Grid Solutions

PNO

Heavy Cantilever Load Condenser Bushings 72.5-1050 kV / Oil-to-Air -Oil-Impregnated Paper

Heavy cantilever load PNO bushings are capacitance-graded bushings with an oil-impregnated paper core. They meet IEC 60137 Standards for 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 (up to and including 420 kV) or 30° (550 kV to 1050 kV).

Voltage and Current Ratings

The rated voltage range for PNO bushings is 72.5 to 1050 kV. PNO bushings, for a rated voltage, are designed to have the same overall dimensions for all normal service currents and connection types.

There are three connection alternatives for the conductor:

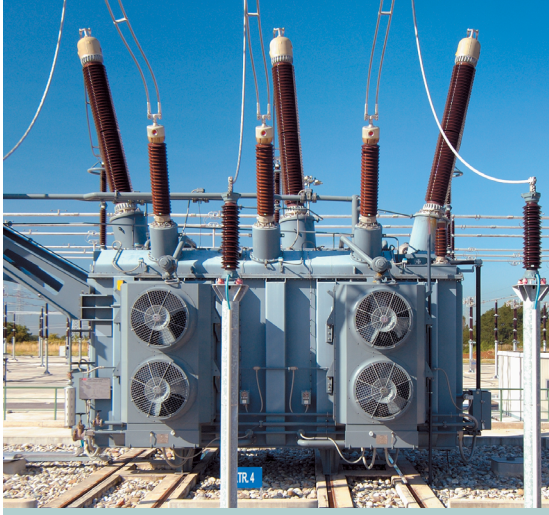
- Draw lead, for bushings at a rated current of 1000 A to 2000 A
- Draw rod, for bushings at a rated current of 1250 A
- Fixed rod type, bottom connected, for bushings at a rated current of 1250 A to 3150 A

Different types of bottom terminals, for draw rod and bottom connection, are available. Special drilling customization is available upon request.

Bushing Design

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

PNO bushings are designed to withstand heavy cantilever loads (level 2 IEC 60137).



Standards

- IEC 60137

Key Benefits

- Bushings with longer lifetime and higher reliability
- Possibility to use bushings under extreme weather conditions (lower pour-point value)
- Easy check of oil level from any position (up to 170 kV)
- No performance reduction with age

GE VERNOVA

PNO Bushings: Main Features

IEC Standard Condenser Bushings for Heavy Cantilever Loads

- Range 72.5 to 1050 kV (50/60 hz)
- Current up to 3150 A
- Oil-Impregnated Paper
- Air-side: porcelain insulator or composite insulator
- Oil-side: epoxy resin insulator (72.5 to 420 kV) or porcelain insulator (550 to 1050 kV)
- Partial discharge: max. 5 pC at 1.5 Um/3
- Provided with power factor tap (voltage tap upon request), air draining plug and oil-side shield
- Draw lead for 1000 A to 2000 A - draw rod for 1250 A - bottom connection for 1250 to 3150 A application
- Head made of special UHV filter prismatic glass with oil level indication (72.5 kV to 170 kV) or with metal oil reservoir and level gauge (245 kV to 1050 kV)
- Flange made of cast aluminum alloy
- Standard angle of installation max. of 45° off vertical (up to and included 420 kV) or max. 30° off vertical (550 to 1050 kV). Other installation angles available upon request.

Fig. 1: Bushings at 245 kV to 1050 kV

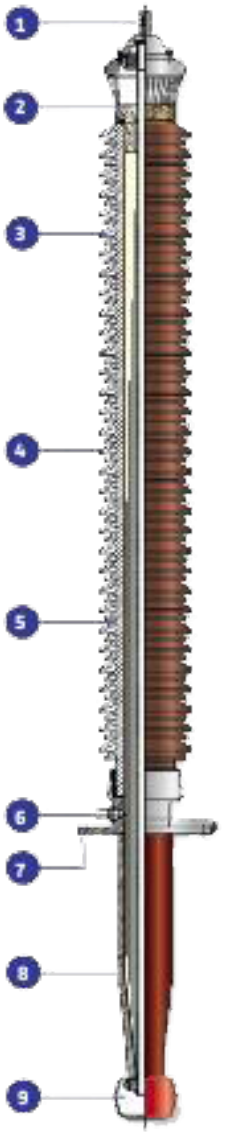


Fig. 2: Bushings at 72.5 kV to 170 kV

Fig. 1: Bushings at 245 kV to 1050 kV

1. *HV Terminal*
2. *Oil level indicator*
3. *Metal oil reservoir*
4. *Porcelain*
5. *OIP Condenser*
6. *Winding tube*
7. *Power factor tap or voltage tap*
8. *Flange*
9. *Epoxy resin or porcelain insulator*
10. *Oil-side shield*

