and 11d).

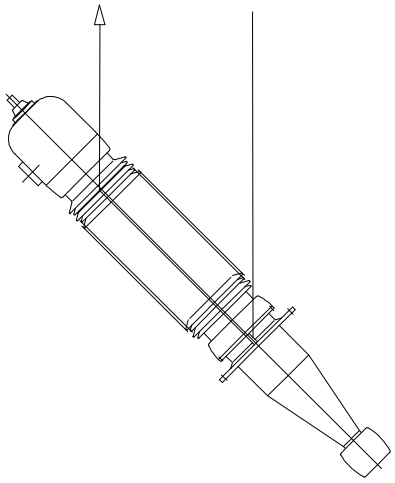


Fig. 11c

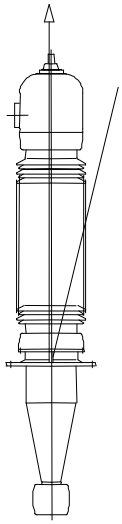


Fig. 11d

- Place the bushing on a trestle (Fig. 11e).

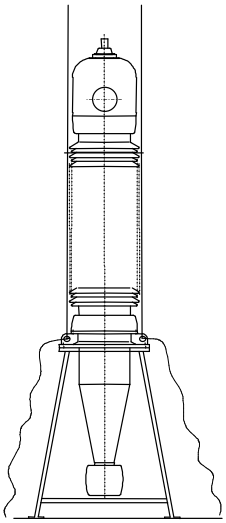


Fig. 11e

Inclined mounting

If the bushing is to be mounted in inclined position, it will be still necessary to operate with two independent tackles.

Apply a rope at the two lifting holes on the flange and fasten it with a string around the upper sheds of the porcelain (from second and third).

Apply the second rope at the two lifting holes (fig. 11a).

Lift the bushing (fig. 11d) and operate with the two tackles in order to give the request inclination (fig. 11c).

3.3. SHIPMENT TO THE END USER

The shipment of the bushings by the transformer manufacturer after the installation on the machine, for the inspection tests, must be made with the original packing or with a new one, made with the same principles.
Particularly the bottom parts of the bushing must be enclosed with the protection bag.
Silicagel salts, if used to protect the oil side from humidity, must be checked: if they have absorbed humidity (i.e. if they are pink colour), they must be dried into an oven (i.e. brought back to blue colour).

CAUTION

When the bushing is positioned in horizontal position in its case, make sure to follow the indications written in the yellow label of fig. 4a and 4b, positioned on the head: it is necessary that the bushing with glass head is laid down with the PD tap placed downwards, as indicated in fig. 4a, and bushing with metallic head is laid down with oil level indicator placed downwards, as indicated in fig. 4b.

4. INSTALLATION ON THE TRANSFORMER

Before installation, keep the bushing in vertical position for 24 hours and gently rock it to release any residual of nitrogen gas, which could be trapped in the insulation. If withstand voltage test shall be applied, keep the bushing for at least 48 hours in vertical position, prior to make the test.
The installation of the bushing on the transformer and the connection to the insulated lead coming from the winding must be executed according to the following information, depending of the bushing's type.

4.2. 800 A - DRAW LEAD CONNECTION

For rated current 800 A the current in the bushing is carried out directly by the lead coming from the transformer's winding, up to the lug placed in the upper part of the bushing.
The connection is constituted by two parts: the upper one is factory installed; the lower one, depending of the type of connection chosen by the customer (brazing or crimping the lead coming from the winding - fig. 12) is supplied separately.

- The upper portion of the lug has to be removed from the bushing in order to properly assemble both pieces.

  To disassemble the HV top terminal cap, remove the 4 x M8 screws and lock washers, which secure it to the bushing head (fig. 13). Pull the HV terminal from the lug, keeping the terminal well centered on the axis of the bushing (fig. 13). The necessary force is small (about 10 kg) because the multi-contact blades, located inside the terminal, press softly on the smooth surface of the lug.

Verify that the O-ring remains placed in its slot.

Remove the locking pin from the draw-pin hole.

Remove the upper section of the draw-lead terminal from the central tube of the bushing.

Brazing lug *Crimping lug*

Fig. 12

- Cut the connection at a right size plus some mm for the welding (or crimping) of the lug; note that the correct lead length is indicated on the "bushing overall dimensions" drawing, supplied with the bushing's order confirmation;

