OIL TO AIR BUSHINGS SERIES

PNO 800 kV

STORAGE, OPERATING

AND MAINTENANCE INSTRUCTIONS

INDEX

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1 DESCRIPTION

1.1 GENERAL

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

"PNO" - Rated voltage 800 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.800.2100.2500

P	Condenser bushing ("P" from Italian word "Passante")
N	Normal tail type, oil to air
O	Oil paper insulation (OIP)
800	Rated voltage (in kV)
2100	BIL – Basic Insulation Level (in kV)
2500	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, 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° from the vertical.

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 metallic tube.
Heated cylinders and infrared rays dry the paper during winding, to reduce the water content in the paper to 1% maximum.
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 several 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 porcelain, brown colour (upon request grey colour or resin fibre-glass envelope covered with silicone sheds), with a creepage distance normally for high (25 mm/kV) or very high-polluted atmosphere (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 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 not removable.
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, casted and/or machined.
The bushing head operates as oil compensator and is provided by an oil level indicator, magnetic type.

1.3.6. Oil side shield

The oil side is shielded by a suitable electrode, made of aluminium sheet, covered by a layer of epoxy resin (thickness: 2-3 mm), with the function of reducing the dielectric stress of the connection. The shield is removable in order to ease the lead connection operations. Under request the shield can be supplied bare or covered by pressboard

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

O-ring type, made of fluorocarbon elastomer, O-ring type, they are compatible with the impregnating oil of the bushing and the 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 fluorine-silicon 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.
The cemented used is a monocalcic aluminized type, quick curing type. 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 plate, with serial number and all the electrical data, in accordance with the prescription of IEC Standards.
The plate (fig. 1) is made of aluminium and is fixed on the flange by nails; the following information are indicated:

Name plate detail

Fig. 1

The month is indicated by a code, as follows:

A = January E = May P = September

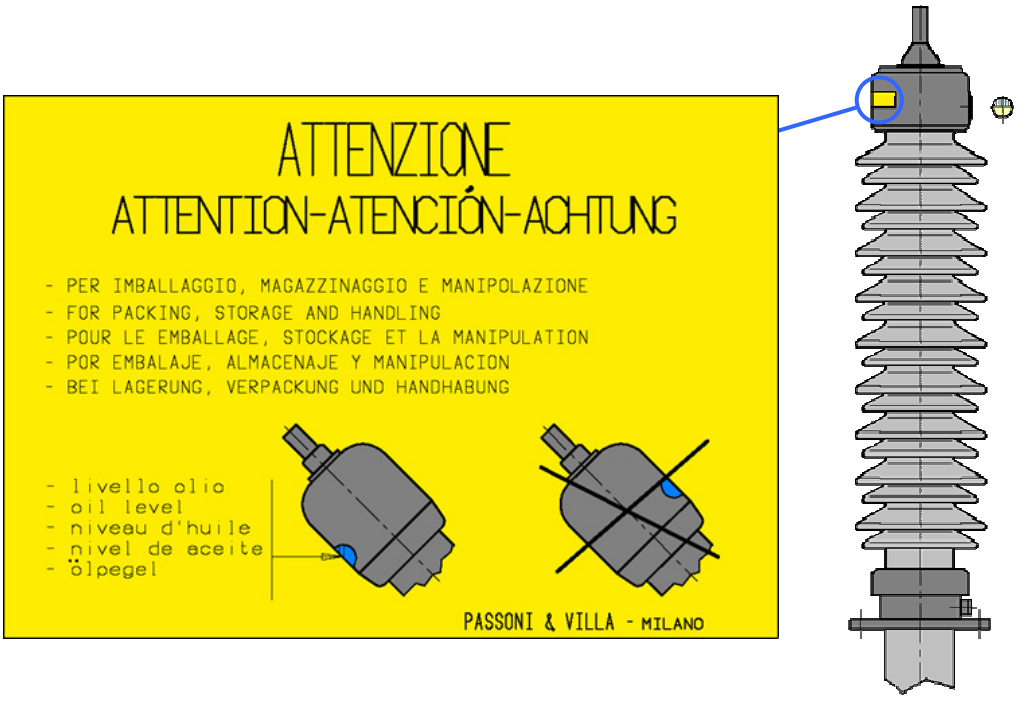
B = February	H = June	R = October
C = March	L = July	S = November
D = April	M = August	T = December

2 PACKING AND STORAGE

2.1 PACKING

After the tests, before packing, the lower part of the bushing is cleaned from the oil (residuals due to the electrical tests in which the oil side of the bushing is immersed in the oil) and the air 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 and indefinitely maintained 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 position grants that the dimensions of cases, containing one bushing, are smaller and the transportation less costly.

CAUTION
When the bushing is horizontally positioned, make sure to follow the indications written in the yellow label of fig. 2, put on the head: the bushing has to be positioned with the oil level indicator towards the bottom.



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;
  - The shock-watch indicator, placed in the external part of each packing case (fig. 3), must be white (NOT ACTIVATED).

Fig. 3

- If the shock watch 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 bushing, 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 the oil side.
- 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

2.3 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 bushing must be kept in its original packing and in its initial position, which 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. 2.

On request, for a long period storage (greater than two years) 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, bushings can be stored at temperature up to – 60°C.
When a 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 bushings type PNO 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. 4. Some indications appear also in the packing case.

Fig. 4

3.2 UNPACKED BUSHING

For security reasons, due to the dimensions of the wooden case, the whole operation must be carried out in two phases:

1. Bushing extraction from the case;
2. Bushing put in vertical position.

3.2.1 Bushing extraction from the case

To take the bushing out of the case, operate according to the following instruction which has to be carefully followed by the people charged to make the job.
Considering the weight and the dimensions it is advisable to use two tackles or two equivalent lifting systems.

- Apply a rope at the two casted lifting holes on the flange (from second and third) (fig. 5a).
- Apply a non metallic rope to the smaller diameter porcelain, in the upper part of the bushing, at about the half part of the cylindrical section.

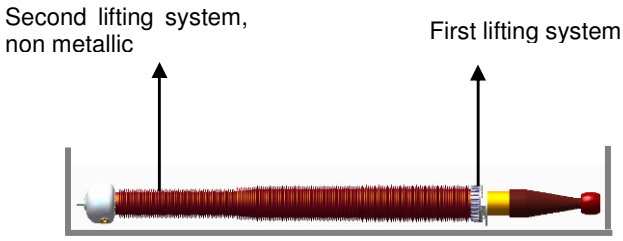


Fig. 5a

CAUTION
Take care to use, for the second lifting system, a non metallic rope, in order to avoid the porcelain shed rupture! Make all these operations only by expert people.

Pay attention to fix the rope like schematized in fig. 5b, to avoid stressing the big shed when the rope will be in tension during the bushing lifting.

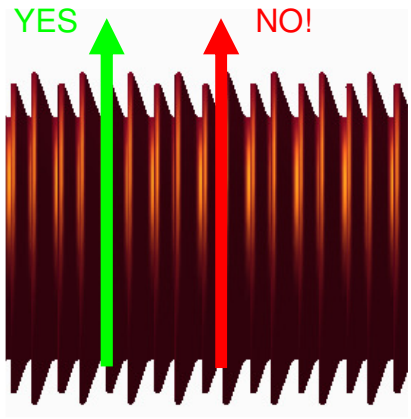


Fig. 5b

- Lift the bushing in horizontal position, putting it on a suitable base, previously prepared (fig. 5c).

