OIL TO AIR BUSHINGS SERIES PAO

VOLTAGE FROM 25 TO 69 kV

INSTRUCTION FOR STORAGE, TRANSPORTATION, INSTALLATION AND MAINTENANCE

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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 25 to 69 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.69.350.1200

P	Condenser bushing ("P" from Italian word "Passante")
A	American Standard type
O	Oil paper insulation (OIP)
69	Rated voltage (in kV)
350	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 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).
The body of 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, under request.

The schematic design is shown in figure 1.

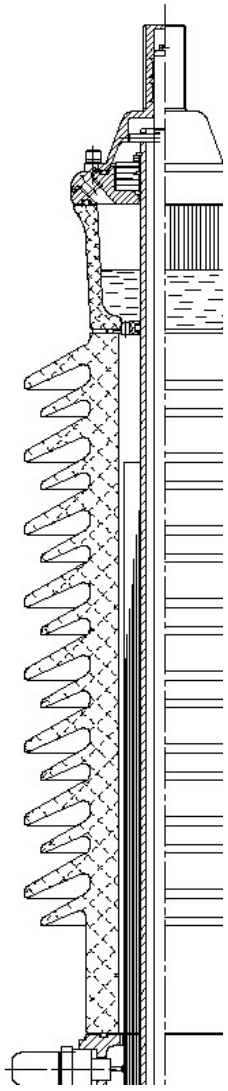


Fig. 1

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

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.
The 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 fiberglass 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.
Other dimensions for CT accommodation are possible, under request

1.3.4 HV TERMINAL

The HV terminal is made of silver-plated copper. Bushings rated 400-800-1200 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. For higher rated currents the central bushing conductor, make also as HV terminal, in silver plated copper.

1.3.5 HEAD AND OIL LEVEL INDICATION

The metal components of the head are made of aluminium alloy casting. Bushings 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.

1.3.6 OIL SIDE SHIELD

The oil side is shielded by a suitable aluminium electrode, with the function of reducing the dielectric strength in oil, according with ANSI dimensions.

1.3.7 FLANGE

The flange is made of aluminium casting, equipped with power factor tap (tested at 2 kV 50 Hz for 72 s), for the measurement of the dielectric characteristics, and lifting holes.

1.3.8 GASKETS

Made of fluorocarbon elastomer, O-ring type. They are compatible with impregnating oil of bushing and hot mineral oil of the transformer.
The gaskets, air side, are carefully protected by means of a sealing, against influence of polluting weather elements. 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.

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 three connection alternatives for the conductor:

- Draw lead connection for 400 A and 800 A.
- Draw rod or bottom connection for 1200 A.
- Bottom connection for upper currents.

Using suitable accessories, the 400/800 A type can easily be converted in 1200 A type and vice versa (for details see par. 4).

1.3.12 NAME PLATE

Each bushing is provided of a name plate, with serial number and all the electrical data, in accordance with the prescription of IEEE Standards.
The plate (fig. 2) 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

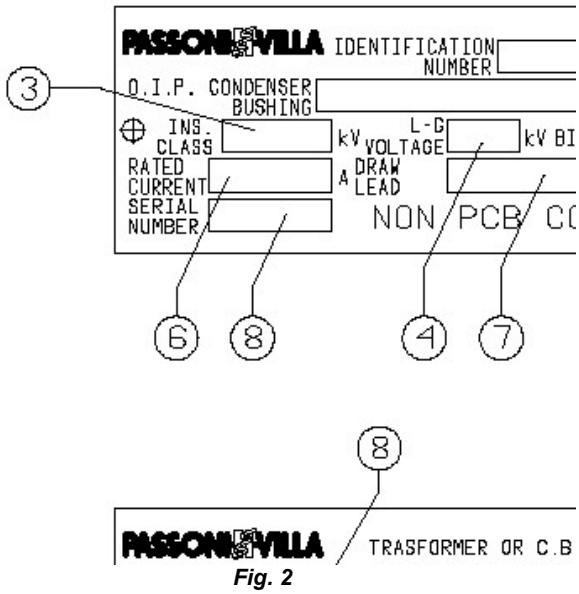


Fig. 2

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

2. PACKING AND STORAGE

After the tests, before packing, the lower part of the bushing is cleaned from the oil and the oil side insulator 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.
This grants that the dimensions of cases are smaller and the transportation less costly.