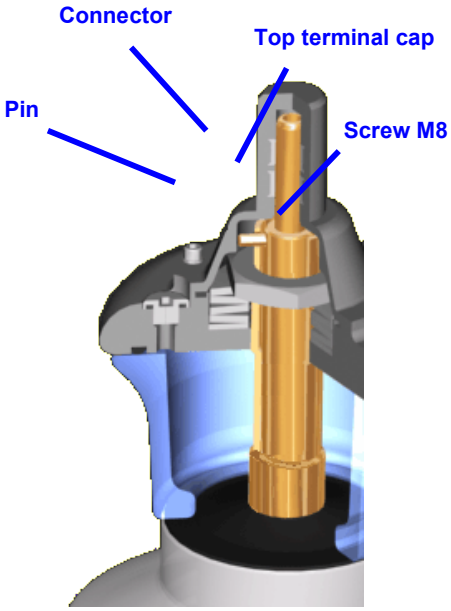


Fig. 13

- Attach the lug to the transformer lead (through brazing or crimping). Use one or more copper leads having total section that gives a current density not higher than 2÷2.5 A/mm2.
- Assemble both draw lead terminal lug sections (upper and lower) using the three screws and washers included with the lower section (fig. 14), type 5/16" - UNF. Tighten the screws by a moment of 13 Nm.

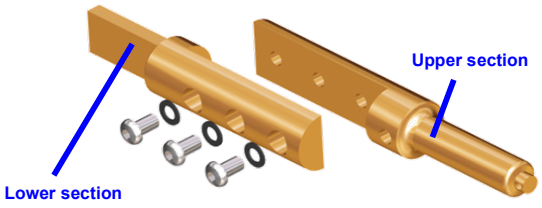


Fig. 14

- Secure a pulling device to the hole foreseen in the top of the lug.
- Place the gasket of the flange on the transformer.
- Pull the assembled inner terminal lug through the bushing from the bottom.
- Lift and install the bushing according to the instructions of par. 3.
- Align the hole in the lug with the hole in the copper tube and secure the lug in position by reinstalling the locking pin.
- Be sure the pin is centered.
- Place the bolts on the flange of the bushing.
- Insert the HV terminal on the lug, keeping the terminal well centered on the axis of the bushing (fig. 13). The necessary force is small (about 10 kg) because the multi-contact blades, located inside the terminal, press softly on the smooth surface of the lug. The top terminal cap will hold the pin in place. Tighten the screws with a moment of 13 Nm. The gasket placed between the two pieces assures the transformer oil tightness and for this reason it is necessary to block the terminal before filling the transformer with oil. The gasket which is necessary to assure the tightness between the oil of the bushing and the oil of the transformer is not involved in this assembly. Clean well the terminal and apply specific grease for electrical contact and then assembly the connector to the terminal.

For a better bushing's tail insulation, it is advisable to protect the lead coming from the winding of the transformer with paper; it is suggested to insulate with a minimum layer of 1,5 mm and a maximum diameter of 2 mm smaller than the internal one of the bushing tube (to allow the transformer oil circulation).

4.3. 1200 A - BOTTOM CONNECTION

For rated current 1200 A the bushing is designed with bottom connection configuration, and its central copper tube acts as current carrying conductor.

The standard bushing is equipped with an 800 A copper lug and with an oil side shield, for draw lead application, so this lug must be removed from bushing and an appropriated 1200 A terminal lug (equipped with multi-spring contacts and supplied separately, see fig. 15) must be inserted into the upper end of the central tube. The oil side shield shall be removed only if is of obstacle in the bottom connection.

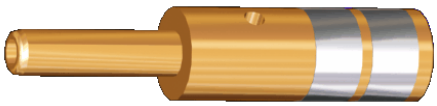


Fig. 15

The procedure to install the bushing in bottom connection configuration is the following:

- Remove the locking pin from the draw pin hole, and then remove the existing draw-lead terminal from the tube (see par. 4.1).
- Insert the appropriate inner terminal lug, suitable for bottom connection (fig. 15), into the copper tube, keeping the terminal well centered on the axis of the bushing (fig. 16). The necessary force is small (about 10 kg) because the multi-contact blades, located inside the terminal, press softly on the smooth surface of the lug.
- Align the draw-pin holes in both the copper tube and inner terminal lug and insert the locking pin. The top terminal cap will hold the pin in place.

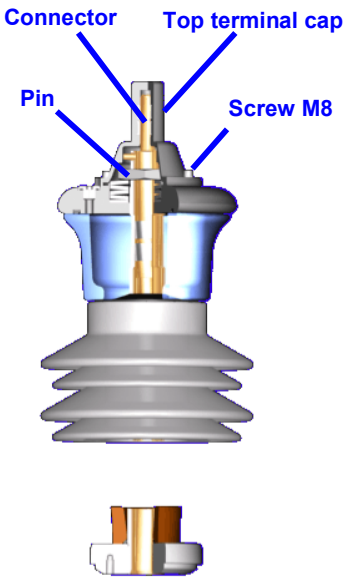


Fig. 16

- Place the gasket on the flange of the transformer.
- Make the connection from the transformer winding to the bottom plate of the bushing, aligning the holes and screwing the foreseen screws. According to IEEE Standard, there are three types of bottom plates, depending of the rated voltage and of the rated current of the bushing (fig. 17, 18, 19). The tighten torque is indicated below the figures.
- If the oil side dielectric shield, when supplied, fixed on the bottom plate (in different ways depending of the bottom plate, see fig. 17, 18, 19, 20), is of obstacle in the bottom connection from the bushing and the lead (surely in the case of the plate for 138-230 kV bushings, fig. 18), remove the shield and make the connection.
- Lift and install the bushing according to the instructions of par. 3.
- Place the bolts on the flange of the bushing.
- Insert the HV terminal on the lug, keeping it well centered on the axis of the bushing (fig. 13). The necessary force is small (about 10 kg) because the multi-contact blades, located inside the terminal, press softly on the smooth surface of the lug. The top terminal cap will hold the pin in place; remember to place the gasket under the terminal.

