

# PNO

## Condenser Bushing from 36 up to 170 kV Oil-to-Air - Oil-Impregnated Paper



PNO bushings are capacitance graded bushings with an oil-impregnated paper core. They meet IEC 60137 Standards: insulated bushings for alternating voltages above 1000 V. They are designed for use in power transformers and can be installed up to a maximum of 45° inclination off the vertical.

Design, components and manufacturing technology promote an average lifetime in excess of 30 years under normal operating conditions.

### Voltage and Current Ratings

Rated voltage range for PNO bushings, normal cantilever load, is 36 to 170 kV. PNO bushings, for a rated voltage, are designed in order to have the same overall dimensions for all normal service currents and connection types.

There are three connection alternatives for the conductor:

- Draw lead connection for bushings at rated current 800 A and 1000 A
- Draw rod connection for 1250 A
- Bottom connection, using a rigid conductor, for 1600 A and above.

Using suitable accessories, any draw rod 1250 A bushing can be converted to draw lead bushings, only for minimum under flange sleeve length, and vice versa. Minimum 1250 A draw lead conductor sections are listed in fig. 11.

### Standards

- IEC 60137

### Key Benefits

- Bushings with longer lifetime and higher reliability
- Possibility to use bushings under extreme weather condition (lower pour-point value)
- No performance reduction with age
- Oil level visible from any side



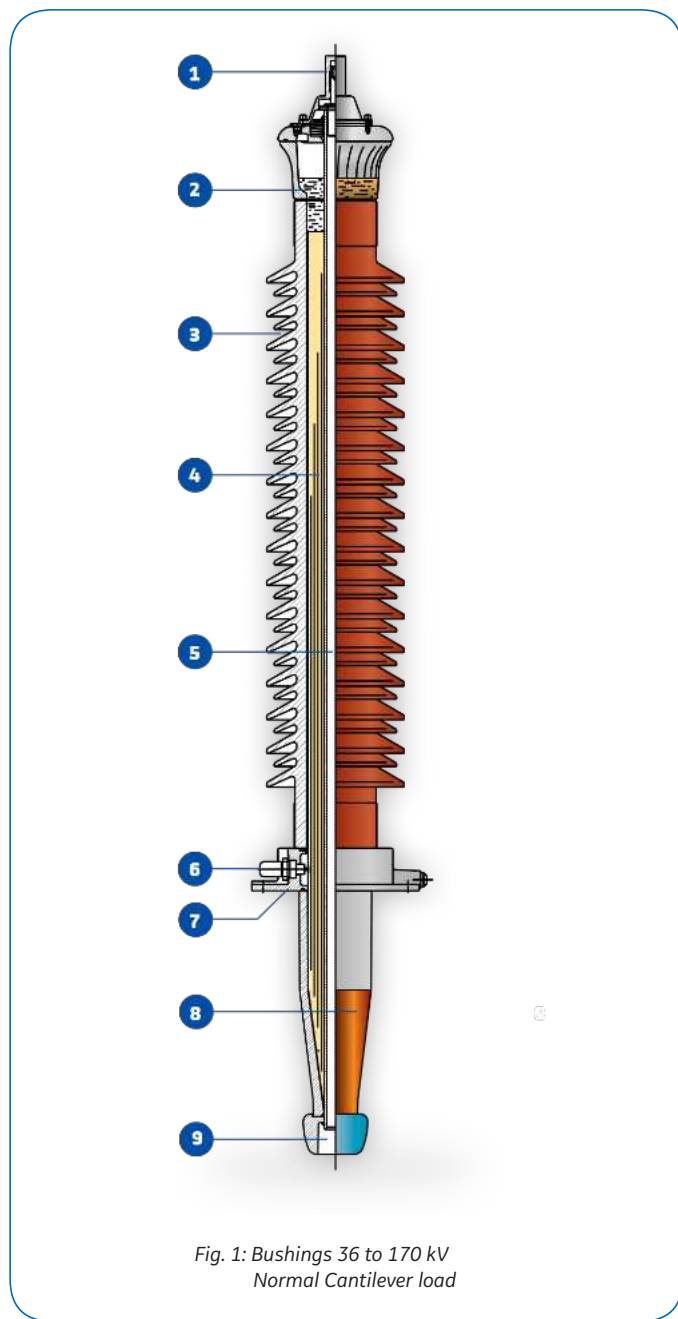
## PNO Bushings Main Features

IEC Standards Condenser Bushings

- Range 36 to 170 kV
- Current up to 3150 A
- Oil-Impregnated Paper
- Air side: porcelain insulator or composite insulator
- Oil side: epoxy resin insulator
- Partial discharge: max. 5 pC at 1.5  $U_m/V_3$
- Provided with power factor tap (voltage tap upon request)
- Draw lead for 800-1000 A - draw rod for 1250 A; bottom connection for 1600 A applications and above
- Head made of special UHV filter prismatic glass with oil level indication visible at any angle of sight
- Flange made of cast aluminum alloy.  
Standard angle of installation max of 45° off vertical