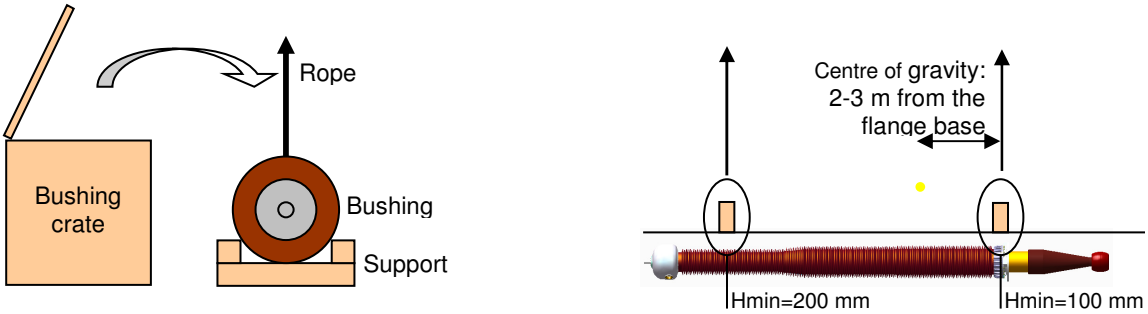


Fig. 5c

WARNING
The base on which the bushing will be put MUST have a suitable soft cushion to avoid porcelain damages. Avoid putting directly the bushing on the floor!

3.2.2 Bushing put in vertical position

To put the bushing in vertical position, a suitable lifting kit must be used. This is composed by five parts (fig. 6):

- PART 1: A collar to be fixed to the cylindrical porcelain;
- PART 2: A fixing tool for the head of the bushing;
- PART 3: Two ropes to connect PART 1 and 2;
- PART 4: The tool provided to maintain parallel the two ropes;
- PART 5: The metallic ropes to lift the bushing.

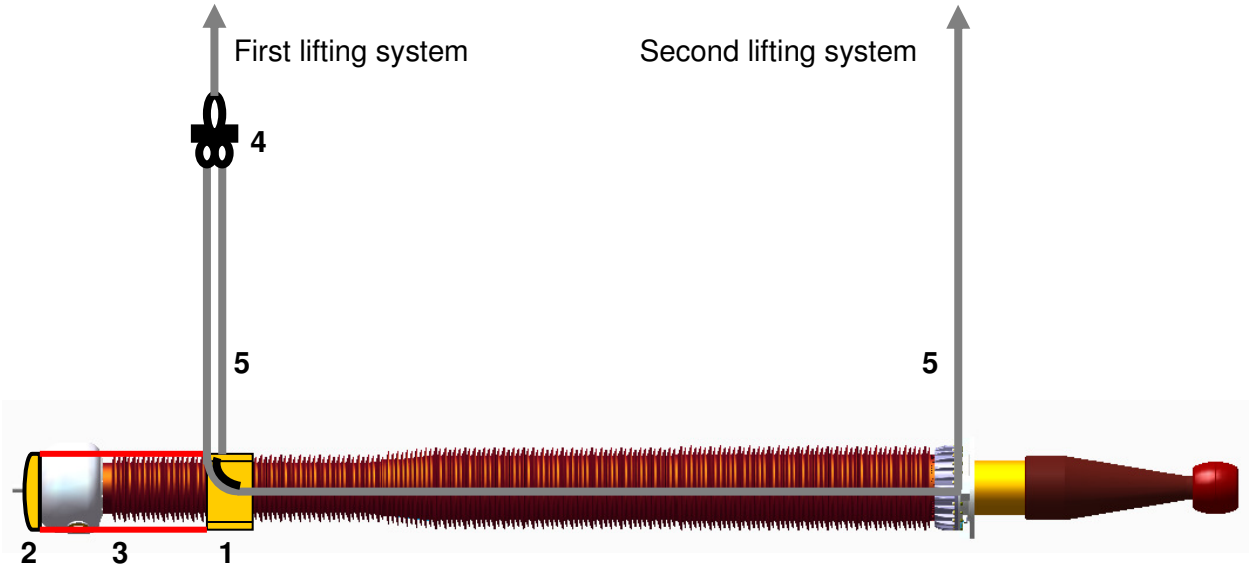


Fig. 6

LIFTING KIT DESCRIPTION AND OPERATIONS TO BE MADE

PART 1 – COLLAR

The PART 1 is an iron collar, made of two pieces, to be fixed on the upper cylindrical part in porcelain of the bushing, see fig. 6 and 7. The surfaces of the collar in contact with the porcelain are covered with a 20 mm thick rubber pad. This pad has the function to protect the porcelain from damages when the collar is mounted. It is composed by two symmetrical parts, to be screwed together by three M16 screws for each side, to fix this collar on the bushing.

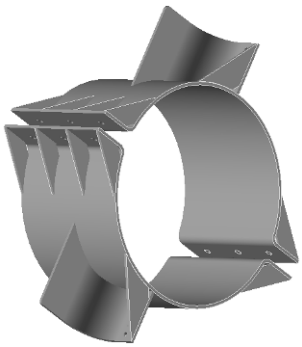


Fig. 7

Pay attention to put the collar in the cylindrical part of the porcelain in the upper part of the bushing, at about half the height, taking care to place it with the two screwing plates in vertical position and the two “ears” for the ropes according to the sketch (fig. 8).

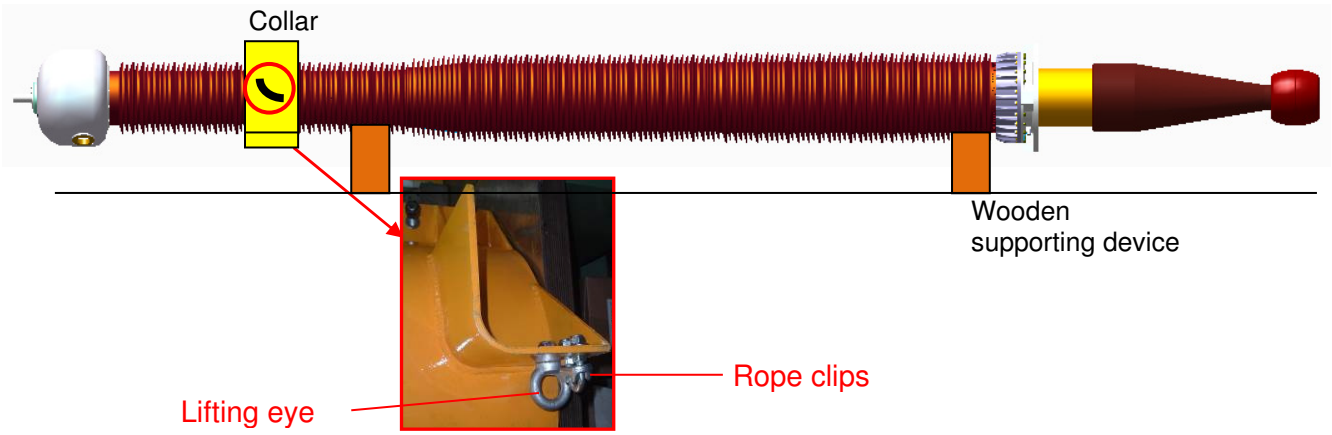


Fig. 8

Be careful to maintain loose the two halves of the collar: the bolts shall be tightened in a second time, after having placed the whole lifting system.

PART 2 – HEAD TOOL

The part 2 is an iron fixing device to be placed on the bushing’s head (fig. 9a) and fixed by using the n.6 M12 screwed studs foreseen for the fixation of the HV air side terminal (fig. 9a and 9b)