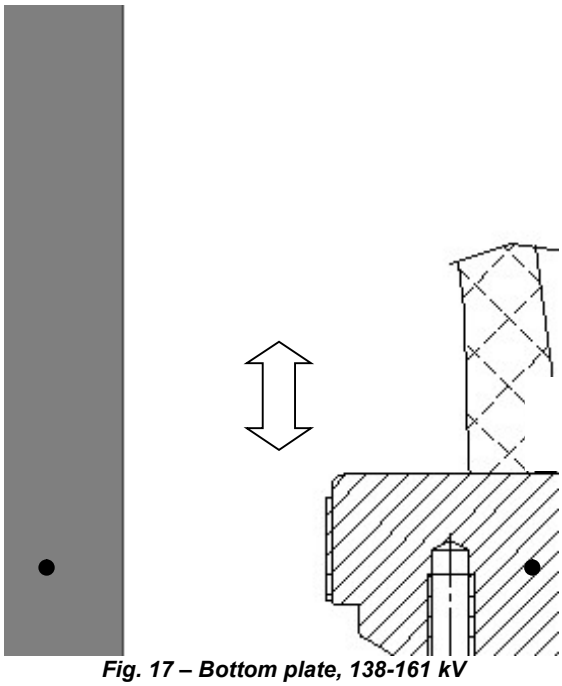


Fig. 17 – Bottom plate, 138-161 kV

Connection: 4 fixing holes 3/8" 16N, 0.75" deep.
Tightening torque: 25 Nm.

Shield screwed on bottom plate, with braking o-ring

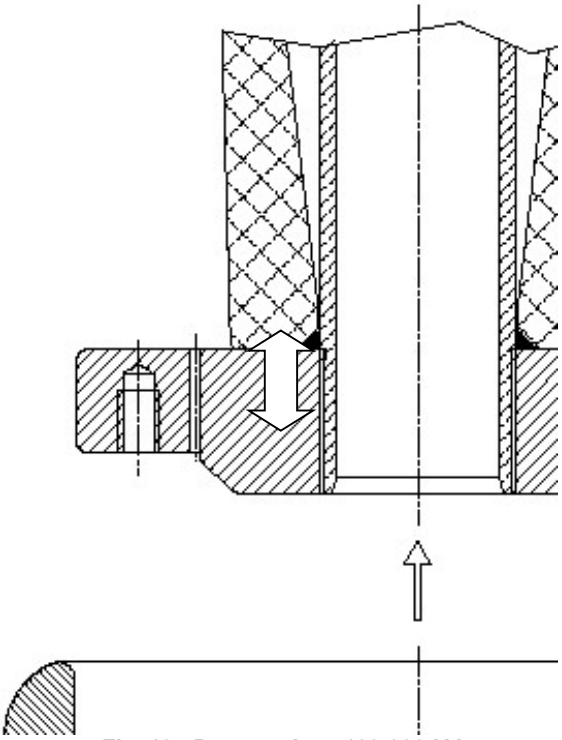


Fig. 18 - Bottom plate, 138-230 kV

Connection: 8 fixing holes ½" 13N, 0.75" deep.
Tightening torque: 50 Nm.