CAUTION

It is necessary that the bushing is laid down with the PF tap placed downwards, as indicated in fig.3.

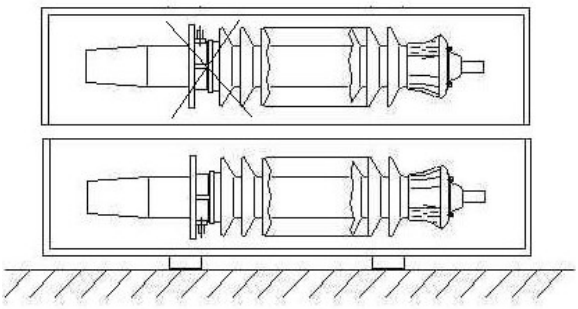


Fig. 3

To remind the operator on this precaution, the label of fig. 4 is stickled on the bushing head.

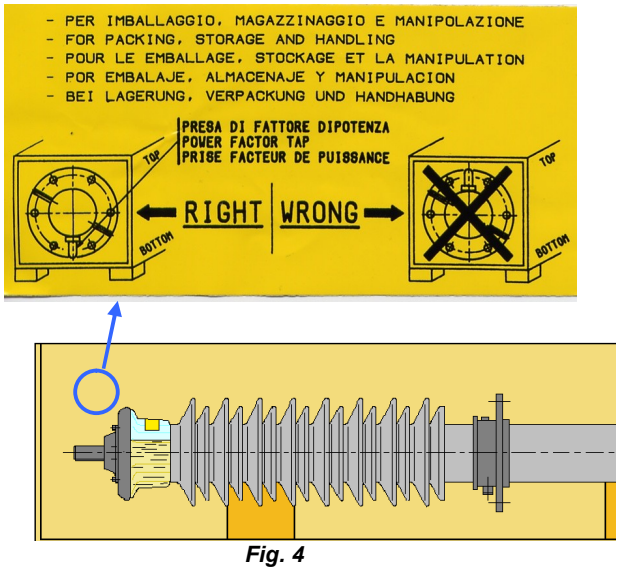


Fig. 4

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

Each bushing is protected with a polyethylene bag hermetically sealed and containing silicagel salt; in such a way the bushing is protected in dry air against the humidity of the ambient.
Although there are 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, that is with the PF tap towards the bottom, as indicated by the yellow label put on the head of the bushing and reproduced in fig. 4.

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 for a long time even in the most unfavourable weather conditions.

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, the 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.

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 enclosed in a cycloaliphatic resin-moulded envelope, which is not hygroscopic, but nevertheless it is better to keep the bushing in a dry ambient.
Until the bushing is not installed on the transformer it has to be considered as an apparatus for indoor installation.

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.

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.

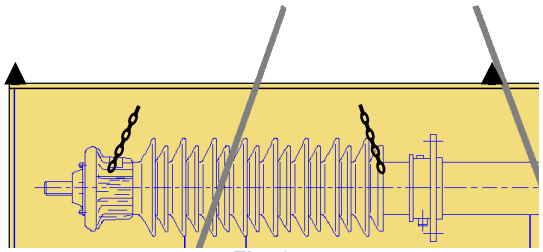


Fig. 6

3.2. UNPACKED BUSHING

To take the bushing out of the case, 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 air side is made with silicone sheds, the rope has not to be fixed between them, because there is a risk of damage. So, place the ropes like in the inclined mounting configuration (see fig. 9 below).

On the flange of bushings two holes M12 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 by expert people.