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Bushing Designation

PNO.420.1550.2500	
PNO	IEC type condenser bushings, oil-impregnated paper (OIP), oil-to-air application
420	Insulation class in kV
1550	BIL in kV
2500	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 (rated current up to 2000 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, 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 up to and including 170 kV 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. 9, 10 and 3). Bushings at 245 kV – 2500 A through 1050 kV have a metal head reservoir and a prismatic glass oil level indicator to verify proper oil level (Fig. 11 to 14, 21, 22 and 3).

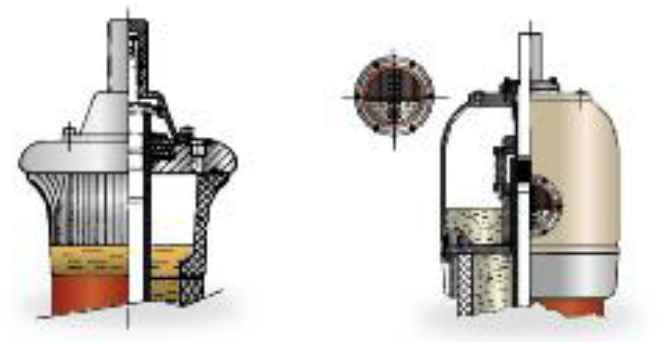


Fig. 3: Oil level indicator for prismatic glass and metal head

Air-Side

The air-side insulator is made of brown porcelain, grey porcelain, or composite insulator (resin fiberglass envelope covered by silicone sheds) is available upon 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 - 1986 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. 4), and/or voltage tap, upon request (Fig. 5)
- Buchholz relay connection: 1/2” gas outlet plug (Fig.23)
- Oil sampling plug (for 145 kV bushings)

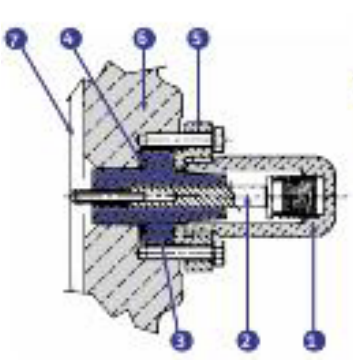


Fig. 4: Power Factor Trap

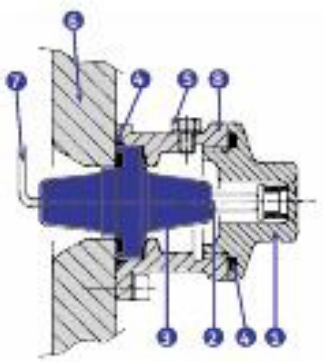


Fig. 5: Power Factor Trap

Fig. 4: Power Factor Trap

Closing and grounding cap
Measurement electrode
Insulation tap
Gasket
Tap flange
Bushing flange
Last layer

Fig. 5: Power Factor Trap

Closing and grounding cap
Measurement electrode
Insulation tap
Gasket
Filling plug
Bushing flange
Connection to internal layer
Tap external housing

Oil-Side

The Oil-side envelope is made of a molded epoxy resin, for bushings up to and including 420 kV, or porcelain, for bushings 550 kV to 1050 kV. 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. The shield can be moved upwards.

Assembling

The coupling between air-side porcelain and metallic parts of the head is made by means of springs or Belleville washers placed into the head of the bushings. The coupling between the air-side porcelain and the flange is realized using quick setting monocalcic-aluminized type cement (Fig. 6). All cemented surfaces, potentially in contact with the external environment, are silicone-sealed.