Fig. 9a - Head fixing device

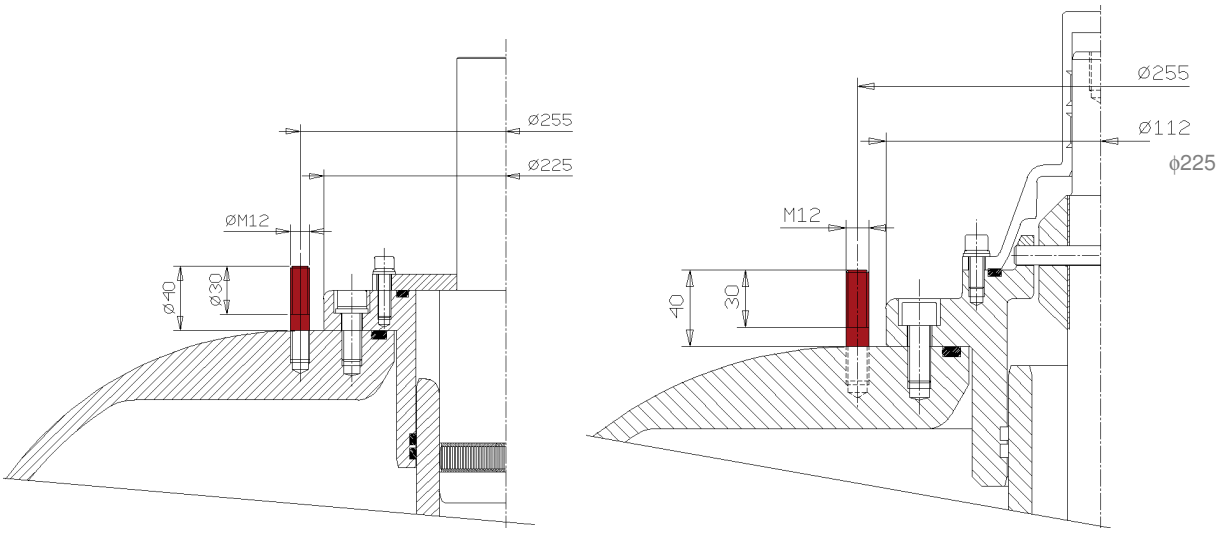


Fig. 9b
Threaded studs on the head casting for head device fixation
(BC type on the left, DL/DR type on the right)

In order to mount this device, the steps are to insert the head tool (fig. 9a) on the head, with its six holes at a PCD of 255 mm, in correspondence of the n. 6 threaded studs, then to fix it with six nuts (torque of 40 Nm), by using these threaded studs.

After the bushing handling this head device will be dismounted by unscrewing the 6 nuts and by removing it from the bushing head.

PART 3 – METAL WIRE ROPES

The part 3 consists of two metallic wire ropes, each of them with a turnbuckle (fig. 10).

Each wire rope with its turnbuckle must be fixed between the hole on the head tool (PART 2) and the lifting eye placed on the “ear” of the collar fixed on the porcelain passing through the fairlead (fig. 11 and fig. 12).

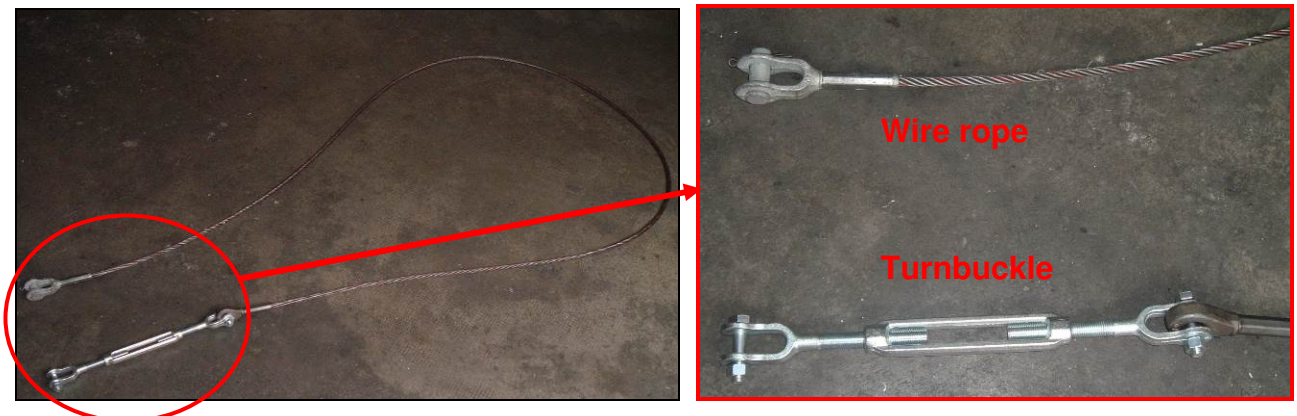


Fig. 10

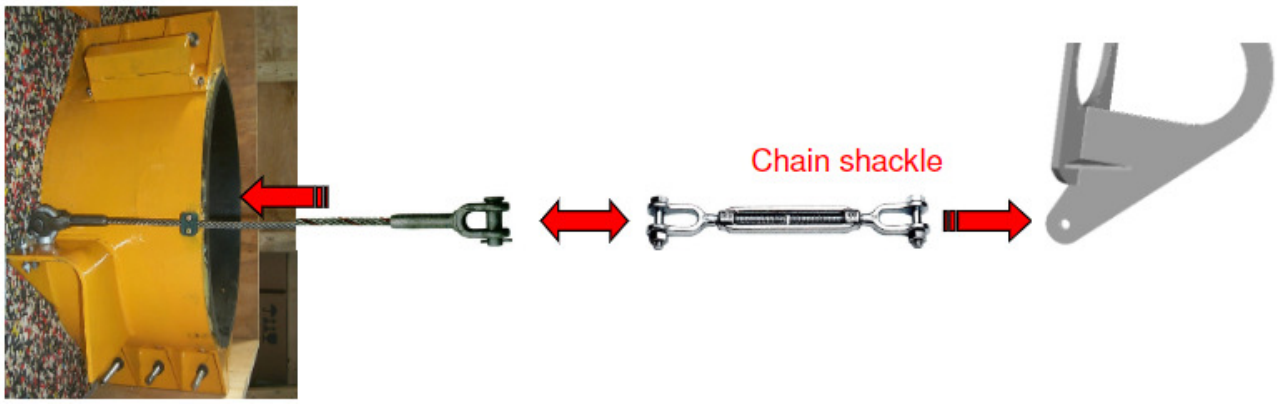


Fig.11

In this way PART1 and PART2 are connected (fig. 12).

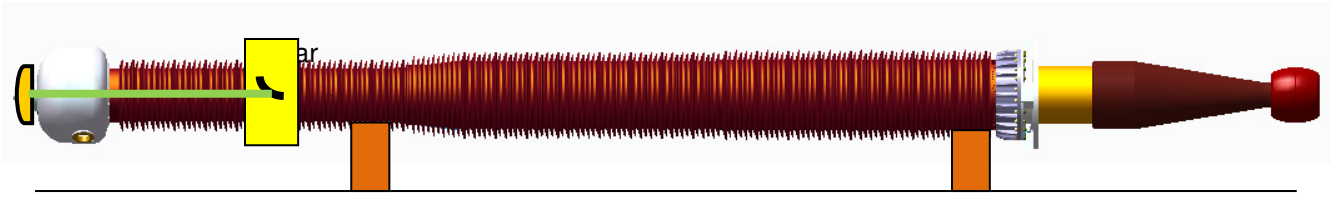


Fig. 12

PART 4 – LIFTING DEVICE

The further step consists in preparing the first lifting system, to be equipped with a special device that can lift the bushing maintaining the two ropes parallel (PART 4), at about 75 cm each other (fig. 13).