**Fig. 1: Bushings 36 to 170 kV Normal Cantilever Load**

1. HV Terminal
2. UHV filter glass
3. Porcelain
4. OIP Condenser
5. Winding tube
6. Power factor tap or voltage tap
7. Flange
8. Epoxy resin insulator
9. Oil side shield



## Bushing Designation

### **PNO.145.650.800**

PNO	IEC type condenser bushings, oil-impregnated paper (OIP) oil-to-air application
145	Insulation class in kV
650	BIL in kV
800	Rated current in A

## Manufacturing

The main electrical component is the condenser body, manufactured using a continuous sheet of pure kraft paper, wound around a central conductor tube or rod. During the winding process, the paper is dried by heated cylinders in order to reduce its water content to 1% maximum. A series of aluminum foils are coaxially inserted between the layers of the paper, to achieve the best possible distribution of the radial and longitudinal electrical gradients between the central tube and the flange, which is grounded. The condenser core is made by computer-controlled winding machines, with subsequent machining to achieve the final shape. After winding, each bushing is individually assembled and placed into an oven and processed under vacuum for the appropriate period of time. Each bushing is then impregnated with synthetic oil, which has been degassed and processed so that it has a maximum water content of 3 ppm. Each bushing is placed under pressure to insure thorough impregnation and to test that it is properly sealed. After impregnation, the bushing is head filled with a nitrogen cushion. This process is an automatic and computer controlled process.

## Top Terminal

Standard bushing top terminal is made of aluminum without any surface treatment. Upon request, it can be supplied in tinned or silvered copper. Draw lead or draw rod type bushings (800 A and 1250 A) have a removable top terminal. This terminal is connected to the copper inner terminal lug or the draw rod by means of multi-blade contacts and is secured to the bushing head by screws. In bottom connected bushings (1600 A), the inner non-removable rod also acts as the top terminal.

## Head and Oil Level Indication

The metal components of the head are made of a cast aluminum alloy. Bushings have an oil head reservoir, prismatic in shape, made of borosilicate glass, and containing a UHV filter. This allows for an easy check of the oil level even from a distance and at any angle of sight.



Fig. 2: Oil level indicator for prismatic glass and metal head

## Air Side

The air side insulator is made of brown porcelain. Grey porcelain or composite insulator (resin fiberglass envelop covered by silicone sheds) is available on request.

The typical creepage distance is suitable for very heavy polluted atmospheres.

The shed configuration is an alternating type: short-long shed. This is the most effective solution, proven by salt spray tests. The shed profile complies with IEC 60815 - 2008 recommendations. A one-piece porcelain or multiple-piece porcelain, in order to meet standards or special requirements, is used for bushings. Multiple pieces are glued using epoxy resin, without use of gaskets and the final porcelain is considered as a single piece (it passes tests IEC 60233- 1974, clause 6 tests).

## Flange

The flange is made of cast aluminum, and is equipped with the following accessories:

- Lifting holes
- Power factor tap, tested at 2 kV for 60 s (fig. 3), and/or voltage tap, upon request (fig. 4)
- Buchholz relay connection: 1/2" gas outlet plug
- Oil sampling plug (for 145 kV bushings).

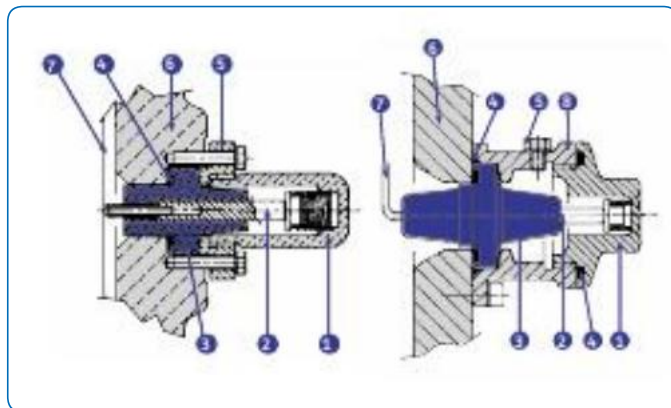


Fig. 3: Power Factor Tap

Fig. 4: Voltage Tap

### Fig. 3: Power Factor Tap

1. Closing and grounding cap
2. Measurement electrode
3. Insulation tap
4. gasket
5. Tap flange
6. Bushing flange
7. Last layer