Fig. 6: Cemented Porcelain

1. Porcelain
2. Cement
3. Metal-cemented ring
4. Flange
5. Silicone sealing

Fig. 6: Cemented Porcelain

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.

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

Transformer Oil

The transformer oil must have a water content less than 15 ppm for voltage up to 145 kV and less than 10 ppm for 145 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), capacitance and partial discharge quantity before and after the series of type tests:

- Dry or wet power-frequency voltage withstand test
- Dry lightning impulse voltage withstand test (BIL)
- Dry or wet switching impulse voltage withstand test (SIL) for bushings rating 245 kV and above
- Thermal stability test for bushings with Um greater than 300 kV
- 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), 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

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 securely 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. 7):

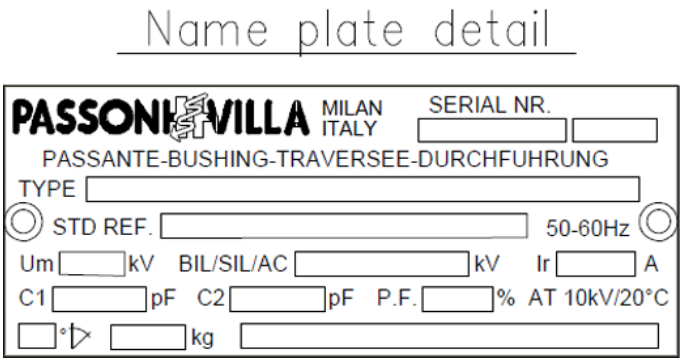


Fig. 7: Identification Nameplate

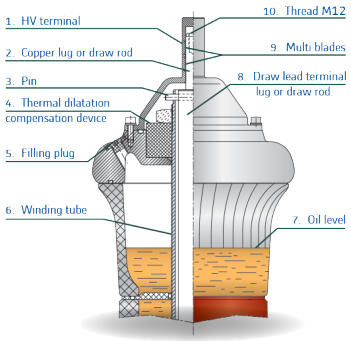


Fig. 8: H1 head type (Draw lead or draw rod up to 170 kV)

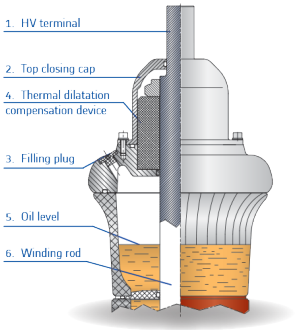


Fig. 9: H2 head type (Bottom connection up to 170 kV - 2000 A)

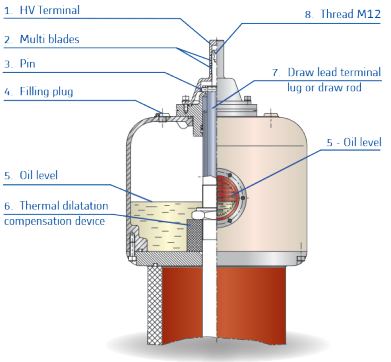


Fig. 10: H3 head type (Draw lead or draw rod 245 to 420 kV)

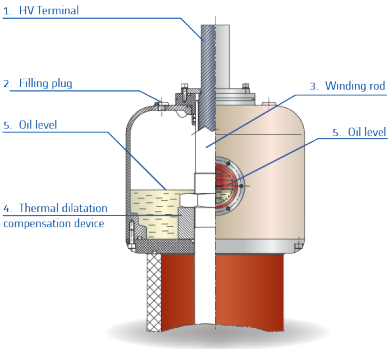


Fig. 11: H4 head type (Bottom connection 245 kV 2500 A to 420 kV - 2000 A)

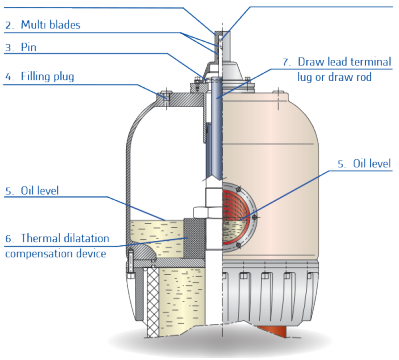


Fig. 12: H5 head type (Draw lead or draw rod 550 kV)