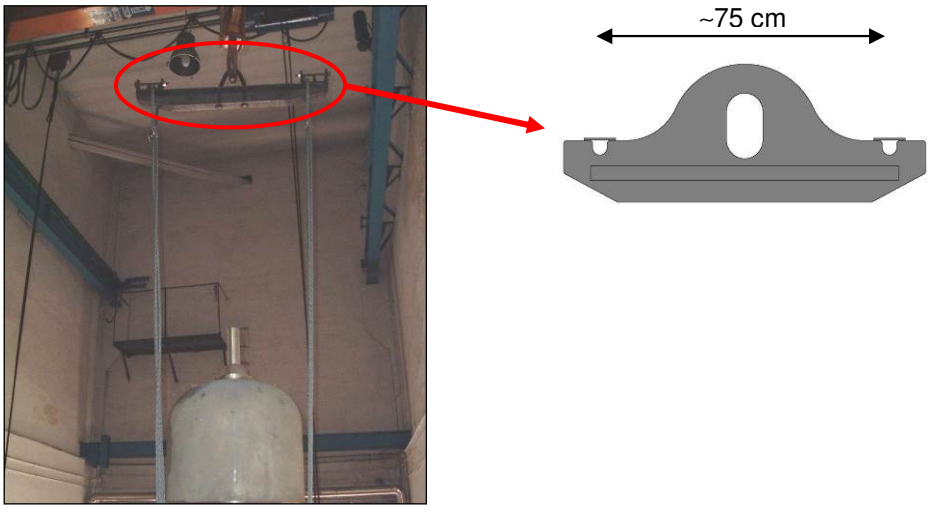
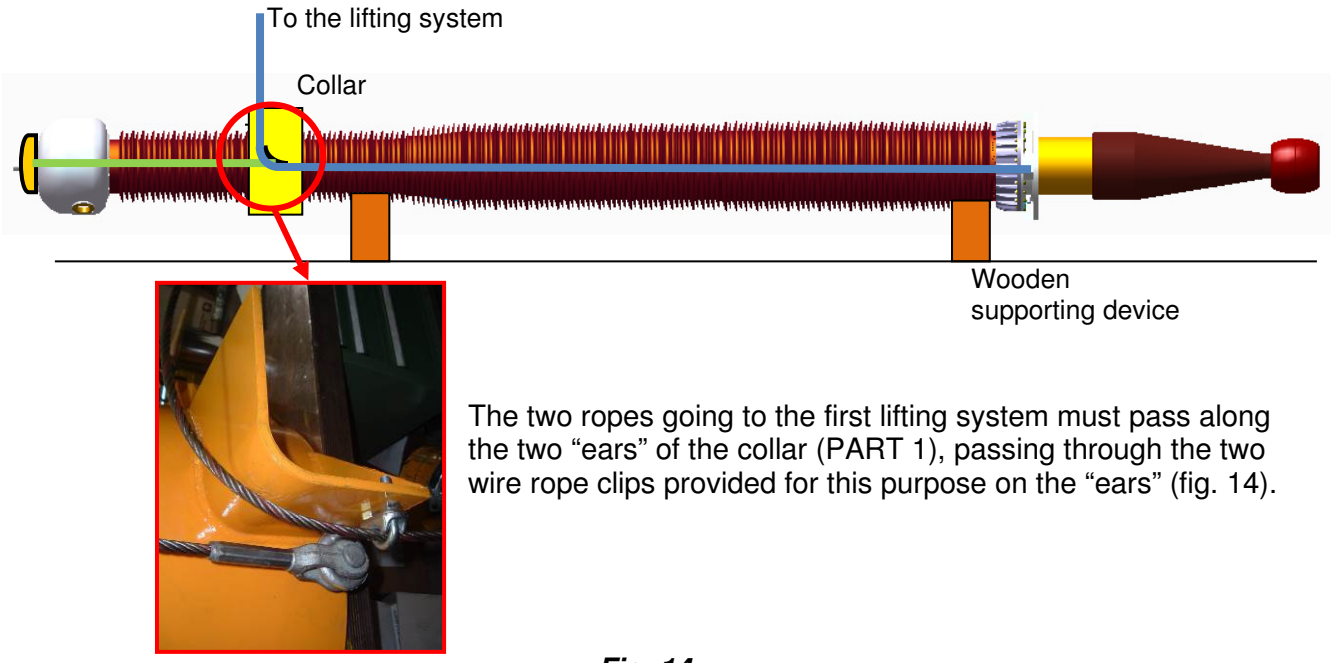


Fig. 13

Connect two flexible metallic ropes (minimum diameter of the metallic lead: 16 mm) to the two opposite eyebolts foreseen on the flange (fig. 15) using two chain shackles. These two ropes will pass parallels along the bushing from the flange up to the lifting system (fig. 14).



The two ropes going to the first lifting system must pass along the two “ears” of the collar (PART 1), passing through the two wire rope clips provided for this purpose on the “ears” (fig. 14).

Fig. 14

From the same chain shackles connect two other metallic ropes going to the second lifting system (fig. 15).
When the two ropes are well placed in the way previously described, the operations to be made are the following:

- Adjust the two wire ropes PART 3 acting on the two turnbuckles in order to maintain the collar (PART 1) in a straight way (with its axis parallel to the bushing);
- Tighten the three plus three bolts of the collar (PART 1), being careful to apply a maximum torque of 25 Nm, in order to avoid damaging the porcelain shed.

CAUTION
Be careful during the screwing operations of this collar: the pressure on the porcelain must be not so high to damage the sheds: the M16 screws must be tightened with a max torque of 25 Nm

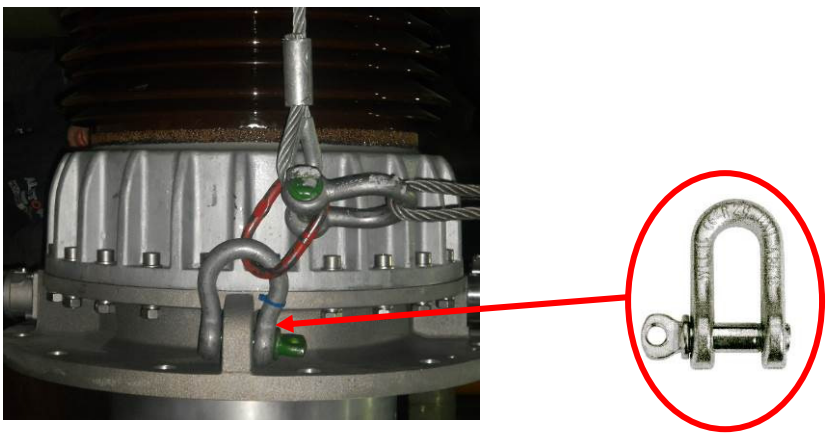


Fig. 15

Pull up the bushing with the first lifting system of few mm in order to tighten the two ropes PART 3.

- Now the two wire ropes (PART 3) connecting the head (PART 2) and the collar (PART 1) must be stretched (fig. 16), by means of the two turnbuckles for each wire, in order to avoid that during the bushing's lifting operations the two wire ropes can move.

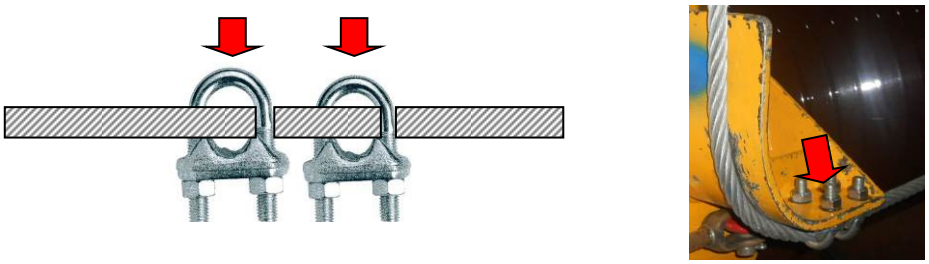


Fig. 16

Now lift and handle carefully the bushing with the two tackles up to the vertical position (fig. 17)

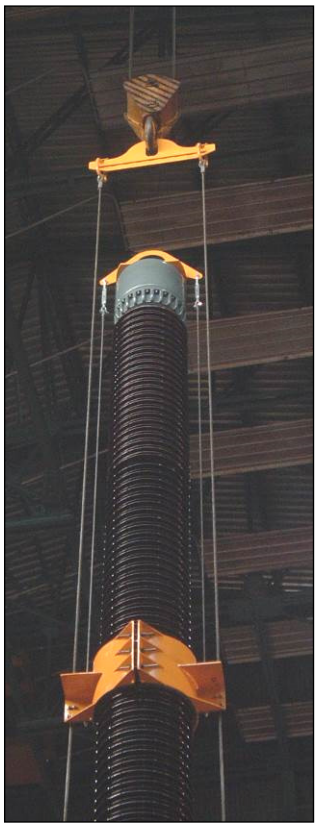


Fig. 17

CAUTION
This is a delicate operation. Before starting the handling, be sure that all components and the ropes are well placed and fixed, then move slowly. Make all these operations only by expert people.

ATTENTION

During handling, **never** lean the bushing or its tail directly on the ground, because due to its heavy weight it can be seriously damaged (fig. 18), nor lay it directly on the floor, because the porcelain is fragile and can break. If necessary, place the bushing on a suitable and stable trestle.