### Fig. 4: Voltage Tap

1. Closing and grounding cap
2. Measurement electrode
3. Insulation tap
4. gasket
5. Filling plug
6. Bushing flange
7. Connection to internal layer
8. Tap external housing

## Oil Side

The oil side envelope is made of a molded epoxy resin. This resin is a two-part compound consisting of a resin base and a hardener; the filler material is quartz sand. The epoxy resin envelope permits shapes, thickness and dimensional tolerances not possible with porcelain.

Under flange sleeve length for CT accommodation, different from standard, is available upon request. In this case, the grounded part is obtained by means of a metallic tube or directly by the last metallic layer inside the condenser body.

## Oil Side Shield

The bottom end of the bushing is shielded by a proper deflector, made of aluminum alloy. It is designed to reduce the electric field stress in oil and to screen the connection between the lead coming from the transformer winding and the bushing itself.

## Assembling

The mechanical coupling among all the parts of the bushing is made by means of springs placed into the head of the bushings.

## Insulating Fluid

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 / 2.5 mm)
- 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

## Gaskets

Made of Viton®, a fluorocarbon rubber elastomer (FPM), o-ring type. They are compatible with all the fluids they are in contact with (bushing impregnating synthetic oil and transformer mineral oil). Air side gaskets are carefully protected, by means of a sealing, against influence of polluting weather elements.

For special requirements, such as low ambient temperatures (down to -55°C), special o-rings are used.



## Arcing Horns

Adjustable arcing horns are available upon request. The upper arcing horn is fixed by means of one screw used to secure the top terminal, while the bottom one is fixed on a proper threaded flange hole.

## Transformer Oil

Transformer oil must have a water content less than 15 ppm for voltage up to 145 kV and less than 10 ppm for 170 kV and above rated voltage. Its dielectric strength must be higher than 60 kV, according to IEC 60156.

## Tests

All bushings have electrical characteristics and are tested in compliance with the latest edition of IEC 60137 Standards: insulated bushing for alternating voltages above 1000 V and main national Standards.

## Type Tests

Measurement of dielectric dissipation factor ( $\tan\delta$ ), capacitance and partial discharge quantity before and after the series of type tests:

- Wet power-frequency voltage withstand test
- Temperature rise test
- Verification of thermal short-time current withstand
- Cantilever load withstand test
- Tightness test
- Verification of dimensions

## Routine Tests

- Dielectric dissipation factor ( $\tan\delta$ ), capacitance and partial discharge quantity measurement
- Dry lightning impulse voltage withstand test (BIL), when prescribed
- Dry power-frequency voltage withstand test
- Measurement of partial discharge quantity
- Test of tap insulation
- Tightness test
- Tightness test at the flange
- Visual inspection and dimensional check