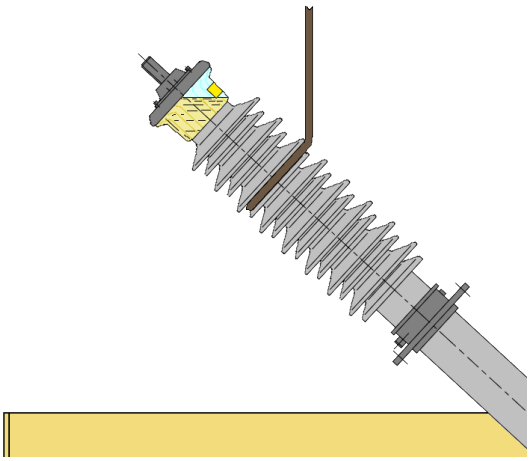


Fig .7

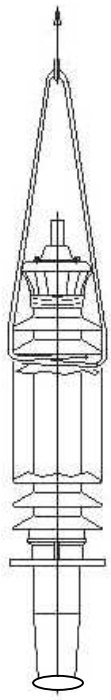


Fig. 8

Inclined Mounting

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

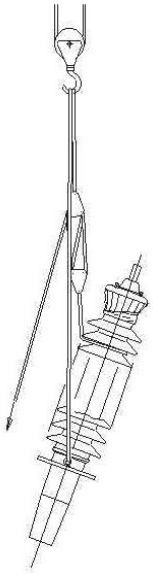


Fig 9

CAUTION

In all the 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.

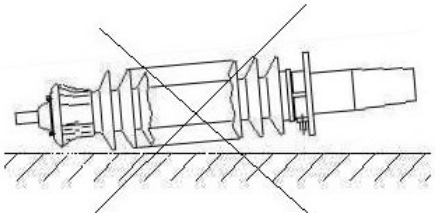


Fig 10

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 part 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. 4, positioned on the head: the bushing must be positioned with the PF tap towards the bottom.

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 has to 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 connection coming from the winding must be executed according to the following information, depending of the bushing's type.

4.1. 400 A - DRAW LEAD CONNECTION

For rated current 400 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. 11) is supplied separately.

Brazing lug *Crimping lug*

Fig. 11

- 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. 12). Pull the HV terminal from the lug, keeping the terminal well centered on the axis of the bushing. 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.
- Cut the connection at a right size plus some mm for the welding of the lug; note that the correct lead length is indicated on the "bushing overall dimensions" drawing, supplied with the bushing's order confirmation;

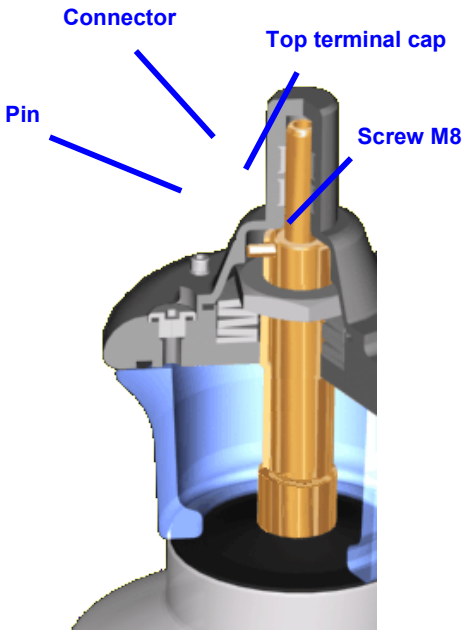


Fig. 12

- 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 the two draw-lead terminal lug sections (upper and lower) using the two screws and washers included with the lower section (fig. 13), type 5/16" - UNF. Tighten the screws by a moment of 13 Nm.