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), in order to be sure that no nitrogen goes in the lower part of the bushing.

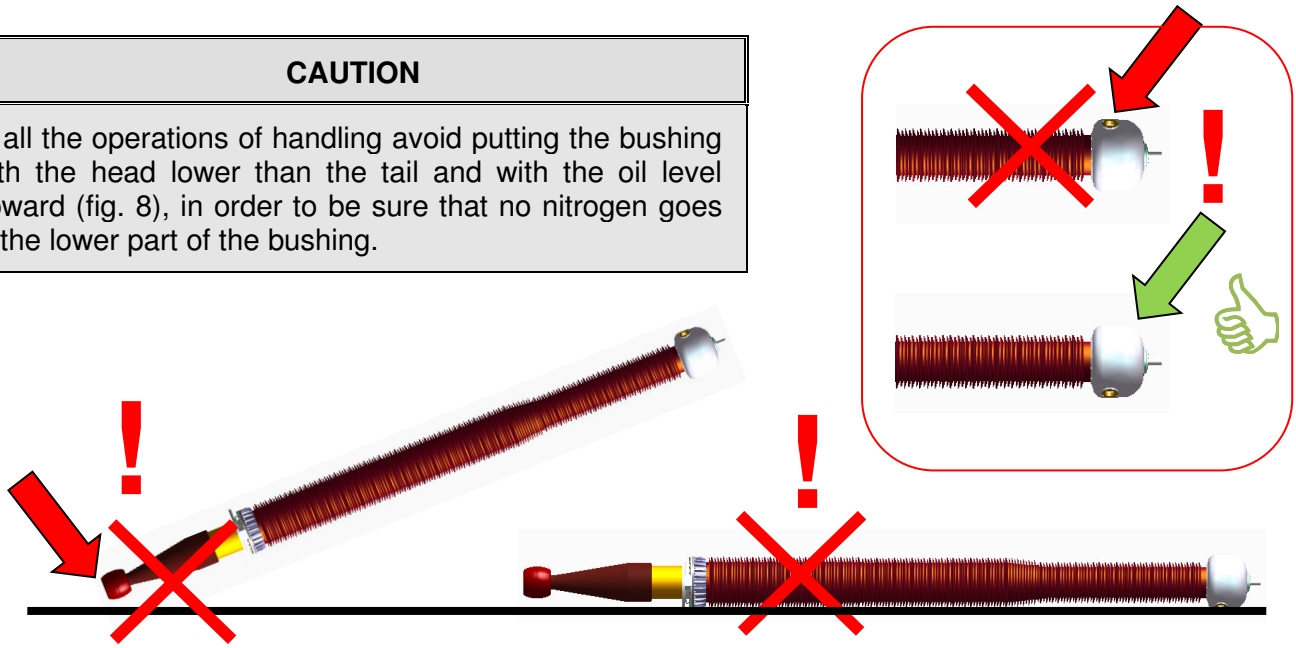


Fig. 18

3.3 SHIPMENT TO THE END USER

Shipment of bushing made by the transformer manufacturer, after the transformer factory tests, must be made either with the original packing or with a new one, made with the same principles.
Particularly both terminals of the bushing should be enclosed with a protection bag, with silica-gel salts, to protect the metal from humidity and avoid any oxidation. Silica-gel salts must be checked: if they have absorbed humidity (i.e. if they are pink colour): in case they must be dried into an oven (i.e. brought back to blue colour).

CAUTION
When the bushing is positioned in horizontal position in the crate, make sure to follow the indications written in the yellow label of fig. 3, fixed on the head lateral surface: the bushing must be positioned with the oil level indicator towards the bottom (fig. 18).

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 case of wrong handling. In any case it is advisable to keep the bushing in a vertical position for about 48 hours prior to electric tests.

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. 19).
Complete the assembly as follows:

- The lug must be removed from the head of the bushing in order to make the connection (ref. fig.19): to disassemble the HV top terminal cap (1), remove the 4 x M8 screws and lock washers (2), 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 (4), located inside the terminal, press softly on the smooth surface of the lug (3). Verify that the O-ring (5) remains in place.
- Remove the locking pin (6) from the lug hole.
- Remove the copper lug (3) from the central tube of the bushing;
- Cut the connection at a right size Lcut plus at least 20 mm for the soldering of the lug; note that the size Lcut 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 with a maximum diameter 3 mm smaller than that of the lug;
- Make the connection, through brazing, of the lead coming from the transformer winding to the copper lug (3);
- Fix an eyebolt on top of the lug, using the M12 hole (7), to which a rope must be tied, for the lug sliding operation into the bushing from the bottom part;
- Place the gasket on the flange on the transformer;
- Slide inside the central bushing’s tube from the bottom the lug with the lead, by pulling it with the rope from the head of the bushing;
- Lift and install the bushing according to the instructions of chapter. 3.
- Align the hole in the lug (3) with the hole in the central tube and secure the lug in position by reinstalling the locking pin (6);

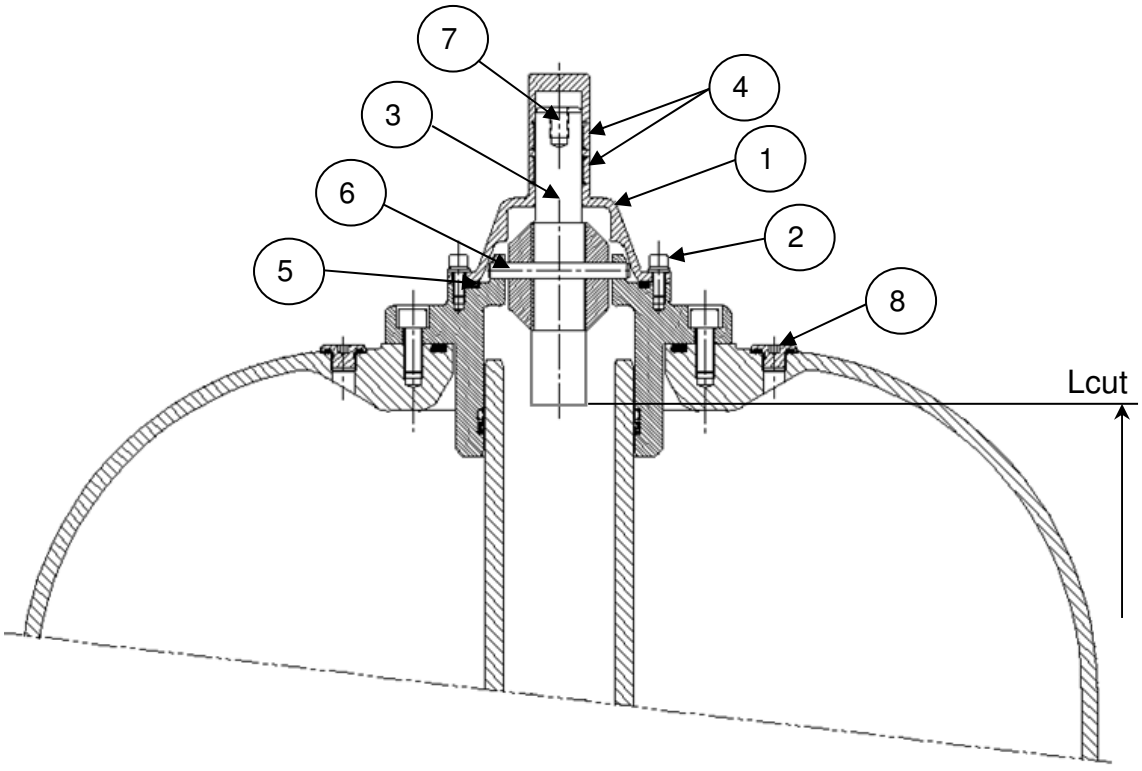


Fig. 19

- Place the bolts on the flange of the bushing to fix it on the transformer.
- Be sure the pin (6) is centred;
- Insert the HV terminal (1) on the lug, keeping it well centered on the axis of the bushing. The necessary force is small (about 10 kg) because the multicontact blades (3), 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 4 screws with a torque of 13 Nm.