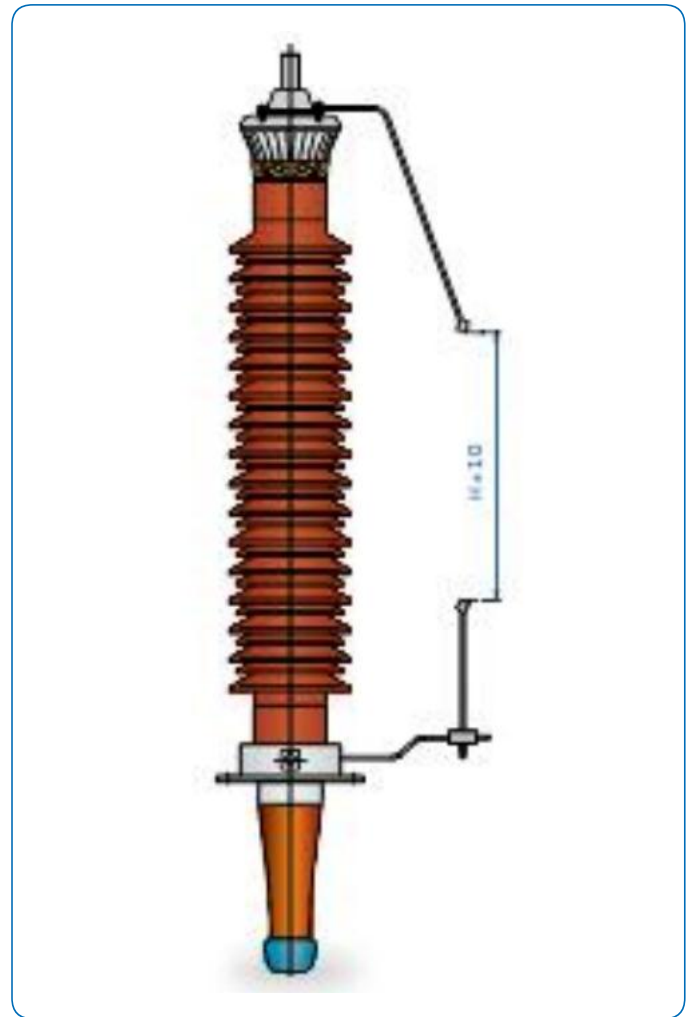


Fig. 5: Discharge distance for a bushing equipped with arcing horns



## PNO Range from 36 to 170 kV: Ratings / Dimensions

Type	Nominal System Voltage	Rated line-to-earth voltage	BIL	Rated current	Dry power frequency withstand voltage (for 60s)	Wet power frequency withstand voltage (for 60s)	Flexible draw lead connection	Rigid draw rod connection	Bottom connection	K min. (CT pocket) [1]	Creepage distance (for very high polluted atmosphere (VHP))	Arcing distance	Cantilever load	Weight [2]	Max. operating altitude	H (discharge distance) +/-10%	
	kV	kV	kV	A	kV	kV				mm	mm	mm	N	kg	m	mm	
36.200.	1000	36	21	200	1000	77	70	X	...	0	943	440	1250	26	1800	220	
	1250				...			X	...								30
	1600				...			...	X								36
	2500				...			...	X								45
	3150				...			...	X								66
72.5.350.	1000	72.5	42	350	1000	155	140	X	...	100	2360	765	1250	42	1700	450	
	1250				...			X	...								51
	1600				...			...	X								60
123.550.	1000	123	71	550	1000	255	230	X	...	100	3893	1160	1600	89	1000	750	
	1250				...			X	...								99
	1600				...			...	X								111
145.650.	800	145	84	650	800	305	275	X	...	100	4540	1410	1250	100	1500	900	
170.750	800	170	98	750	800	355	325	X	...	0	5500	1600	1250	120	1500	1000	

[1] Other available standard: 300 mm

[2] For K minimum

Type	D1	D2	D3	D4	D5	D6	R7	D10	D11	D13	L2	L3	L4	L5[2]	L6	L8	L9	t1	n.	F																
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm																
36.200.	1000	100	185	225	40	170	35	...	...	690	80	...	537	...	...	...	...	14	6	...																
	1250																				...	...	32	...	180	...	20									
	1600																				...	125	...	88	...	746	525	...	...	16						
	2500																				130	250	290	60	230	...	...	...	760	125	265	...	...	...	16	8
	3150																				...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
72.5.350.	1000	100	185	225	40	170	35	60	...	1015	80	345	859	22	...	...	...	14	6	16																
	1250																				...	140	60	95	32	...	22	20								
	1600																				...	...	...	1070	125	367	...	...								
123.550.	1000	130	250	290	40	230	35	200	70	130	...	1415	1245	80	425	1260	50	...	16	8	16															
	1250																					...	230	145	200	...	1470	125	440	...	110	...				
	1600																					...	...	...	...	...	...	...	...	...	...	...				
145.650.	800	145	290	335	40	230	35	225	70	130	...	1665	1495	80	475	1510	50	...	19	12	16															
170.750	800	145	290	335	40	230	35	225	70	130	...	1855	1685	80	475	1702	50	...	19	12	16															

[2] For K minimum

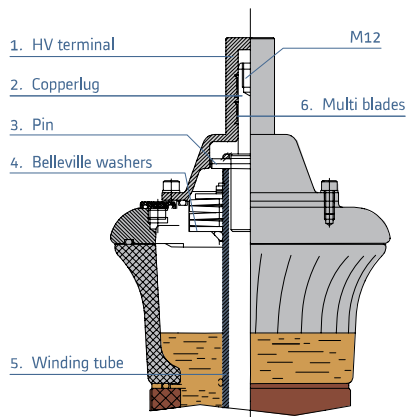


Fig. 6:  
H1 head type (Draw lead or draw rod)