Shield fixed on bottom plate with 4 screws ½" 13N

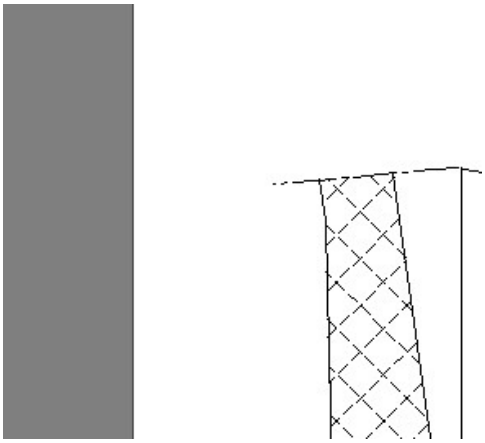


Fig. 19 - Bottom plate, 345-765 kV

Connection: 8 fixing holes ½" 13N, 0.75" deep
Tightening torque: 50 Nm

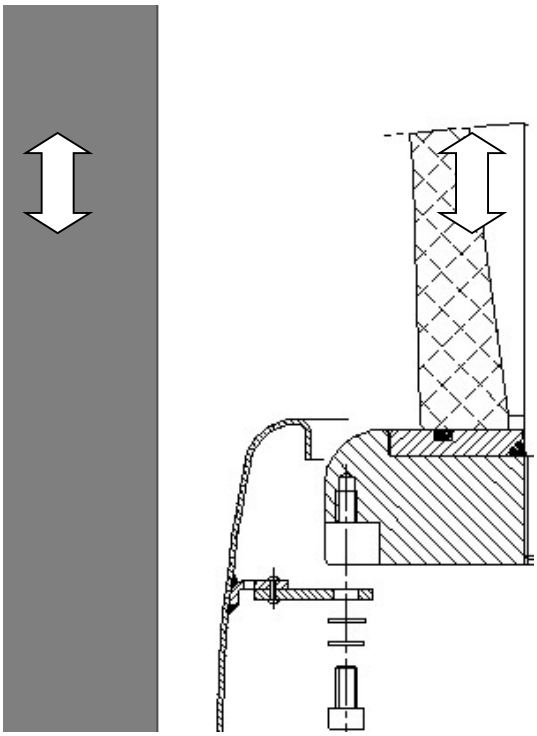


Fig. 20 - Shield for bottom plate, 345-765 kV

Fixed on terminal with 4 screws M8
(tightening torque: 13 Nm).
The shield fixing system don't interfere
with the fixing holes of the bottom plate.

CAUTION

If the oil side dielectric shield, fixed on the bottom plate (in different ways depending of the bottom plate, see fig. 17, 18, 19, 20), is of obstacle in the bottom connection from the bushing and the lead (surely in the case of the plate for 138-230 kV bushings, fig. 18), remove the shield and realize the connection coming from the winding. In this case the standard shield can not be installed.

4.4. BOTTOM CONNECTION FOR In>1200 A

For rated current greater than 1200 A the bushing is already foreseen for bottom connection, without the need to change any lug; the conductor is rigid and not removable. A fixed conductor carries out the current, from the bottom plate, oil side, up to the HV terminal, air side. The connections are foreseen according to IEEE Standard dimensions (see fig. 17, 18, 19).

5. TEMPERATURE LIMITS

Bushings of the series PAO are designed for operation at temperatures according to IEEE Standard.

Ambient temperature:	Maximum:	+ 40°C
	Minimum:	- 30°C
Oil temperature:	Maximum:	+ 95°C

For special requirements regarding low ambient temperatures (up to –55°C) special o-rings are foreseen, made of fluor-silicone mixtures for low temperatures. The spring closing system is calibrated in order to maintain the bushing hermeticity at these extreme conditions and the oil maintains its proprieties. For any other special or different condition please inform the manufacturer and ask the permission to put in service the bushings.

6. SERVICE AND MAINTENANCE

6.1. METAL PARTS

The flange and the metallic components of the oil expansion vessel of the bushings are made of aluminum alloy casting and do not require any special surface treatment / maintenance.
Only in case of installation in aggressive environment (i.e.: coastal, high pollution, high salinity), it's recommended to protect said metal parts with a layer of antirust coating.

6.2. CHECKS AFTER INSTALLATION

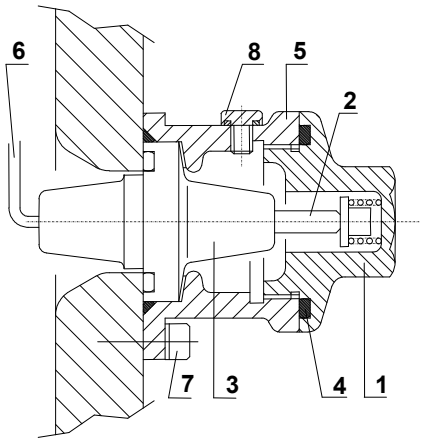
After the installation on the transformer it is advisable to make a check of the bushing capacitance and tgδ.

The measurement of main capacitance (C1) must be carried out between the HV terminal and the voltage tap, the measurement of C2 between voltage tap and flange.

The capacitance values measured in manufacturer's HV laboratory are shown in the test report of the bushings.

During the operation, the voltage tap (named also Potential Device tap) has to be grounded maintaining screwed its proper cap (see fig. 21).
If present and used, it must be grounded through the connected measuring instrument.

If a Potential Device is connected to the potential device tap, the internal part of the connection shall be filled with mineral oil through the oil filling plug placed in the upper part of the tap (fig. 21 item 8), to avoid possible internal and dangerous sparking.
If not used the voltage tap can remain empty, but we recommend filling it of mineral oil to prevent the entrance of moisture, that during the years can cause the corrosion of the tap connection contact, with dangerous sparking problems.