  The gasket, O-ring type (6), placed between top terminal and head, assures the transformer oil tightness and for this reason its slot should be clean and without any scratch (in case of scratches pass a fine sandpaper and clean the surfaces with a soft cloth and a light solvent).

  Due to its function of tightness, it is necessary to block the terminal before making vacuum and filling the transformer with oil.

  The gasket necessary to assure the tightness between the oil of the bushing and the oil of the transformer is on the contrary is not involved in this operation of assembly.

  The external connection to the HV terminal (from the overhead line) must be of compatible material with that of the terminal. When the external line must be connected, clean well the HV terminal with a soft cloth and a light solvent and apply specific grease for electrical contact, then assemble the connector to the HV terminal.

  In case of HV terminal oxidation, before installing the external line connector pass a fine sandpaper in order to take away the oxidation layer, then clean with a soft cloth with a light solvent.

4.2 DRAW ROD CONNECTION

In this type of execution, the internal bushing's conductor carrying the current is a rigid and removable rod.
It can be also sectioned in parts, in order to make easier the handling and braze or fix in advance its bottom part with the lead coming from the winding of the transformer.

The central rod is provided with some devices (fig. 20), suitable both to centring and to strengthening the very long central rod itself.

In order to divide the sections of the rod, for each connection to be opened operate as follows:

1) Unscrew the 4 M8 screws (1) placed on the centring and connection device (fig 20);

2) Open it as it is shown in fig 21;

3) Dismount the central conductor by unscrewing the 4 screws M8 (2).

The procedure to be followed to handle the rod 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 can be brazed or fixed by screws (depending on the type, see for example fig. 23) to the lower extremity of the conductor.

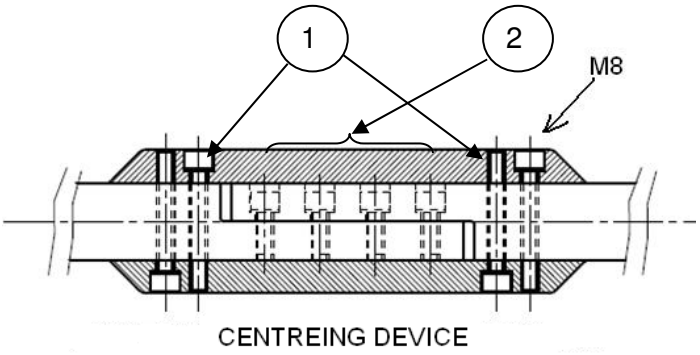


Fig 20

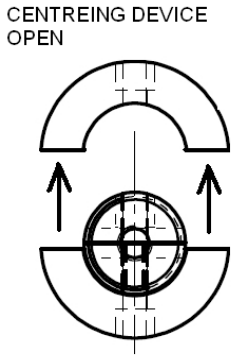


Fig 21

To remount the rod, operate in reverse sequence, taking into account that the torque to tighten the M8 screws is 20 Nm.

CAUTION
Considering the length and the weight of the central rod, be extremely carefully during its handling, to avoid any deformation or rupture. Furthermore, to avoid deformation, place it on a flat surface when is out of the bushing.

4.3 BOTTOM CONNECTION

In this type of execution, the current is carried directly by the central bushing conductor, not removable; the passage of current from the bottom terminal and the tube and from the tube (1) and the top bushing terminal (2) (fig. 22) is obtained by means of special rings equipped with multicontact blades (3).

There are different types of bottom connection terminals for the transformer winding connection. Refer for type and its dimensions to the overall bushing drawing.

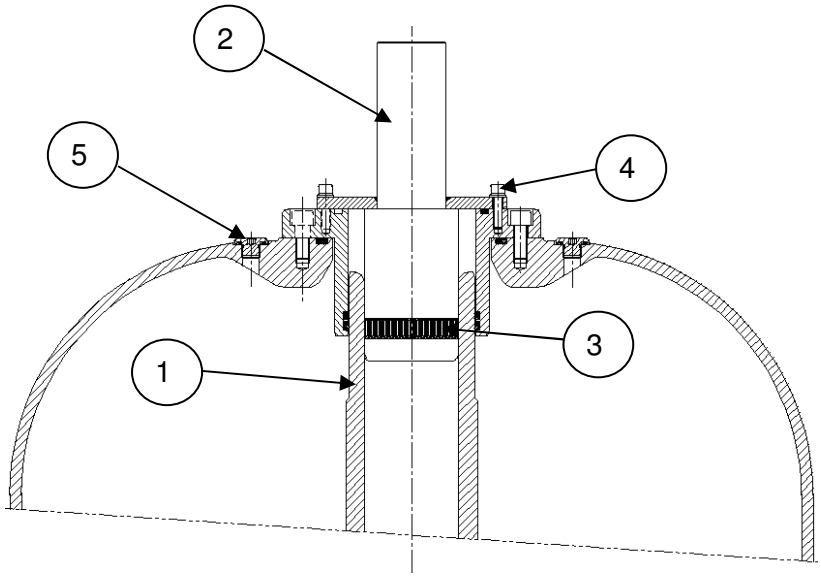


Fig. 22

In this kind of bushing connection, the top terminal (2) must be not dismounted. It is fixed with six M8 screws to the bushing head and includes in one piece also the internal connection lug with multicontact blades (3).

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. At the end of this operation these six screws shall be tightened with a torque of 13 Nm.

WARNING
In the bottom connection execution, the top HV terminal has not to be dismounted. Only if the transformer oil filling is not made under vacuum it is suggested to loosen the six screws M8 of the HV terminal, in order to permit to the air inside the central tube of the bushing to flow out during transformer filling. Then these four screws **MUST** be tightened with a torque of 13 Nm: If not tightened, some water could enter in the central tube and go into the transformer oil.

4.4 OIL SIDE SHIELD

The bottom end of the bushing is shielded by a suitable aluminium insulated electrode, with the function to screen the connection between the lead coming from the transformer winding and the bushing itself.
This shield is removable to make easier the connection between transformer lead and bushing.

There are two shield versions:

- Shield removable upwards: it can be unscrewed upwards (fig. 24).
- Shield with bayonet type coupling: it can be removed downwards rotating and pulling down its body (fig. 23).

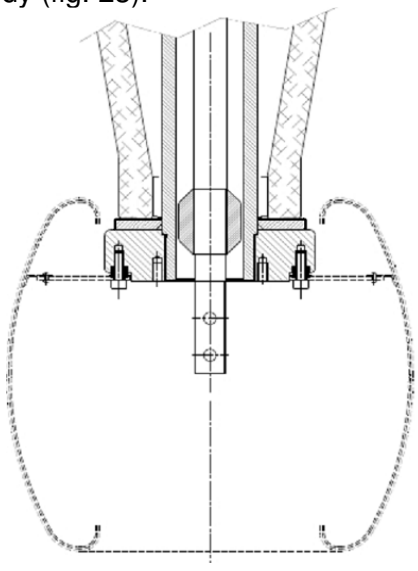


Fig. 23
Draw rod: palm type bottom terminal and bayonet type shield

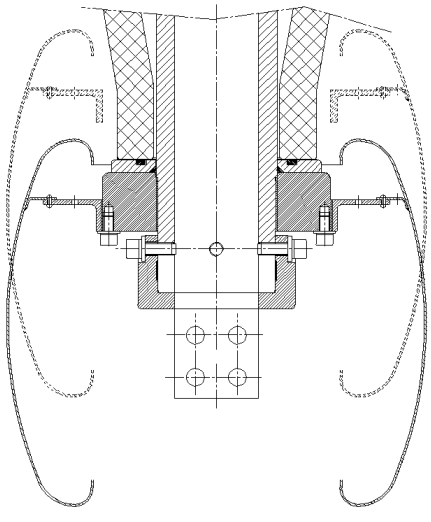


Fig. 24
Shield removable upwards

CAUTION
During handling, take care not damaging the external finishing coat of the dielectric shield (if present), important in the dielectric strength of the bushing oil side.

