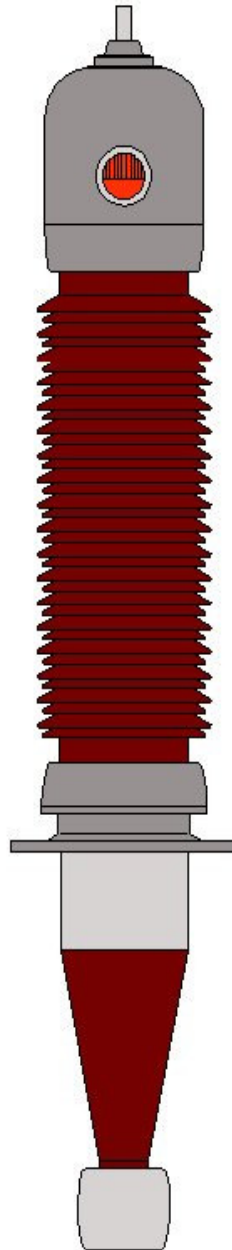




Via Mario Villa, 210
20099 Sesto San Giovanni (MI), Italy
Tel. +39 02 24 10 50 01
www.ge.com

IS 2470 GB
Page 1 of 16

OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 kV TO 765 kV



STORAGE, OPERATING AND MAINTENANCE INSTRUCTIONS

Property of GRID SOLUTIONS SPA

This document and any information therein contained are proprietary and confidential and must not be distributed, published, or more generally disclosed for any purpose whatsoever. Effectivity of paper copy should be checked prior to use.



**OIL-TO-AIR BUSHINGS SERIES PNO
VOLTAGE FROM 245 TO 765 kV**

IS 2470 GB

Page 2 of 16

Instruction Manual

Rev. L – Aug. 2019

INDEX

1 DESCRIPTION.....3

1.1 GENERAL3

1.2 SAFETY3

1.3 TECHNICAL CHARACTERISTICS3

2 PACKING AND STORAGE.....5

2.1 PACKING5

2.2 ACCEPTANCE5

2.3 STORAGE6

3 LIFTING AND TRANSPORTATION6

3.1 PACKED BUSHING6

3.2 UNPACKED BUSHING6

3.3 SHIPMENT TO THE END USER.....7

4 INSTALLATION ON THE TRANSFORMER.....8

4.1 DRAW LEAD CONNECTION8

4.2 DRAW ROD CONNECTION9

4.3 BOTTOM CONNECTION9

4.4 OIL SIDE SHIELD10

4.5 ICE AND SNOW DEPOSITS10

4.6 OIL FILLING OF THE TUBE OF THE BUSHING10

4.7 OIL LEVEL REGULATION11

4.8 CONNECTION TO BUCHHOLZ RELAY11

5 TEMPERATURE LIMITS11

6 SERVICE AND MAINTENANCE.....11

6.1 METAL PARTS11

6.2 CHECKS AFTER INSTALLATION11

6.3 DISASSEMBLY OF THE BUSHING12

6.4 MAINTENANCE13

6.5 MEASUREMENT OF DIELECTRIC LOSSES13

6.6 CHECKS ON OLD BUSHINGS14

6.7 EXTRAORDINARY CHECKS14

6.8 OIL SAMPLING14

7 DISPOSAL AT THE END OF LIFETIME16

Revision L	August 2019
Revision I	November 2017
Revision H	March 2015
Revision G	May 2012
Revision F	October 2010



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 3 of 16

Instruction Manual

Rev. L – Aug. 2019

1 DESCRIPTION

1.1 GENERAL

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

“PNO” - Rated voltage from 245 to 765 kV

according to IEC 60137 Standard “Insulated bushings for alternating voltages above 1000 V” 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:

PNO.525.1550.1250

P Condenser bushing (“P” from Italian word “Passante”)

N Normal tail type, oil to air

O Oil paper insulation (OIP)

525 Rated voltage (in kV)

1550 BIL – Basic Insulation Level (in kV)

1250 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.

The 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 CHARACTERISTICS

These bushings are capacitance-graded type (fig. 1), 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, for installation with inclination up to 30° or 45° from the vertical, depending on the voltage class and the bushing dimensions (indication to be checked on the drawings)

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 or conductor rod.

Heated cylinders and infrared rays dry the paper during winding, to reduce the water content in the paper to 1% maximum.

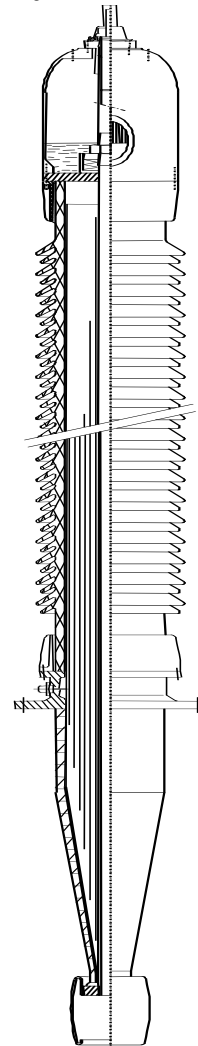


Fig. 1

During the 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 to obtain the best impregnation and to test the perfect tightness.