1 - Closing and grounding cap (removable)
2 - Measurement electrode
3 - Insulating bushing
4 – Gasket
5 - Mounting flange
6 – Internal connection
7 – Fixing screw (not removable)
8 – Oil filling screw

Fig. 21
Potential Device tap (voltage tap)

WARNING

If the voltage tap is not used, we recommend checking if the cap of the oil filling screw (fig. 21 item 8) has been properly applied and screwed. On the contrary, moisture entering can cause the corrosion of the tap connection contact, with dangerous sparking problems.

Don't unscrew the screws item 7 of fig. 21, that fix the PD flange to the bushing.

If accidentally this operation happens some oil goes out from the bushing and the electrical contact between the internal condenser body and the flange can be damaged.

6.3. DISASSEMBLY OF THE BUSHING

To disassemble the bushing operate according to the constructive solution adopted for the transformer, in parallel with the following suggestions:

- Withdraw the terminal from the lug (fig. 13). For bushings with In>1200 A, bottom connected, this is not necessary. For this operation the terminal has to be drawn in longitudinal way and, at the same time, rotating a little in clockwise and counter clockwise direction.
- Secure a pulling device to the hole foreseen in the top of the lug (only in the draw lead configuration).
- Remove the locking pin (only in the draw lead configuration).

- Fix the bushing as indicated in paragraph 3.
- Remove the bolts that fix the flange and lift the bushing following the indication given in par. 3.
- Separate the upper part of the lug from the lower one, connected to the lead coming from the transformer's winding (draw lead configuration), or unscrew the inner conductor from the bottom plate of the bushing (bottom configuration connection).

6.4. MAINTENANCE

The bushings PAO are hermetically sealed and therefore an excellent preservation in time of the dielectric properties of the oil paper is ensured. As for the preservation of the active part, these bushings require no maintenance.
It is recommended to perform every 5 years the measurement of the dielectric losses (tgδ).
As for the preservation of the external surfaces, the manufacturer suggests performing the following inspections.

Porcelain

Check for chips, cracks and contamination. Minor chips maybe painted with an insulating varnish to obtain a glossy finish which will prevent dirt and moisture attack.
Bushings with major chips or cracks which appreciably decrease the creepage distance should be removed from service and replaced.
Wash periodically the porcelain surfaces, on which dust, saline compounds, combustion resituates, dirt, oil and other deposits may easily collect and reduce consequently the flashover value.
If the transformer has to be put in service during winter, it is recommendable before to clean the bushing's porcelain from ice or snow that can reduce the dielectric withstand capability.

HV terminals

Check the connections in order to avoid poor contacts and consequent overheating.
Pay particular care to the air side connections, more subject to oxidation than the oil side ones.
In case of connections surfaces very oxidised, clean them slightly passing fine sandpaper, paying attention not damaging the silver layer. After this operation, clean well the surfaces with a light solvent (for example alcohol).

Voltage tap (Potential device tap)

If not used, check the proper location and the suitable complete screwing either of the tap cap and the oil filling screw (fig. 21). Voltage tap if not used can remain empty, but we recommend filling it with mineral oil to prevent the entrance of moisture, that during the years can cause the corrosion of the tap connection contact, with dangerous sparking problems.

Oil level

Check the oil level of the bushing and add oil if necessary. The refilling can be done throughout the tap positioned in the upper part of the head (fig. 22 for bushing up to 230 kV and fig. 23 for bushings with rated voltage greater than 230 kV), close to the HV terminal, by using some transformer mineral oil, accurately treated and degassed.

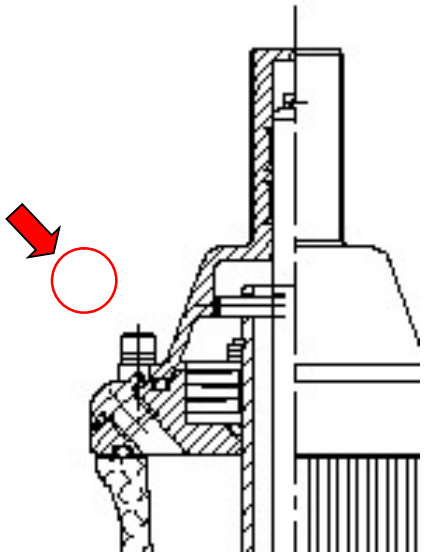


Fig. 22 – Filing cap for PAO with Ur≤230 kV

The refilling of the gas cushion on the top head of the bushing with nitrogen or dry air is not strictly necessary.
In case the oil level should go down, check carefully if any external leakage is present. If nothing will be detected, then refill the bushing. If the oil level still goes down, it is necessary to remove the bushing from the service and to repair it.
Close the cap with a tightening torque of 100 Nm.

CAUTION
To prevent oxidation of the bushing oil and humidity entering, the filling plug must be closed just after the conclusion of the refilling operation.