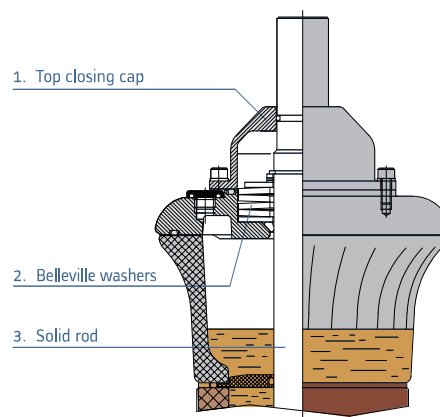


Fig. 7:  
H2 head type (Bottom connection)

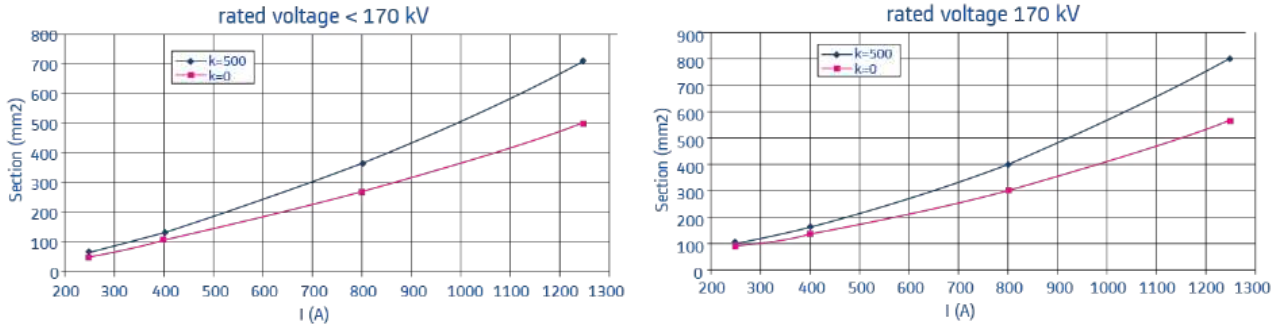


Fig. 8:  
Draw lead conductor sections

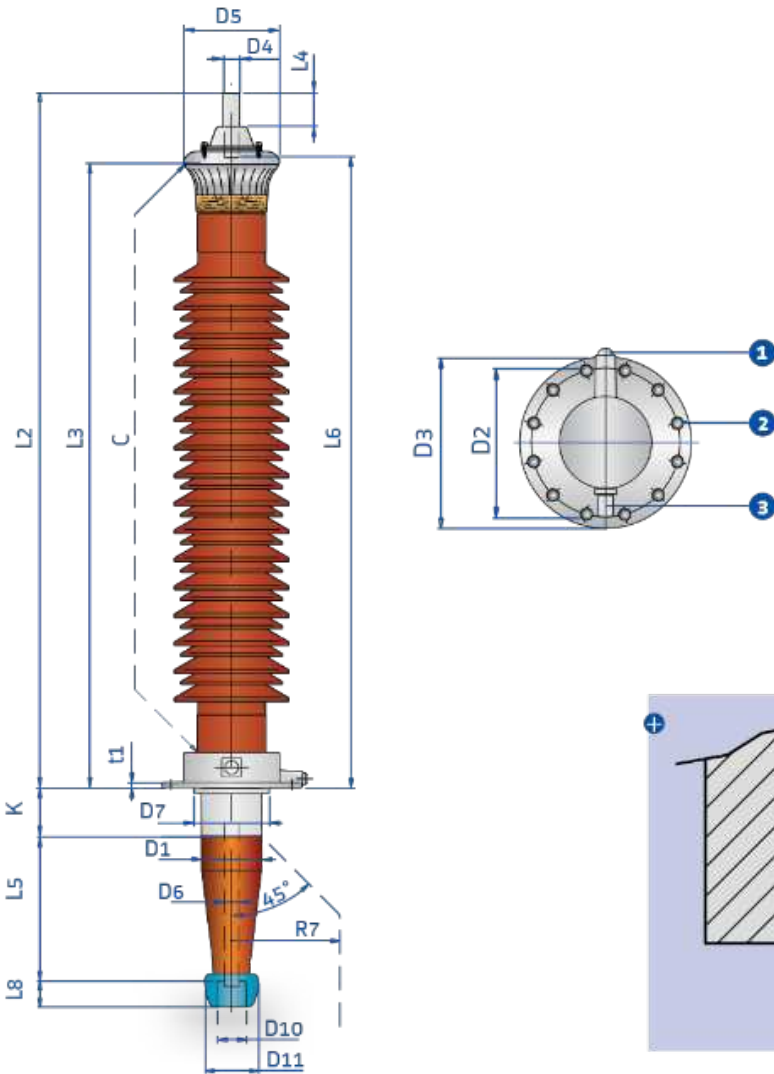


Fig. 9:  
PNO Bushings 36 through 170 kV

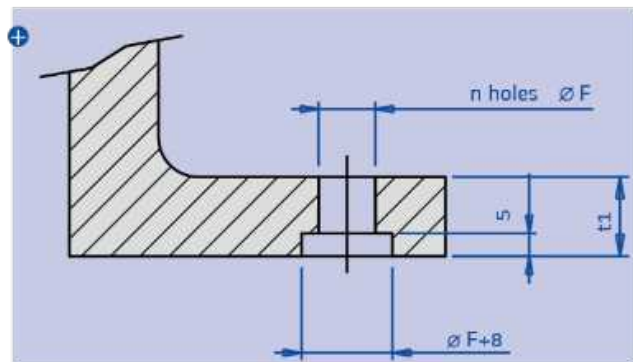


Fig. 10:  
Flange fixing holes

## Packing - Transportation

After tests and before packing, the bushing is cleaned of any oil and or dust. Thanks to a special device to prevent the diffusion of the nitrogen cushion out of the head and into the lower end of the bushings, each bushing can be packed and shipped secured in horizontal position. This insures minimal crate dimensions and reduced transportation costs.