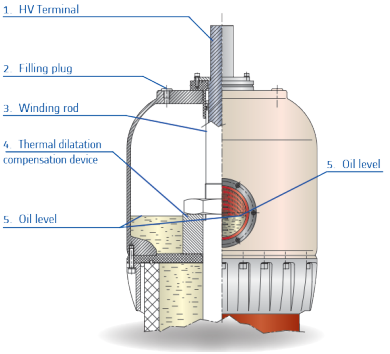


Fig. 13: H6 head type (Bottom connection 420 kV 2500 A to 550 kV)

PNO Range from 72.5 to 1050 kV: Ratings / Dimensions

PNO RANGE FROM 72.5 THROUGH 1050 kV		NOMINAL SYSTEM VOLTAGE	RATED LINE-TO EARTH VOLTAGE	BIL	RATED CONT. CURRENT	DRY POWER FREQUENCY WITHSTAND VOLTAGE (60S)	WET POWER FREQUENCY	WET SWITCHING IMPULSE WITHSTAND VOLTAGE	FLEXIBLE DRAW LEAD CONNECTION	RIGID DRAW ROD CONNECTION	BOTTOM CONNECTION	HEAD TYPE (FIG. 8 TO 13, 20, AND 21)	K min. (CT POCKET)	MIN. CREEPAGE DISTANCE FOR VERY HIGH POLLUTED ATOMOSPHERE	C ARCING DISTANCE	(HEAVY) CANTILVEVER	WEIGHT	MAX. ALTITUDE
Type		**kV**	**kV**	**kV**	**A**	**kV**	**kV**	**kV**					**mm**	**mm**	**mm**	**N**	**kg**	**m**
PNO 72, 5.350.	1000	72.5	42	350	1000	155	140		X			H1	100	2300	705	2000	42	1000
	1250				1250					X							54	
	1600				1600						X						63	
	2500				2500						X	H2	0	2410	800	3150	75	2000
	3150				3150						X					4000	95	
PNO 123.550.	1000	123	71	550	1000	255	230		X			H1	100	3813	1080	3150	91	1000
	1250				1250					X							102	
	1600				1600						X	H2					115	
	2500				2500						X	H4	0	4329	1120	3150	148	
	3150				3150						X					4000	168	
PNO 145.650.	1000	145	84	650	1000	305	275		X			H1	100	4495	1330	3150	103	1000
	1250				1250					X							102	
	1600				1600						X	H2					140	
	2500				2500						X	H4	0	4495	1350	4000	160	1300
	3150				3150						X						190	
PNO 170.750.	1000	170	98	750	1000	355	325		X			H1	0	5420	1520	4000	125	1500
	1250				1250					X							132	
	1600				1600						X	H2					152	
	2500				2500						X	H4	300	5775	1560	5000	200	1300
	3150				3150						X						205	
PNO 245.1050.	1250	245	141	1050	1250	505	460	850	X			H3	0	9350	2440	4000	315	1000
	2000				2000						X	H4				5000	373	
	3150				3150						X						375	
PNO 300.1050.	1250	310	173	1050	1250	505	460	850	X			H3	0	9350	2440	4000	315	1000
	2000				2000						X	H4				5000	373	
	3150				3150						X						375	
PNO 362.1300.	1600	362	209	1300	1600	570		950	X			H3	300	10153	2706	4000	440	1000
	2000				2000						X	H4				5000	460	
	3150				3150						X						465	