After impregnation, the head of bushing is filled with nitrogen cushion. All this process is automatic, and computer controlled.



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 4 of 16

Instruction Manual

Rev. L – Aug. 2019

1.3.2 Air side

The air side envelope is made of porcelain, brown colour (upon request grey colour or resin fibre-glass envelope covered with silicone sheds), with a creepage distance normally 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 Standards.

More pieces of porcelain are used, epoxy resin glued, without using gaskets in between.

1.3.3 Oil side

The oil side envelope is made of moulded epoxy resin for bushings up to 420 kV. 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 resin is bi-components type, i.e. consists of a resin base and a hardener, the charge material is quartz sand. The epoxy resin envelopes have shapes, thickness and dimension tolerance not possible to be achieved by porcelains, moreover they can grant the possibility of making metal parts embedded in the mass itself.

For bushings greater than 420 kV the oil side envelope is made of one-piece porcelain.

Versions with under flange sleeve in oil side for CT accommodation are available upon request.

1.3.4 HV terminal

The HV terminal can be removable in case of draw lead or draw rod execution; it is coupled to the conductor by means of multi-blades contacts, and it is fixed on the head by means of four screws. In case of bottom connection execution, it is fixed.

Terminal can be made of aluminium or copper, depending from the rated current of the bushing; the aluminium one can be without any surface treatment or silver plated; the copper one is always tinned.

1.3.5 Head and oil level indication

The metal components of the head are made of aluminium alloy casting and acts as oil reservoir.

The bushing head operates as oil compensator and is provided by an oil level indicator, prismatic glass type or magnetic type.

1.3.6 Oil side shield

The oil side is shielded by a suitable electrode, made of aluminium sheet, with the function of reducing the dielectric strength in oil. The shield is removable in order to ease the lead connection operations.

1.3.7 Flange

The flange made of aluminium casting and is equipped with the following accessories:

- Power factor tap;
- Buchholz relay connection;
- Oil sampling valve;

- Lifting holes;

- Potential device tap (voltage tap) – on request.

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.

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 -60°C) special o-rings are foreseen, made of Fluor-silicone 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, to have a stronger mechanical resistance.

The cement used is a monocalcic aluminized type, curing quick. All the cement surfaces in contact with the external ambient are protected by means of a silicone sealing.

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. Name plate

Each bushing is provided with a name plate, indicating serial number and all the electrical data, in accordance with the prescription of IEC Standards.

The plate (fig. 2) is made of aluminium and is fixed on the flange by nails. The plate includes the following information:

- 1 – Serial number
- 2 – Month & year of production
- 3 – Type of bushing
- 4 – Standard reference
- 5 – Rated frequency
- 6 – Max. system voltage
- 7 – Insulating voltages
- 8 – Rated current
- 9 – Main Capacitance measured value
- 10 – Tap capacitance measured value
- 11 – Dissipation factor measured value
- 12 – Max. mounting angle
- 13 - Weight

	OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV	IS 2470 GB
Page 5 of 16	Instruction Manual	Rev. L – Aug. 2019

Name plate detail

PASSONI & VILLA MILAN ITALY		SERIAL NR. <input type="text"/>	M/YEAR <input type="text"/>
PASSANTE-BUSHING-TRAVERSEE-DURCHFÜHRUNG			
TYPE <input type="text"/>			
STD REF. <input type="text"/>			50-60Hz
Um <input type="text"/> kV	BIL/SIL/AC <input type="text"/>	kV	Ir <input type="text"/> A
C1 <input type="text"/> pF	C2 <input type="text"/> pF	P.F. <input type="text"/> %	AT 10kV/20°C
<input type="text"/> °C	<input type="text"/> kg		

Fig. 2

The month is indicated by a code, as follows:

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

2 PACKING AND STORAGE

2.1 PACKING

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 glued in the bushing's head.

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

CAUTION
<p>When the bushing is positioned in horizontal position, make sure to follow the indications written in the yellow label of fig. 3, positioned on the head: the bushing must be positioned with the oil level indicator towards the bottom.</p>

2.2 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;



Fig. 3

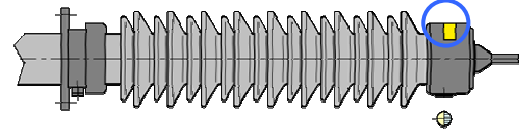


Fig. 4

- The shock and tilt indicators, placed in the external part of each packing case (fig. 5 and 5A), must be NOT ACTIVATED.





OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 6 of 16

Instruction Manual

Rev. L – Aug. 2019

If a 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 the oil level is correct;
- 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.