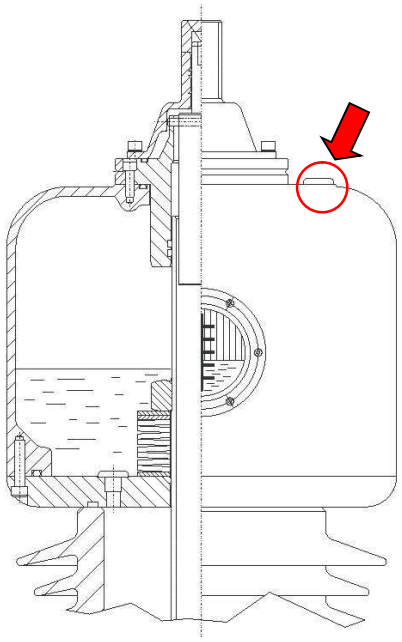


Fig. 23 – Filing cap for PAO with Ur>230 kV

6.5. MEASUREMENT OF DIELECTRIC LOSSES

Test in the factory

Standard IEEE C57.19.01 states that an oil paper bushing must have a tanδ less than $5x10^{-3}$.
The measurement is performed in manufacturer's Test Laboratory by means of a Schering bridge (Tettex type) at the voltages requested by the Standards.
All values are shown in the Routine Test Report.
Measurement at the voltage of 10 kV is carried out in order to have a reference value for comparison with measurements made at site during the service of the bushing.

Test on the bushing installed on the transformer

With the bushing already installed on the transformer and the HV terminal disconnected, the measurement can be performed by means of a bridge, by applying a voltage of 10 kV between the HV terminal and PD tap, maintaining grounded the flange (C1 measurement). The bushing is considered good if a tgδ less than the maximum one established by the Standards is measured.
If a tgδ higher than the above one is measured, please contact the manufacturer who will decide if it is necessary to make other tests before removing the bushing from service or to ship it back, in order to make a complete check and eventually to carry out an oil treatment or eventually to replace the active part with another of new manufacture.
In order to measure the C2 value (capacitance between the PD tap and flange) the flange has to be supplied with a voltage maximum of 10 kV and the PD tap has to be connected to the bridge.
A field measurement of tgδ and capacitance can differ from the measurements carried out in the factory due to the different conditions of test and relevant accuracy: for this reason, a light shifting (max 10% for tgδ) is acceptable.
Furthermore, the installation conditions, due to stray capacitances, can affect the capacitance value. For this reason, it is advisable to measure capacitance and tgδ upon the installation and use these values as base for future comparison measurements.

CAUTION

A field measurement of tgδ and capacitance can differ from the measurements carried out in the factory due to the different conditions of test, the relevant accuracy, the installation conditions that create stray capacitances: for this reason, a light shifting (max 10% for tgδ and 1-2% for capacitance) is acceptable.

For this reason, it is advisable to measure capacitance and tgδ upon the installation and use these values as base for future comparison measurements.

6.6. CHECKS ON OLD BUSHINGS

Before remounting an old bushing, it is advisable to carry out a tightness test and an electrical check.

6.6.2. Tightness test

Fill completely the bushing through the oil filling plug placed in the top bushing's head (fig. 22 and 23) with treated oil and regulate the pressure at 2 bar relatives for 24 hours. Make a visual check, then restore the oil level. No leakages shall be detected.

6.6.3. Electrical checks

The old bushings are suitable for service if, as regards the values of reception test, there is no increase higher than (note: values only indicatives):

- 5% for the capacitance C1 (this assure that there isn't a perforation between two layers);
- 30% for tgδ of capacitance C1;
- 100% for tgδ of capacitance C2.

An increase of the last value means a decreasing of the dielectric characteristics of the external layers of the paper and/or of the oil in the interspace between the condenser body of the bushing and the external housing.

6.7. EXTRAORDINARY CHECKS

If the electric measurement detects a tgδ higher than the limits it is suggested to carry out an oil sampling (See par. 6.8) and to perform the following tests:

- Humidity content

  Original value: ≤ 10 ppm

  During working: ≤ 20 ppm

- Dielectric strength

  Original value: ≥ 62 kV/2,5 mm

  During working: ≥ 45 kV/2,5 mm

- Dielectric losses (tgδ)

  Original value: ≤ 7*10-3

  During working: ≤ 12*10-3

- Gas chromatography (DGE)

  Make reference to relevant Standards

If these checks give negative results, it is necessary to ship back the bushing to the manufacturer who will perform a complete set of electrical tests and eventually will decide to make an oil treatment to the bushing or to replace the active part with another one of new construction.

6.8. OIL SAMPLING

CAUTION

The operation must be carried out when the line is off.

The abovementioned operations involve, on the whole, a sampling of about 0.2-0.3 litres of bushing oil.

The oil taken out has to be restored by adding the same quantity of transformer mineral oil, accurately treated and degassed.. The refilling must be done through the tap located on the top of the bushing's head (fig. 22 and 23), which must be closed immediately after the end of the operations.