4.5 ICE AND SNOW DEPOSITS

If the transformer is installed in an arctic climate with bushings mounted in inclined position (about 30°), and has to 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, in order to improve the bushing cooling.

After the closure of the bushing, it is necessary to make the vacuum in the transformer and then fill it with oil; in this way the oil will fill the central tube of the bushing.
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. 25).

Furthermore lift a bit the HV terminal in order 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 (ref. to item 1 of fig. 19 in case of draw lead or draw rod types, ref. to item 2 of fig. 22 in case of bottom connection bushings; make reference to paragraph 4.3).

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

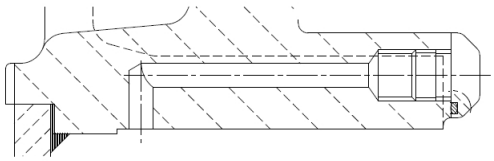


Fig. 25

CAUTION
The characteristic of withstanding vacuum and temperature refers to new bushings. In case of old bushings, the natural ageing phenomenon of the gaskets must be considered

4.7 OIL LEVEL REGULATION

In the factory the oil level in the head is adjusted to reach about half of level (prismatic indicator or magnetic) at 20°C.

Bushings are filled in order to assure, in vertical position, a visible oil level or a suitable magnetic indication 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 is suggested to adjust the oil level.
To carry out this operation remove some bushing oil or add transformer mineral oil accurately treated, through the head's plug placed in the upper part of the head, close to the HV terminal (item 8 – fig. 19, item 5 – fig. 22) in order to have a suitable oil level in the whole range of operating temperatures. The cap must then be re-screwed with a torque of 100 Nm.

4.8 CONNECTION TO BUCHHOLZ RELAY

A 1/2" GAS plug is placed on the bushing flange (fig. 25) in order to:

- Connect the relay tube, if foreseen;
- Eliminate the air pocket which may be formed during some executions and during 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.

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.

In order 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/mm^2.

For special requirements regarding low ambient temperatures (up to –60°C) special o-rings are foreseen, made of flour-silicone for low temperatures. The spring closing system is calibrated in order to keep the bushing tightness up to these extreme conditions while 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

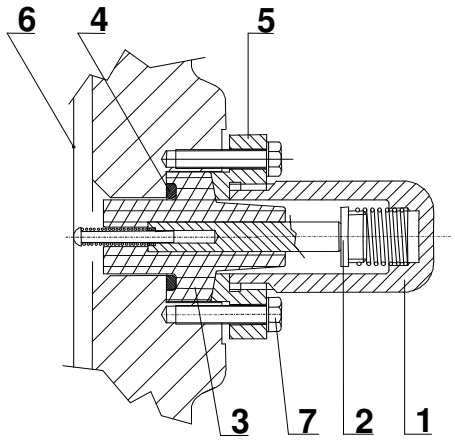
The flange and the metallic components of the oil expansion vessel of the bushings are made of Aluminium alloy casting and do not require any special surface treatment / maintenance.
Only in case of installation in aggressive environment (i.e.: coastal, high pollution, high salinity), it's recommended 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 and keep the measured values as reference for future checks.

Normally the measurement (C1) must be carried out between the HV terminal and the Power Factor tap (schematised in fig. 26).
During operation, the PF tap must be grounded keeping screwed its proper tap.

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



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

Fig. 26
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.26) is well screwed. A forgetfulness of this generates during service a voltage on the tap that exceeds its insulation dielectric strength: this may lead to a catastrophic bushing failure.

On request bushings can be provided with PD (Voltage) tap, which is suitable either for the connection to a Potential Device system or for the measurement of the power factor (fig. 26).

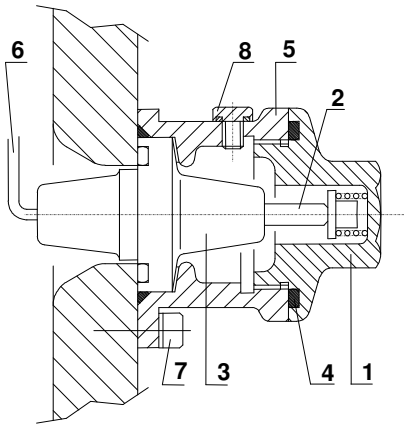
In bushings provided of PD tap one measurement can be carried out between the HV terminal and PD tap (C1) and another one between PD and PF tap (C2).

If present and not used, the potential device tap must be grounded maintaining screwed its proper cap (see fig. 27). If present and used, it must be grounded through the connected measuring instrument.

WARNING
Don't unscrew the screws item 7 of fig. 26, 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 or lost, with consequent possible catastrophic failure of the bushing.

If a Potential Device system is connected to the potential device tap, we recommend filling with oil the internal part of the connection through the oil filling plug placed in the upper part of the tap (fig. 28 - item 8), to avoid possible internal and dangerous sparking.

If not used the voltage tap can remain empty, but we recommend filling it with mineral oil to prevent any 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. 28
Potential Device tap (voltage tap)

WARNING
If the potential device tap is not used, it is recommended to control if the cap of the oil filling screw (fig. 28 - 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.

6.3 DISASSEMBLY OF THE BUSHING

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

- Bring the transformer oil up to a level lower than the bushing flange;
- For draw lead and draw rod type bushings withdraw the terminal from the lug (fig. 19). For this operation it is necessary to draw the terminal upwards and, at the same time, rotating slightly in clockwise and counter clockwise direction. For bottom connection bushings, loose the terminal six M8 screws, in order to let the transformer oil level to go down inside the bushing central tube, and then remove the connection in the oil side.
- Secure a pulling device to the M12 threaded hole on 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 insulation 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) following the instruction under par. 5.
As for the preservation of the external surfaces, the manufacturer suggests performing the following inspections:

Porcelain

Check for chips, cracks and contamination. Minor chips can be painted with an insulating varnish to obtain a glossy finish which will prevent dirt and moisture attack.
Bushings with major chips or external cracks which appreciably decrease the creepage distance should be removed from service and replaced.
Wash periodically the porcelain surface, 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 on both sides in order to avoid poor contacts and consequent overheating.
Pay special care to the air side connection, more subject to oxidation than the oil side one.

In case of connection surfaces very oxidised, clean them slightly passing a fine sandpaper, paying attention to not damage the tinned or silvered layer, if present. After this operation, clean well the surfaces with a light solvent (for example alcohol) and a soft cloth.

Power factor tap

Check the proper location of the tap cap and its suitable complete screwing in order to prevent entrance of moisture (Fig. 26).

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, in order to prevent entrance of moisture (fig. 28). 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

Metal parts

It is advisable after a period of 10 years for bushings indoor installation and after 5 years for outdoor ones, to give a further paint coating.

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, close to the HV terminal (item 8 – fig. 19, item 4 - fig. 22), by using some transformer mineral oil, accurately treated and degassed. Mineral oil is fully compatible with the impregnating DDB synthetic bushing oil.
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 sent it back to the manufacturer for the checks and repair.

CAUTION
To prevent oxidation of the bushing oil and humidity entrance, the filling plug must be closed just after the conclusion of the refilling operation, to be made during a dry day

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.

6.5 MEASUREMENT OF DIELECTRIC LOSSES

Test in the factory

The Standard - IEC Publication 60137 - states that the oil-paper bushings must have a tanδ less than $7x10^{-3}$.
The measurement is performed in manufacturer's High voltage 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 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 (or PD if present), maintaining grounded the flange (C1 measurement). The bushing is considered good if a tanδ less than the maximum one established by the Standards is measured.
If a high tanδ measured, please contact the manufacturer that will decide if it is necessary to make other tests before removing the bushing from service and 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 shall 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 must be connected to the bridge (C2 measurement).

A field measurement of tanδ and capacitance can differ from the measurements carried out in the factory due to the different conditions of test, different temperatures and relevant accuracy: for this reason, a light shifting (max 10% for tanδ) is acceptable. Furthermore, the installation conditions, due to stray capacitances, can affect the capacitance value. For this it is advisable to measure capacitance and tanδ 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. 19, item 8, fig. 22 – item 5) 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

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

- 1% for the capacitance C1 (this assures that there isn't a perforation between two layers)
- 30% for tanδ of capacitance C1.
- 100% for tanδ of capacitance Co.