2.3 STORAGE

Although there is no preclusion for the bushings remaining in the open air, it is preferable to store them in a closed location.

The bushings must be kept in their original packing and in their initial position, that is with the oil level indicator 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 silica gel 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 par. 5), where special o-rings are foreseen, the bushings can be stored at temperature up to -60 °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 to the final installation of the bushing on the transformer, special care must be taken to avoid that the lower part of the bushing, if made of epoxy resin, remains outside and in very humid places for long periods. In fact, the resin-moulded envelope 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 must be considered as an apparatus for indoor installation.

3 LIFTING AND TRANSPORTATION

The bushings type PNO are 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.

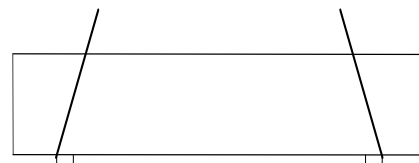
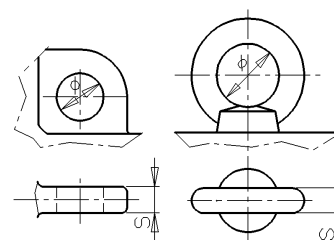


Fig. 6

3.2 UNPACKED BUSHING

To take the bushing out of the case, operate 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 on the flange and fasten it with a string around the upper petticoats of the porcelain (from second and third) (fig. 6a). Note that the lifting flange holes may be of two different types (fig. 7): the first type is an eyebolt screwed on one flange's fixing hole, the other one is cast on the flange itself. The dimensions and type of the flange eyebolts it is M20.



Cast eyebolt Screwed eyebolt

Fig. 7



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 7 of 16

Instruction Manual

Rev. L – Aug. 2019

If the air side is silicone made, the rope must not be fixed between petticoats, because there is the risk to damage them. So, place the rope between the head and the first petticoat

- Apply a second rope at the same two lifting holes (fig. 7a).

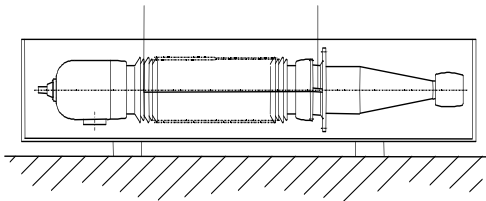


Fig. 7a

- Lift with the two tackles and hold the bushing in horizontal position (fig. 7b).
- Handle with the two tackles to bring the bushing to the vertical position (fig. 7c and 7d).
- Place the bushing on a trestle (Fig. 7e).

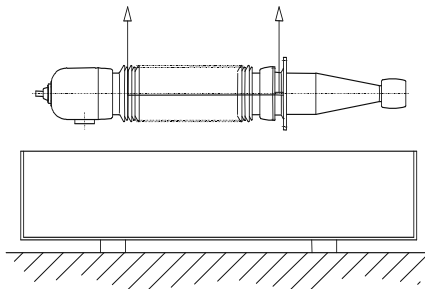


Fig. 7b

CAUTION

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

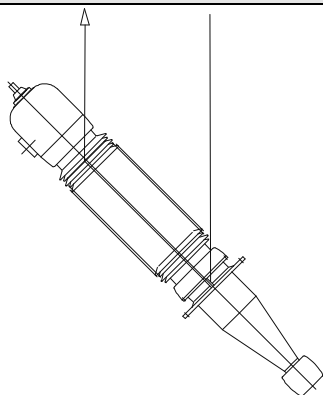


Fig. 7c

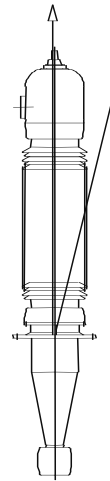


Fig. 7d

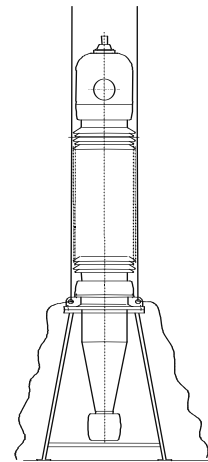


Fig. 7e

Inclined mounting

If the bushing must 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 petticoats of the porcelain (from second and third).

Apply the second rope at the two lifting holes (fig. 7a).

Lift the bushing (fig. 7d) and operate with the two tackles to give the request inclination (fig. 7c).

CAUTION

In all the operations of handling avoid putting the bushing with the head lower than the tail and with the oil level upward (fig. 8), to be sure that no nitrogen goes in the lower part of the bushing.

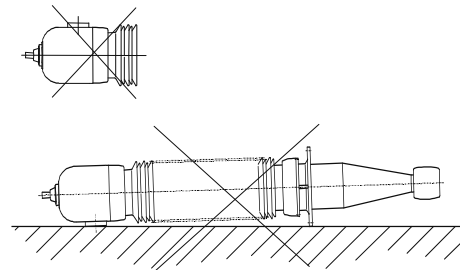


Fig. 8

3.3 SHIPMENT TO THE END USER

Shipment of bushing made by the transformer manufacturer, after the transformer factory tests, has to be made either with the original packing or with a new one, made with the same principles.