CAUTION

The oil sampling operation has to be carried out as quickly as possible and in a period with a low humidity level, in order to not pollute the oil inside the bushing.

6.8.2. Bushings with rated voltage of 115 kV and 138 kV

On the bushing flange there is a screw plug (1/4"), which is positioned at about 180° from the PD tap: this is the oil sampling plug (see fig. 24).

Equipment

To carry out oil sampling from a bushing having the oil sampling plug, we need the following:

- A 150 cm^3 oil syringe (item 4) (Lab. Type);
- A two-way cock (item 3) with a suitable connection to the syringe;
- A semi-rigid pipe (item 2);
- An appropriate plug that can be screwed at one side on the bushing sampling plug and that can be connected at the other side on the tube (item 1). Note that the flange hole has a thread of ¼" GAS;
- A syringe cap;
- Adhesive tape.

Preparation

Operate as follows (see fig. 24):

- Clean the plug zone accurately;
- Prepare all the syringe apparatus, with the cock (item 3) and the pipe (item 2);
- Loose the filling tap located on the top of the bushing's head (fig. 21);

WARNING

This operation is important to ease the oil exit and above all to remove the low depression that can be generated inside the bushing in case of low temperature, phenomenon that can allow a dangerous air incoming in the bushing from the sampling plug.

- Unscrew the oil sampling plug and screw the connecting cap (item 1), on which the tube (item 2) is to be applied in sequence. Note that when the oil sampling plug is unscrewed, some oil will exit from the hole in a continuous manner: in fact inside there is no valve. The flow out of oil is low, but the apparatus is to be linked immediately;
- Wash the syringe with oil two times by repeating the following operations:

  - Open 2nd way of cock (item 3);
  - Fill in slowly the syringe with some oil (about 10-30 cm^3), in order to wash it and to let the exit of the air bubbles contained in the pipe;
  - Open 1st way of cock (item 3);
  - Empty the stringe (item 4);
  - Close 1st way of cock (item 3).

Oil Sampling

For sampling please follow these instructions:

- Close the 1st way of the cock (item 3) and open the 2nd way;

- Slowly fill the syringe with the oil up to the appropriate volume (approx. 60-100 cm^3);
- Shut off 2nd way of the cock (item 3);
- Unplug the cock (item 3) and place a closing cap;
- Remove the syringe by unplugging the cock (item 3) from the tube (item 2);
- Set the syringe with the cock (item 3) being up;
- Clean the syringe and block it with adhesive tape on which you will write down the bushing part number;

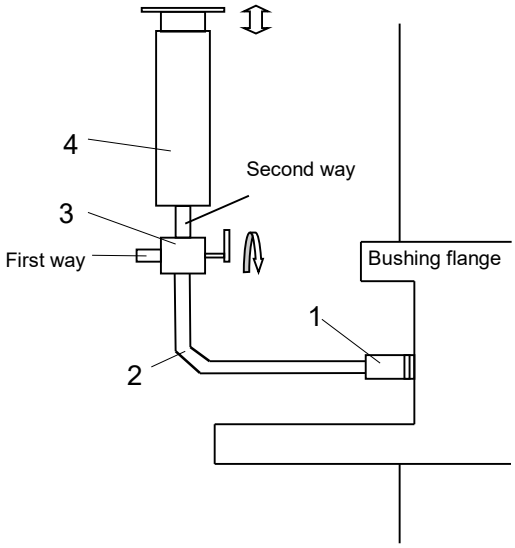


Fig .24

- Overturn the syringe and keep it with its cap down;
- Remove the pipe from the plug, unscrew the plug and screw immediately its proper tap, to avoid further oil flow from the bushing.

If the oil flows out too slowly, it is suggested to rise the internal pressure of the bushing by means of an injection of nitrogen through the filling hole positioned in the upper part of the head (M16 threaded, fig. 22), close to the HV terminal: in this way the nitrogen injected goes only in the gas cushion situated in the head of the bushing, which must be maintained in vertical position (or close to the vertical position).
After the oil sampling the bushing pressure must be restored to the previous value, which is zero bar relatives.

6.8.3. Bushings with Ur greater than 138 kV

On the bushing flange there is a valve (see fig. 25 and 26) positioned in closed position: it is the oil sampling valve. On this valve it is fixed a metallic closing disc. To make the oil sampling it is necessary to dismantle this closing disc and to mount another one provided by a suitable connection.

Equipment

To carry out oil sampling from the bushing, it is needed the following:

- A 150 cm^3 oil syringe (fig. 25 item 4) (Lab. Type);
- A semi-rigid pipe (fig. 25 item 2);
- An appropriate little flange suitable for fixing to the sampling valve (having 4 threaded M8 holes positioned at 90° from each other, with a holes wheelbase of 50 mm; the o-ring housing is positioned on the valve body). This small flange will have a suitable connection to the sampling semi-rigid pipe (fig. 25 item 1);
- A two-way cock (fig. 25 item 3) with a suitable connection to the syringe;
- A syringe cap;
- Adhesive tape.