Proper protection is used for oil side shields. Bushings up to and including 170 kV are normally shipped in crates containing three pieces.

## Nameplate

Each bushing is provided with a nameplate, containing complete electrical data and the serial number, in accordance with the requirements of IEC Standards.

The aluminum nameplate, is secured to the flange with rivets and includes the following information (fig. 13):

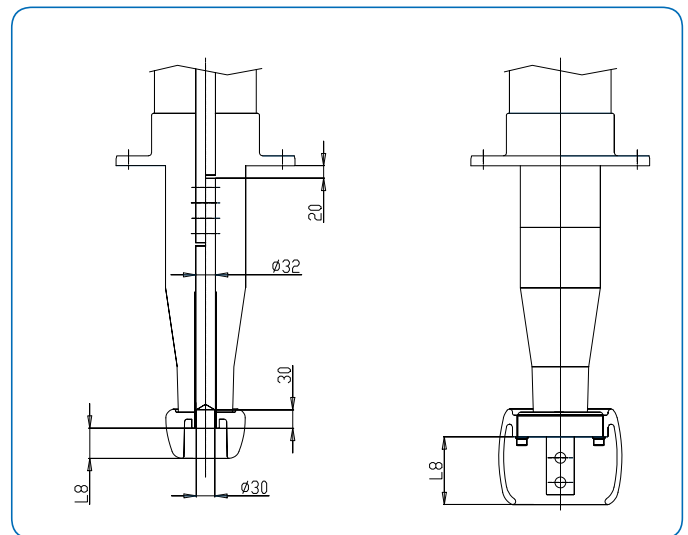


Fig. 11: 36-170 kV bushing tail: draw rod connection

Fig. 12: 36-170 kV bushing tail: bottom connection

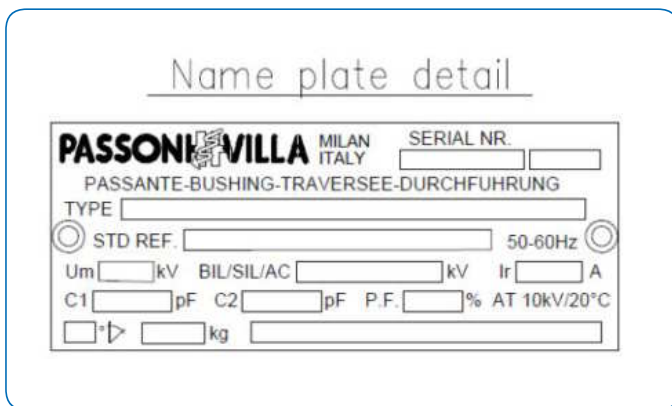


Fig. 13: Identification Nameplate

For more information please contact  
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### Worldwide Contact Center

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