Particularly if the bottom part of the bushings is made of epoxy resin, it must be enclosed with the protection



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 8 of 16

Instruction Manual

Rev. L – Aug. 2019

bag. In this case silica gel salts used to protect the oil side from humidity, must be checked: if they have absorbed humidity (i.e. if they are pink colour), they have to be dried into an oven (i.e. brought back to blue colour).

CAUTION

When the bushing is positioned in horizontal position in the case, make sure to follow the indications written in the yellow label of fig. 3, positioned on the head: the bushing has to be positioned with the oil level indicator 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 may have been trapped in the insulation. In any case it is advisable to keep the bushing in a vertical position for about 48 hours prior to electrically testing it.

The installation of the bushing on the transformer and the coupling with the insulated connection coming from the winding must be executed according to the following information:

4.1 DRAW LEAD CONNECTION

In this type of execution, 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 (fig. 11 and fig. 12).

Complete the assembly as follows:

- The lug has to be removed from the head of the bushing in order to make the connection: to disassemble the HV top terminal cap (1), remove the 4 x M8 screws and lock washers, which secure it to the bushing head. Pull the HV top terminal (1) from the lug (3), keeping the terminal well centered on the axis of the bushing. The necessary force is small (about 10 kg.) because the multicontact blades (2), located inside the terminal, press softly on the smooth surface of the lug (3). Verify that the o-ring remains seated in the recessed gasket retention groove.
- Remove the locking pin (4) from the lug hole;
- Remove the copper lug (3) from the central tube of the bushing;
- Cut the connection at a right size L_{cut} plus 20 mm for the soldering of the lug; note that the size L_{cut} is indicated on the "bushing overall dimensions" drawing, supplied with the bushing's order confirmation;
- Make a hole, in the lug, having sufficient diameter for the connection but a maximum diameter 3 mm lower than that of the lug;

- Make the connection, through brazing, of the draw lead to the copper lug;
- Fix a thread to the lug, using the M12 hole (fig. 1);
- Place the gasket on the flange on the transformer;
- Slide inside the central bushing's tube from the bottom the lug with the lead;
- Lift and install the bushing according to the instructions of par. 3.
- Align the hole in the lug with the hole in the central tube and secure the lug in position by reinstalling the locking pin;
- Be sure the pin is centred;

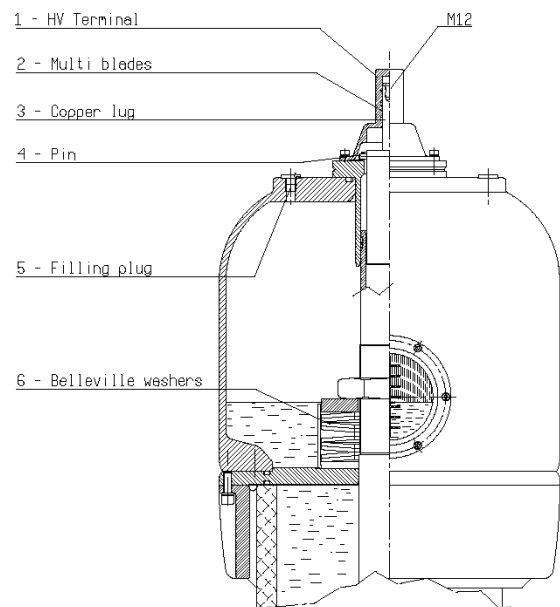


Fig. 9

- Mount the terminal on the lug as described hereunder;
- 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. The necessary force is small (about 10 kg) because the multicontact 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 by 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 a 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 allow the oil circulation).

4.2 DRAW ROD CONNECTION

In this type of execution, the internal bushing's conductor, carrying the current, is rigid and removable. It can be also sectioned in two parts, to make easier the transport of the transformer.

The procedure is similar as the draw lead execution, but now instead of a lug it is used a conductor that is placed inside the bushing all along it and coming out from the bottom part.

The connection coming from the transformer has to be soldered to the lower extremity of the conductor.

4.3 BOTTOM CONNECTION

In this type of execution, the current is carried directly by the central bushing conductor; the passage of current from the bottom terminal and the tube and from the tube and the top bushing terminal (item 2 of fig. 10, 11, 12, 13, 14) is obtained by means of special inner lugs, equipped with multi-contact blades (item 1 – fig. 10, 11, 12, 13, 14).

There are some types of bottom connection terminals, upon customer request (fig. 11, 12, 13, 14), all made of copper:

- Palm type (fig. 11);
- Cross type (fig. 12);
- Hexagon type (fig. 13);
- Clamping type (fig. 14).