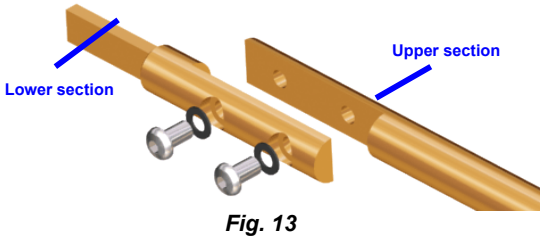


Fig. 13

- 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. 12). 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. The connector to the HV terminal must be of compatible material. 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 tube (to permit the oil circulation).

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, like in the 400 A application (fig. 14).

This is not a standard current rating for IEEE Standard, but it is possible to easily have such a rated current in PAO bushings simply substituting the standard 400 A upper part of the lug with the 800 A type, supplied separately together with the lower part (fig. 14), which depends of the type of connection chosen by the customer (brazing or crimping the lead coming from the winding), as per the 400 A application.

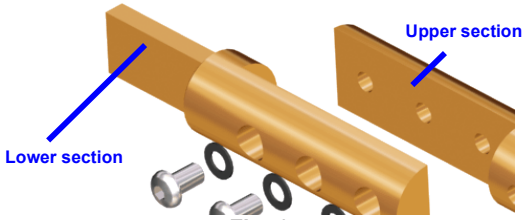


Fig. 14

The operations to be done for bushing installation are the same already described in the 400 A application (ref. to par. 4.1). In this case the connection between the two parts is fixed through three screws instead of two. The screw type and the tightening torque is the same as the 400 A application (13 Nm).

4.3. 1200 A - DRAW ROD / BOTTOM CONNECTION

For rated current 1200 A the conductor is rigid and removable, divided in two parts (fig. 15).
The procedure to install the bushing in draw rod connection is similar as above, but now the current is carried by rigid conductor that is placed inside the bushing all along it and coming out from its bottom part.
The type of connection to the bushing can be or draw rod or bottom type, using the same conductor but fixing it to the bushing in two different manners.

To install this type of connection please follow carefully following items.

- Connect the lead coming from the transformer to the lower extremity of the threaded conductor (1.5 in. -12N x 2.125 in. usable thread).
- Assemble the two sections (upper and lower) using the four screws (5/16" – UNF type) and washers included with the lower section (fig. 15). Tighten the screws by a moment of 13 Nm.

Fig. 15

- Secure a pulling device to the hole foreseen in the top of the lug.
- Place the gasket on the flange of the transformer.

4.3.1. Draw rod connection

- Pull the assembled inner terminal lug through the bushing from the bottom (fig. 16).
- 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 conductor in position by installing the locking pin.
- Be sure the pin is centred.

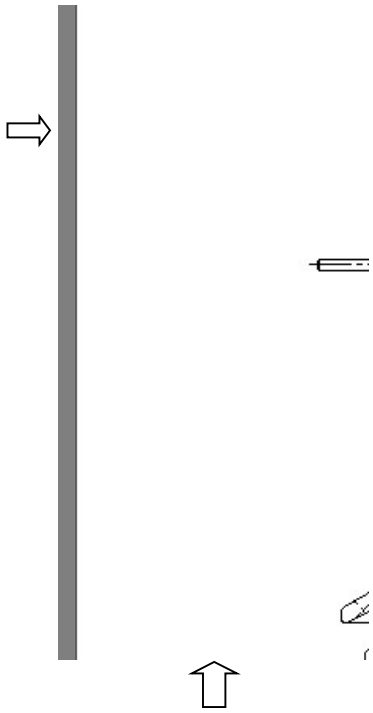


Fig. 16 – Draw rod connection

- 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. 12). 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.

4.3.2. Bottom connection

- Pull the assembled inner terminal lug through the bushing from the bottom (fig. 17).
- Fix it to the bottom plate of the bushing, aligning the holes and screwing the four foreseen screws, 5/16" – UNF type. Tighten the screws with a torque of 13 Nm. Do not use the locking pin in the head.

WARNING

In the bottom connection application, do not use the locking pin located in the head of the bushing, to permit the dilatation of the conductor.