An increase of the last value means a worsening of the dielectric characteristic 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 (tanδ):

Original value:	≤ 7*10-3
During working:	≤ 12*10-3

Gas chromatography (DGE):

Refer to Standards (IEC 60599 and IEC TR 61464)

If these checks give results out from the limits, 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. 29 and 30) positioned in closed position: it is the oil sampling valve. On this valve it is fixed by screws a metallic closing disc. To make the oil sampling it is necessary to dismantle this closing disc and to mount another one provided with a suitable connection.

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

Equipment

To carry out oil sampling from the bushing, we need the following (see fig. 30):

- A 150 cm^3 oil syringe (item 1) (lab. type);
- A semi-rigid pipe (item 3);
- An appropriate small flange suitable for fixing to the sampling valve (having 4 holes diam. 9 mm positioned at 90° each other's, with wheelbase of 50 mm; with O-ring slot, ref. to fig. 29). This small flange will have a suitable connection to the sampling semi-rigid pipe (item 3);

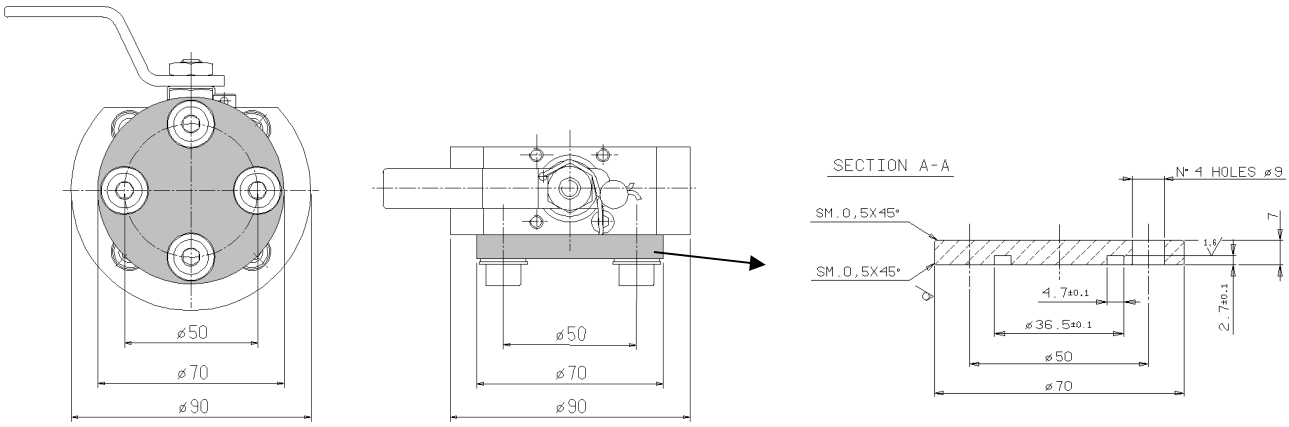
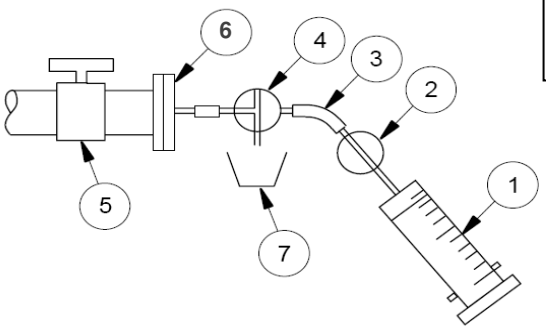


Fig. 29

- A two-way valve (item 4) with a suitable connection to the syringe;
- A closing valve (item 2)
- A syringe cap;
- Adhesive tape.

1. Syringe
2. Stop valve
3. Semi-rigid pipe
4. Two-way valve
5. Bushing flange
6. Adaptation flange
7. Waste vessel



Note: the following figures have been taken from IEC 60567

Fig. 30

Preparation

Operate as follows:

- Clean the plug zone accurately;
- Prepare all the syringe apparatus, with the valves (2 and 4) and the tube (3);
- Dismantle the closing flange by unscrewing the 4 screws M8 and fix the adaptation flange (6), provided by a suitable connection to the semi-rigid pipe;

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 as first operation to loosen the filling tap located on the top bushing's head.

- Wash the syringe (1) with oil two times by repeating the following operations (ref. fig. 30 & 31):

- Open the closing valve (2)
- Open 2nd way of the valve (4);
- Fill-in slowly the syringe (1) 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 the valve (4);
- Empty the syringe (1);
- Close 1st way of the valve (item 4).

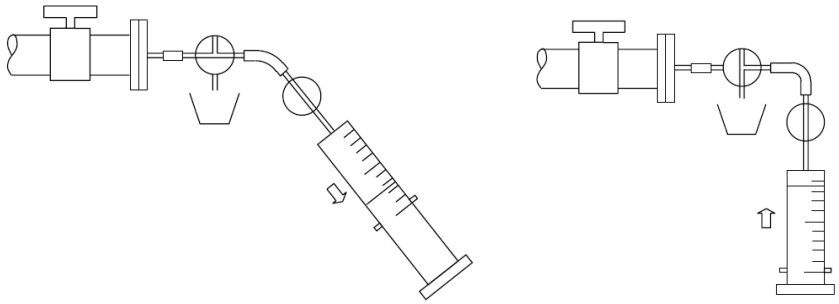


Fig. 31

Oil sampling

For sampling please follow these instructions (ref. to fig. 30 & 32):

- Close the 1st way of the valve (4) and open the 2nd way;
- Slowly fill the syringe (1) with the oil up to the appropriate volume (approx. 60-100 cm^3);
- Shut off the 2nd way of the valve (4), the syringe valve (2) and the bushing's valve (5);
- Remove the syringe by unplugging the valve (2) from the tube;
- Set the syringe with the valve (2) being up;
- Unplug the valve (2) and place a closing cap on the syringe (operation only optional; the syringe can remain with the valve (2) mounted, to avoid air contamination);
- Clean the syringe and block it with adhesive tape on which you will write down the bushing serial number;
- Overturn the syringe and keep it with its cap down;
- Remove the pipe (2) from the plug, unscrew the sampling flange (6) and screw the original one;
- Screw completely the filling tap on the head of the bushing (item 8 - fig. 19, item 5 – fig. 22).

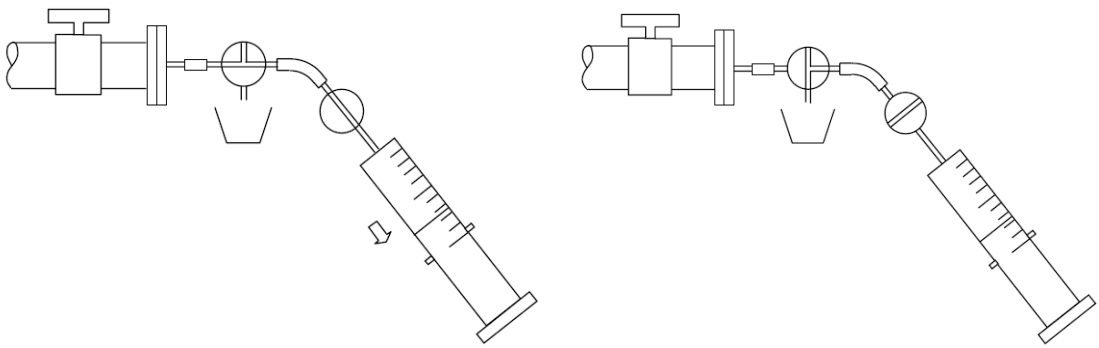


Fig. 32

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

If necessary (bushing oil level too low) 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 (item 8 - fig. 19, item 5 – fig. 22), which must be closed immediately after the end of the operation.

CAUTION
The oil sampling operation must 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.