Every type of bottom connection terminal has a system of holes to make the transformer winding connection. In the case of hexagon type of bottom connection, the holes are threaded.

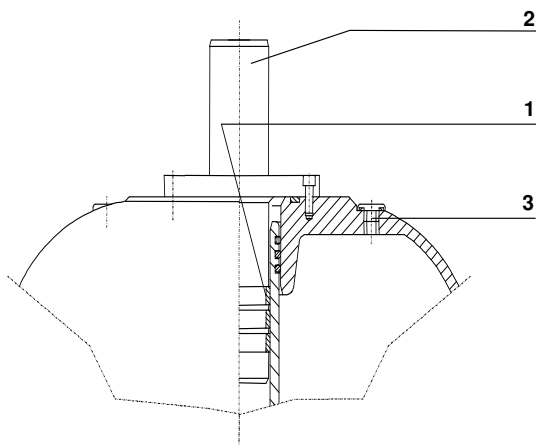


Fig. 10

In this type of bushing connection, the top terminal (2) has not to be dismantled. It is fixed with four M8 screws to the bushing head and includes in one piece also the internal connection lug with multi-contact blades (1).

Only if the transformer oil filling is not made under vacuum it is suggested to loosen the four screws of the HV terminal, to permit to the air inside the internal central tube of the bushing to flow out during filling. Then these four screws must be tightened with a torque of 13 Nm.

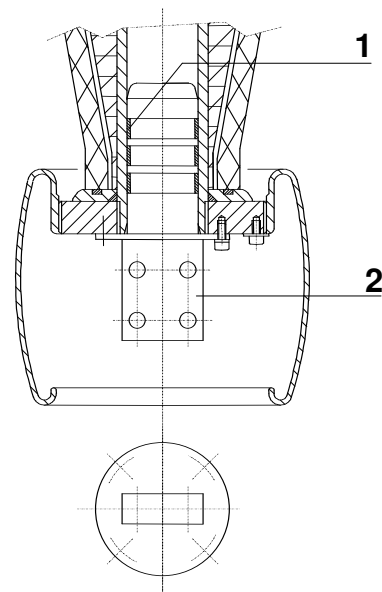


Fig. 11
Palm type bottom terminal

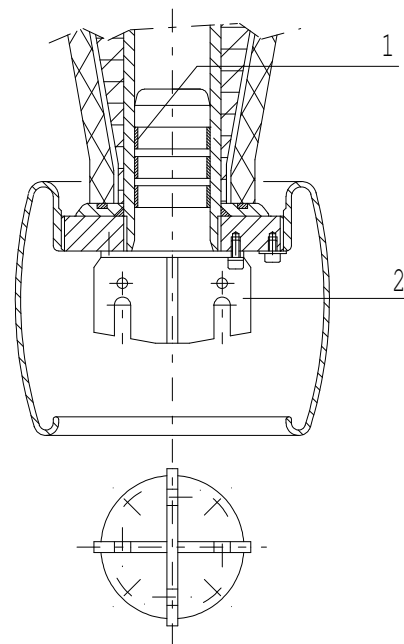


Fig. 12
Cross type bottom terminal

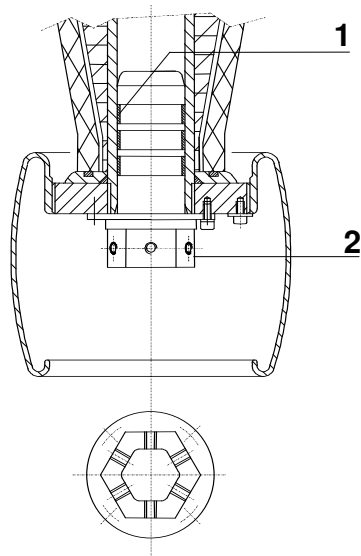


Fig. 13
Hexagon type bottom terminal

CAUTION

In the bottom connection execution, the top HV terminal has not to be dismantled. Only if the transformer oil filling is not made under vacuum it is suggested to loosen the four screws of the HV terminal, in order to permit to the air inside the internal central tube of the bushing to flow out during filling. Then these four screws must be tightened with a torque of 13 Nm.

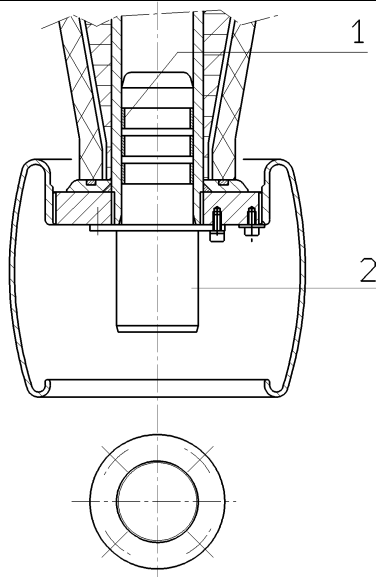


Fig. 14
Clamping type bottom terminal

4.4 OIL SIDE SHIELD

The bottom end of the bushing is shielded by a suitable aluminium insulated electrode. It has the function of increasing the dielectric strength in oil and screen the connection between the lead coming from the transformer winding and the bushing itself.