- 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 the terminal well centered on the axis of the bushing (fig. 12). 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 connection for In=1200 A

4.4. BOTTOM CONNECTION FOR In>1200 A

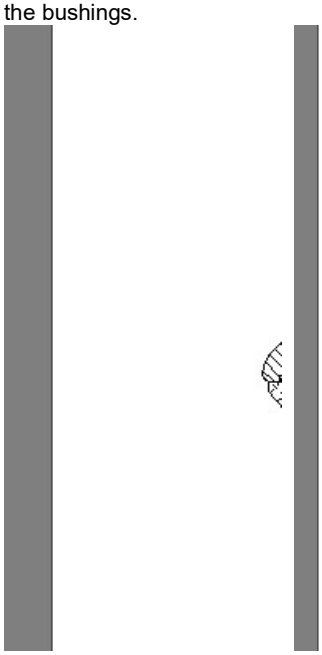
For rated current greater than 1200 A the conductor is rigid and not removable. A fixed rod, one piece made, carries out the current, from the bottom connection, oil side, up to the HV connection, air side. The connections are foreseen according to IEEE Standard dimensions: air side one is threaded (1.5 in. x 12 for 2000 A type, 2.0 in. x 12 for 3000 A type), oil side connection is palm type.
In fig. 18 there is an example of PAO 2000 A and PAO 3000 A structure, showing the oil side and air side connections.

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 fluorine-silicone mixtures for low temperatures.
The spring closing system is calibrated in order to maintain the bushing's 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.



2000 A *3000 A*

Fig. 18 – Bottom connection for In>1200 A

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.

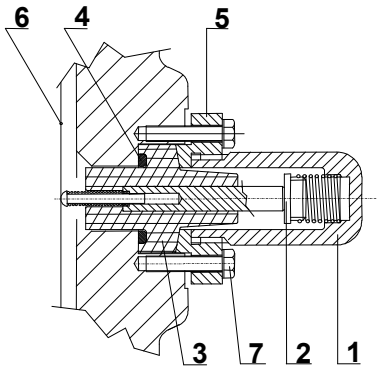
6.1. CHECKS AFTER INSTALLATION

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

Normally the measurement (C1) must be carried out between the HV terminal and the Power Factor tap.

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

Remember that during bushing service the connection tap must be grounded or directly by screwing the tap cap or through the measuring instrument connected to the power factor tap, schematised in fig. 19



1 - Closing and grounding cap (removable)
2 - Measurement electrode
3 - Insulating bushing
4 – Gasket
5 - Mounting flange
6 - Last layer
7 – Fixing screw (not removable)

Fig. 19
Power factor tap

WARNING

The PF tap must be grounded during the normal operation of the bushing.
Do not apply voltage to the bushing if the PF cap is removed. The cap grounds the tap connection.

It is advisable to check that the cap of the PF tap (see fig. 19) is well screwed. A forgetfulness of this generates during service a voltage on the tap that exceeds the insulation dielectric strength: this may lead to a catastrophic failure.

6.2. DISASSEMBLY OF THE BUSHING

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

WARNING

Don't unscrew the screws item 7 of fig. 18, that fix the PF 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.

- Withdraw the terminal from the lug (fig. 12). For this operation it is necessary to draw the terminal 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.
- Remove the locking pin (only in the draw lead configuration). If In>1200 A, bottom connection configuration, these operations are not necessary.
- Fix the bushing like indicated in par 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 connection).

6.3. 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).

Power factor tap

Check the proper location of the tap cap and its suitable complete screwing in order to prevent entrance of moisture (fig. 19).

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. 20), close to the HV terminal, by using some transformer mineral oil, accurately treated and degassed.