Preparation

Operate as follows:

- Clean the plug zone accurately;
- Prepare all the syringe apparatus, with the cock (fig. 24 item 3) and the tube (fig. 25 item 2);
- Dismantle the closing flange unscrewing the 4 screws M8 and fix the sampling flange, provided by a suitable connection to the semi-rigid pipe (fig. 25 item 1);
- Wash the syringe with oil two times by repeating the following operations:
  - Open 2nd way of cock (fig. 25 item 3);
  - Fill in slowly the syringe with some oil (about 10-30 cm^3), in order to wash it and to let the exit of the air bubbles contained in the pipe;
  - Open 1st way of cock (fig. 25 item 3);
  - Empty the syringe;
  - Close 1st way of cock (fig. 25 item 3).

WARNING

To ease the oil exit and to remove the low depression that can be generated inside the bushing in case of low temperature, phenomenon that can allow a dangerous air incoming in the bushing from the sampling valve, it is suggested to loosen the filling tap located on the top bushing's head.

Oil sampling

For sampling please follow these instructions:

- Close the 1st way of the cock (fig. 25 item 3) and open the 2nd way;
- Slowly fill the syringe with the oil up to the appropriate volume (approx. 60-100 cm^3);
- Shut off both 2nd way of the cock (fig. 25 item 3) and the bushing's valve;

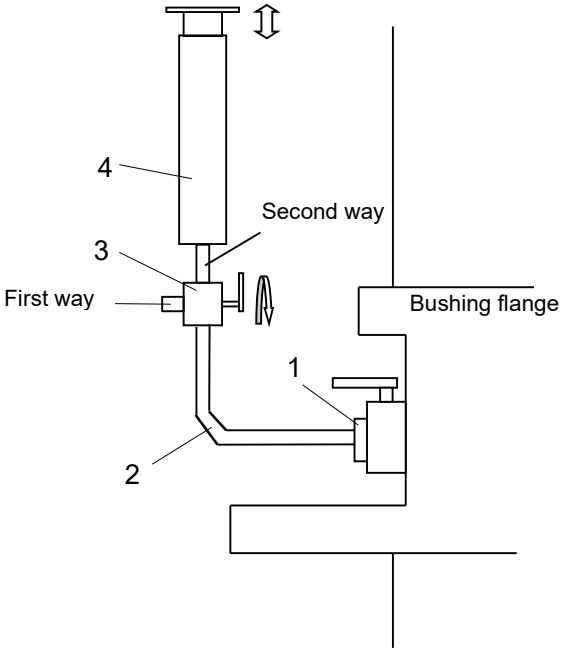


Fig. 25

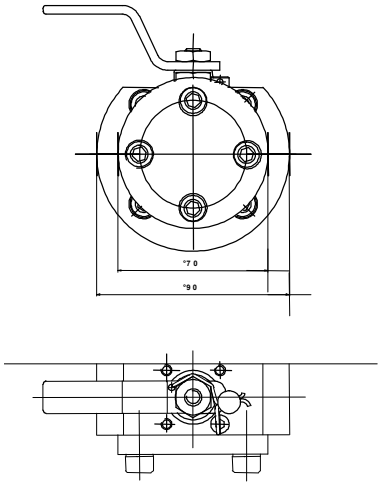


Fig. 26

- Remove the syringe by unplugging the cock (fig. 25 item 3) from the tube;
- Set the syringe with the cock (fig. 25 item 3) being up;
- Unplug the cock (fig. 25 item 3) and place a closing cap on the syringe;
- Clean the syringe and block it with adhesive tape on which you will write down the bushing part number;
- Overturn the syringe and keep it with its cap down;
- Remove the pipe from the plug, unscrew the sampling flange and screw the original one;
- Screw completely the filling tap on the head of the bushing (fig. 23)

7. DISPOSAL AT THE END OF LIFETIME

The bushing consists of the following material:

Component	**Material**
Winding conductor	Copper or aluminium alloy
Terminals and bottom plates	Copper, aluminium alloy or brass; optional silver or tin coating
Insulating oil	Mineral oil acc. IEC60296
Winding	Cellulose paper and thin aluminium foils
Nuts, bolts, washers and springs	Stainless steel, carbon steel
Top oil expansion vessel	Borosilicate glass
Flange and extension	Aluminium alloy
PF tap and cover	Nickel or tin coated brass, tin coated copper
Top insulator	Either porcelain acc. to IEC60672 or composite insulator made of: Glass fibre reinforced epoxy Silicone
Insulator fittings	Aluminium alloy
Bottom insulator	Either porcelain acc. IEC60672 or epoxy resin
Bottom shield	Aluminium alloy covered with either epoxy paint or epoxy resin