This deflector is removable to make easier the connection between transformer cable and bushing.

There are two shield's versions:

- Deflector removable upwards: it can be unscrewed upwards (fig. 15).
- Deflector with bayonet coupling: it can be removed downwards rotating and pulling down its body.

In the first execution, in a suitable slot on the thread there an O-ring is placed to act as a brake against a possible deflector's movement due to vibrations during service. Take care that this remains in its slot during deflector dismantling.

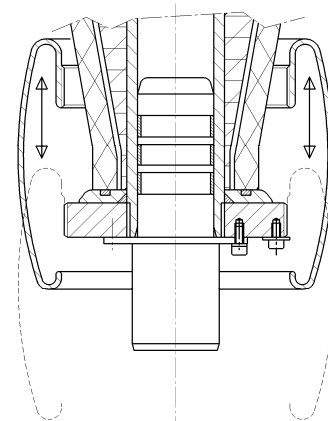


Fig. 15

CAUTION

During handling, take care to not damage the external finishing coat of the dielectric shield, important in the dielectric strength of the bushing oil side.

4.5 ICE AND SNOW DEPOSITS

If the transformer is installed in arctic climate with bushings mounted in inclined position, and must be put in service, it is recommendable before to remove from every bushing's porcelain excessive ice or snow deposits, which can reduce the dielectric withstand capability.

4.6 OIL FILLING OF THE TUBE OF THE BUSHING

It is foreseen that the bushing operates with the inner tube filled with the transformer's oil at least up to the flange, to improve the bushing cooling.

After the closure of the bushing, it is necessary to make the vacuum on the transformer and then fill it with oil.



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 11 of 16

Instruction Manual

Rev. L – Aug. 2019

In case the oil filling is made from the top of the transformer without the vacuum treatment, it is necessary to be sure that the oil level reaches the bushing flange, without the presence of air bubbles.

For this purpose, the flange is provided with a plug which allows the air to flow out (fig. 16).

Furthermore, lift a bit the HV terminal to allow the air to go out and complete the filling of the transformer and of the lower part of the inner tube of the bushing.

Bushings can withstand the vacuum conditions and temperature (up to 90°C) which occur during the treatment of the live part made inside the transformer case.

CAUTION

The characteristic of withstanding vacuum and temperature refers to new bushings. In case of old bushings, it must be considered the natural de-rating and ageing of the gaskets

4.7 OIL LEVEL REGULATION

In the factory, the bushings are filled with oil in order the oil level reaches about the half of the prismatic indicator at 20°C.

Bushings are filled to assure, in vertical position, a visible oil level in the whole range of operating temperatures.

When the bushing is mounted on the transformer in inclined position with an angle higher than 10-15° from the vertical, it should be better to regulate the oil level.

Remove some bushing's oil or add transformer mineral oil accurately treated, through the head's plug placed in the upper part of the head, near the HV terminal (item 5 – fig. 9, item 3 – fig. 10) to have a visible oil level in the whole range of operating temperatures.

4.8 CONNECTION TO BUCHHOLZ RELAY

A 1/2" GAS plug is placed on the bushing flange (fig. 16) in order to:

- Connect the relay tube, if foreseen;
- Eliminate the air pocket which may be formed during some executions and by the filling of the upper part of the transformer not under vacuum.

In this case we suggest unscrewing the plug and leave the air flowing. When the oil begins to come out, close the plug.

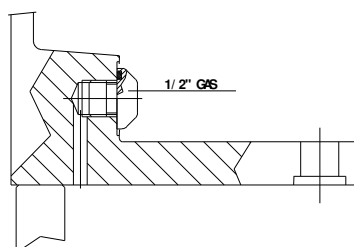


Fig. 16

5 TEMPERATURE LIMITS

Bushings of the series PNO are designed for operation at temperatures according to IEC 60137 Standard:

Ambient temperature:	Maximum:	+ 40°C
	Max. daily mean:	+ 30°C
	Minimum:	- 25°C
Oil temperature:	Maximum:	+100°C
	Max. daily mean:	+ 90°C

The over-temperatures allowed are in accordance to IEC 60137 Standard.

To comply with these limits, in bushing with draw lead connection, it is suggested to use one or more leads, having a total section that gives a current density not higher than 2 A/mm².

For special requirements regarding low ambient temperatures (up to -60°C) special o-rings are foreseen, made of Fluor silicon mixtures for low temperatures. The spring closing system is calibrated 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 Aluminium 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.

Normally the measurement (C1) must be carried out between the HV terminal and the Power Factor tap (schematised in fig. 17).

During operation, the PF tap must be grounded maintaining screwed its proper grounding cap.