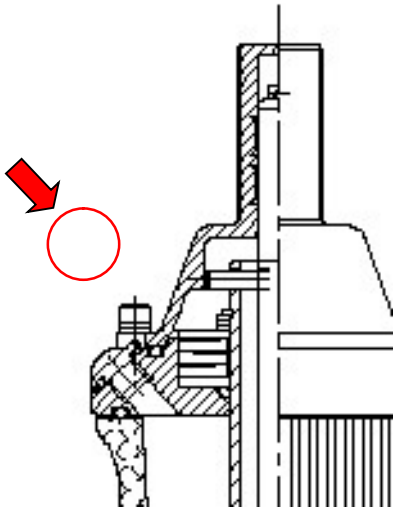


Fig. 20

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 has to be closed just after the conclusion of the refilling operation.

6.4. 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 PF 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 Co value (capacitance between the PF tap and flange) the flange has to be supplied with a voltage maximum of 2 kV and the PF tap has to be connected to the bridge.

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.

6.5. CHECKS ON OLD BUSHINGS

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

6.5.1. Tightness test

Fill completely the bushing through the oil filling plug placed in the top bushing's head (fig. 20) 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 must be detected.

6.5.2. 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 Co.

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.

6.6. 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;
  - Original value: $\leq 5*10^{-3}$
  - During working: $\leq 12*10^{-3}$
- Gas chromatography
  - Make reference to 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.

6.7. 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 shall 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. 20), 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.

The oil filling plug is situated in the head of the bushing, close to the high voltage terminal (fig. 20 and 21)

Due to the method used to take the oil sampling it must be underlined that is not possible to evaluate the right content of nitrogen (N_2) and oxygen (O_2).

One must take care to CO and CO_2 quantity, because these gases are contained in a certain quantity in the air and are consequently able to pollute the oil.

Equipment

To carry out oil sampling from a bushing, it is necessary to have the following elements:

- A 100-150 cm^3 oil syringe (lab. Type);
- A two-way cock with a suitable connection to the syringe;
- A semi-rigid pipe;
- A syringe cap;
- Adhesive tape.

Preparation

Operate as follows (see fig. 21):

- Clean the oil sampling plug zone accurately;
- Prepare all the syringe apparatus, with the cock and the tube;
- Unscrew the oil sampling tap and put the pipe, on which the cock and the syringe are applied in sequence, in the bushing's head. Be sure that the pipe is immersed in the oil;
- Open the 1st way of the cock, closing the cock's 2nd way;
- Drain oil from the bushing, sucking it with the syringe, letting it flow out until there are no more air bubbles;
- Shut off the cock's 1st way opening the cock's 2nd way;
- Empty the syringe;
- Shut off the cock's 2nd way opening the cock's 1st way.
- Fill in again the syringe with some oil (about 10-20 cm^3);
- Close the cock's 1st way and open the 2nd way of cock;
- Empty the syringe.

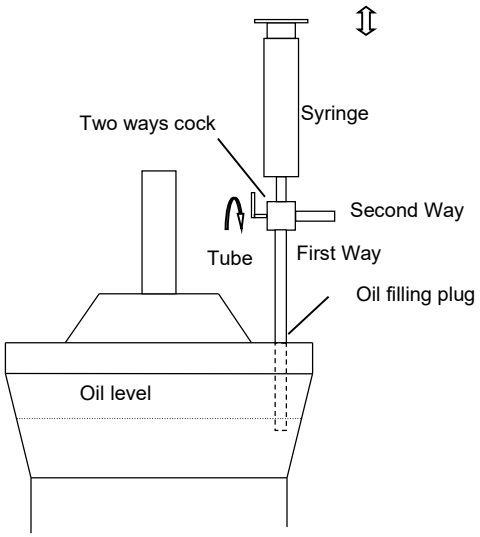


Fig. 21

Oil sampling

- Close the cock's 2nd way opening the 1st way;
- Drain oil from the bushing, slowly sucking it with the syringe up to appropriate volume (approx. 60-100 cm^3);
- Shut off 2nd way of the cock;
- Extract the tube from the bushing;
- Set the syringe with the cock being up;
- Unplug the cock and place the closing cap;
- 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;
- Screw the oil filling plug on the head of the bushing;
- Clean the oil sampling zone accurately.

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