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

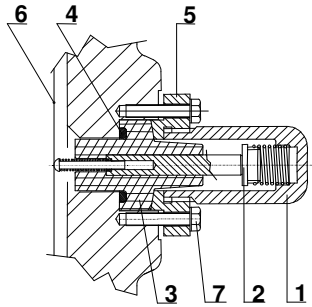
On request bushings can be provided with PD (Voltage) tap, which is suitable either for the connection to a Potential Device or for the measurement of the power factor (fig. 19).

In bushings provided of PD tap the measurement can be carried out between the HV terminal and PD tap (C1) and another one between PD and PF tap (C2).



If present and not used, the Potential Device tap must be grounded maintaining screwed its proper grounding cap (see fig. 19).

If present and used, it must be grounded through the connected measuring instrument.



- 1 - Closing and grounding cap (removable)
- 2 - Measurement electrode
- 3 - Insulating bushing
- 4 - Gaskets
- 5 - Mounting flange
- 6 - Last layer
- 7 - Fixing screw (irremovable)

Fig. 17
Power factor tap (standard)

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. 17) 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.

Upon request on the bushing's flange it can be mounted another type of PF tap (fig. 18), according to the French Standard NFC 52062.

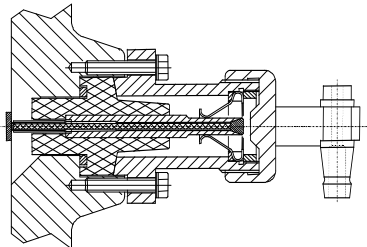


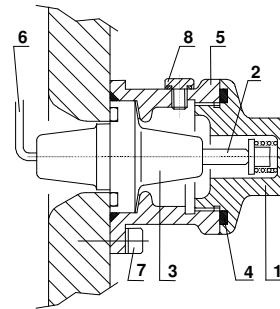
Fig. 18
Power factor tap NFC (on request)

WARNING

Don't unscrew the screws item 7 of fig. 17, 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.

If a Potential Device is connected to the potential device tap, we recommend filling of oil the internal part of the connection through the oil filling plug placed in the upper part of the tap (fig. 19 item 8), to avoid possible internal and dangerous sparking.



- 1 - Closing and grounding cap (removable)
- 2 - Measurement electrode
- 3 - Insulating bushing
- 4 - Gasket
- 5 - Mounting flange
- 6 - Internal connection
- 7 - Fixing screw (irremovable)
- 8 - Oil filling screw

Fig. 19
Potential Device tap (voltage tap)

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.

WARNING

If the potential device tap is not used, we recommend controlling if the cap of the oil filling screw (fig. 19 item 8) have been properly applied and screwed. On the contrary moisture entering can cause the corrosion of the tap connection contact, with dangerous sparking problems.

6.3 DISASSEMBLY OF THE BUSHING

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



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 13 of 16

Instruction Manual

Rev. L – Aug. 2019

- Bring the oil until a level lower than the bushing flange;
- For draw lead and draw rod type bushings withdraw the terminal from the lug (fig. 9). 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. For bottom connection bushings, loose the terminal four screws, to let go down the transformer oil level inside the bushing central tube, and then remove the connection in the oil side.
- Secure a pulling device to the hole foreseen in the top of the lug and remove the locking pin (not for bottom connection execution);
- 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;

6.4 MAINTENANCE

The bushings PNO 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 ($\tan\delta$) following the instruction under par. 5.

As for the preservation of the external surfaces, the manufacturer suggests undergoing 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 must 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 to avoid poor contacts and consequent overheating.

Pay special attention on 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 to not damage the tinned layer, if present. 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 to prevent entrance of moisture (Fig. 17).

Potential device tap (Voltage tap)

If present and not used, check the proper location and the suitable complete screwing either of the tap cap and the oil filling screw, to prevent entrance of moisture (Fig. 19). Voltage tap If not used 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

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, near the HV terminal (item 5 – fig. 9, item 3 - fig. 10), by using the same transformer mineral oil, accurately treated and degassed. Close the cap with a tightening torque of 100 Nm.

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 would 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.

The oil inside the bushing is not toxic and perfectly miscible with mineral transformer oil, both from the physical and chemical point of view and from the dielectric and thermal properties.

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.

6.5 MEASUREMENT OF DIELECTRIC LOSSES

Test in the factory

The Standard - IEC Publication 60137 - states that the oil-paper bushings must have a $\tan\delta$ less than 7×10^{-3} . The measurement is performed in our Test Laboratory by means of a Schering bridge (Tettex type) at the voltages requested by the Standards.

All values are shown in the Test Report.

Measurement at the voltage of 10 kV is carried out to have a reference value for comparison with measurements made at site during the service of the bushing.



OIL-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 14 of 16

Instruction Manual

Rev. L – Aug. 2019

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 (or PD if present), maintaining grounded the flange (C1 measurement). The bushing is considered good if a $tg\delta$ less than the maximum one established by the Standards is measured.

If a $tg\delta$ 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, 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.

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

In case of presence of PD tap, this one can be supplied with a max voltage of 10 kV and the PF tap has to be connected to the bridge (C2 measurement).

A field measurement of $tg\delta$ 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 $tg\delta$) is acceptable. Furthermore, the installation conditions, due to stray capacitances, can affect the capacitance value. For this it is advisable to measure capacitance and $tg\delta$ 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.

6.6.1. Tightness test

Fill completely the bushing through the oil filling plug placed in the top bushing's head (fig. 10, item 3) 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.

6.6.2. Electrical checks

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

- 1% for the capacitance C1 (this assure that there isn't a perforation between two layers)
- 30% for $tg\delta$ of capacitance C1.
- 100% for $tg\delta$ of capacitance Co.

An increase of the last value means a de-rating of the dielectric characteristic of the external layers of the paper and/or of the oil in the interspaces between the

condenser body of the bushing and the external housing.

6.7 EXTRAORDINARY CHECKS

If the electric measurement detects a $tg\delta$ 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 ($tg\delta$):
 - Original value: $\leq 7 \cdot 10^{-3}$
 - During working: $\leq 12 \cdot 10^{-3}$
- Gas chromatography (DGE):
 - Refer to relevant Standards (IEC 60599, IEC TR 61464)

If these checks give negative results, it is necessary to ship back the bushing to the manufacturer who will execute 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

On the bushing flange, there is a valve (see fig. 20 and 21) positioned in closed position: it is the oil sampling valve. On this valve, it is screwed 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.

CAUTION

The operation is to be obviously carried out when the line is off.

Equipment

To carry out oil sampling from a bushing, we need the following (see fig. 20):

- A 150 cm³ oil syringe (item 4) (Lab. Type);
- A semi-rigid pipe (item 2);
- An appropriate little flange suitable for fixing to the sampling valve (having 4 holes positioned at 90° each other, with a hole wheelbase of 50 mm; the o-ring housing is positioned on the valve body). This little flange will have a suitable connection to the sampling semi-rigid pipe (item 1);



- A two-way cock (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 (item 3) and the tube (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 (item 1);
- 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 cm³), 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 syringe;
 - 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 cm³);
- Shut off both 2nd way of the cock (item 3) and the bushing's valve;
- Remove the syringe by unplugging the cock (item 3) from the tube;

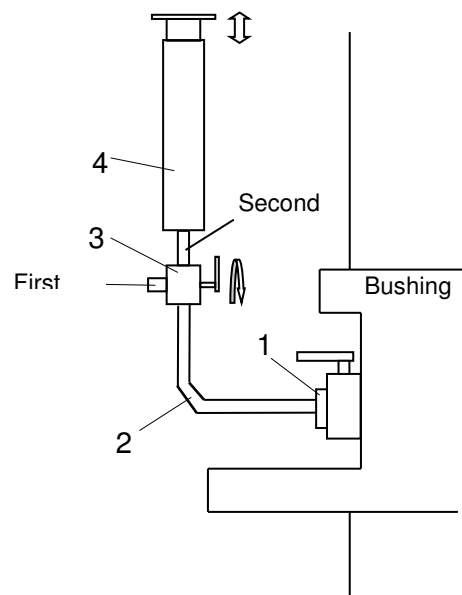


Fig. 20

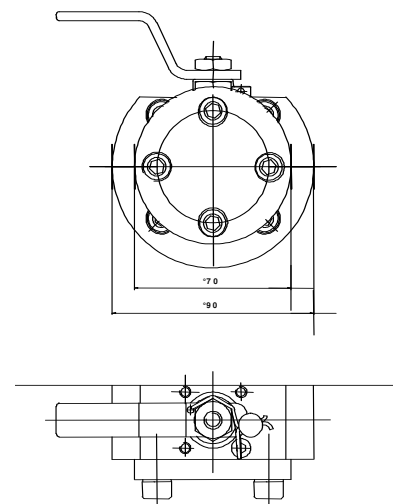


Fig. 21

- Set the syringe with the cock (item 3) being up;
- Unplug the cock (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 (item 3, fig. 10).

The abovementioned operations involve overall a sampling of about 0.2-0.3 litres of bushing oil.

The oil taken out must be restored by adding the same quantity of transformer mineral oil, accurately treated and degassed. The refilling must be done through the

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-TO-AIR BUSHINGS SERIES PNO VOLTAGE FROM 245 TO 765 kV

IS 2470 GB

Page 16 of 16

Instruction Manual

Rev. L – Aug. 2019

tap located on the top of the bushing's head (item 3, fig. 10), which must be closed immediately after the end of the operations.

CAUTION

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

7 DISPOSAL AT THE END OF LIFETIME

The bushing consists of the following material:

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