PNO RANGE FROM 72.5 THROUGH 1050 kV		NOMINAL SYSTEM VOLTAGE	RATED LINE-TO EARTH VOLTAGE	BIL	RATED CONT. CURRENT	DRY POWER FREQUENCY WITHSTAND VOLTAGE (60S)	WET POWER FREQUENCY	WET SWITCHING IMPULSE WITHSTAND VOLTAGE	FLEXIBLE DRAW LEAD CONNECTION	RIGID DRAW ROD CONNECTION	BOTTOM CONNECTION	HEAD TYPE (FIG. 8 TO 13, 20, AND 21)	K min. (CT POCKET)	MIN. CREEPAGE DISTANCE FOR VERY HIGH POLLUTED ATOMOSPHERE	C ARCING DISTANCE	(HEAVY) CANTILVEVER	WEIGHT	MAX. ALTITUDE
Type		**kV**	**kV**	**kV**	**A**	**kV**	**kV**	**kV**					**mm**	**mm**	**mm**	**N**	**kg**	**m**
PNO 420.1425.	1600	420	243	1425	1600	695		1050	X			H3	300	10153	2706	4000	440	1400
	2000				2000						X	H4				5000	460	
	3150				3150						X	H4					465	
PNO 420.1550.	1600	420	243	1550	1600	750		1175	X			H3	300	14360	3780	4000	700	1200
	2000				2000						X	H4				5000	735	
	3150				3150						X	H4					740	
PNO 550.1675.	1250	550	318	1675	1250	750		1175	X			H3	300	14360	3801	4000	1000	1300
	2000				2000						X	H4				5000	1042	
	3150				3150						X	H4					1042	
PNO 550.1800.	1250	550	318	1800	1250	870		1300	X			H3	300	16110	4260	4000	1100	1000
	2000				2000						X	H4				5000	155	
	3150				3150						X	H4					1160	
PNO 550.1800.	1250	550	318	1800	1250	870		1300	X			H3	300	17800	4701	4000	1185	1600
	2000				2000						X	H4				5000	1221	
	3150				3150						X	H4					1225	
PNO 765.2100.	1250	765	442	2100	1250	920		1425	X		X	H7/H8	100	19500	5140	4000	2950	1000
	1600				1600				X		X	H7/H8					2950	
	2000				2000						X	H8				5000	2950	
	2500				2500						X	H8					3000	
	3150				3150						X	H8					3000	
PNO 765.2100.	1250	1050	606	2400	1250	1200		1800	X		X	H7/H8	150	26250	5735	4000	4000	1000
	2000				2000						X	H7/H8						
	2500				2500						X	H8				5000	5000	
	3150				3150						X	H8						

Note: For ratings not listed, please contact the Grid Solutions team.

DIMENSIONS		D1	D2	D3	D4	D5	D6	D7	R7	D10	D11	L2	L3	L4	L5*	L6	L8	T1	N.	F
Type		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	N.	mm
PNO 72,5.350.	1000	100	185	225	40	170	35	–	140	60	95	1015	850	80	345	859	22	14	6	16
	1250											1015				–				
	1600						–			–		1070			367	–	–			
	2500	145	290	335	60	230			160		130	1200	965	125	295	–		19	12	
	3150											1200				–				
PNO 123.550.	1000	130	250	290	40	230	35	–	200	70	130	1415	1245	80	425	1260	50	19	8	16
	1250															–				
	1600						–			145	200	1470	1485	125	440	–	110			
	2500	145	290	335	60	230										–		22	12	52
	3150								160	165	220	1713	1335		340	–	130			
PNO 145.650.	1000	145	290	335	40	230	35	–	225	70	130	1665	1495	80	475	1510	50	19	12	16
	1250															–				
	1600						–					1720			490	–				
	2500	175			60	300		195	230	165	220		1565	125	390	–	130	22		15
	3150											1943				–				
PNO 170.750.	1000	145	290	335	40	230	35	–	260	70	130	1855	1685	80	475	1700	50	19	12	16
	1250															–				
	1600						–					1911			490	–				
	2500	175			60	300		195		165	220		1775	125		–	130	22		
	3150											2153			790	–				
PNO 245.1050.	1250	200	400	450	40	300	55	–	350	110	200	3035	2665	80	665	2835	85	22	12	23
	2000				60		–			175	250	3041		125	670	–	180			
	3150						–									–				
PNO 300.1050.	1250	200	400	450	40	300	55	–	350	110	200	3035	2665	80	665	2835	85	22	12	23
	2000				60		–			175	250	3041		125	670	–	180			
	3150						–									–				
PNO 362.1300.	1600	220	400	450	40	380	60	250	400	170	250	3410	2936	80	1035	–	180	22	12	23
	2000				60		–					3437		150		–				
	3150						–									–				

DIMENSIONS		D1	D2	D3	D4	D5	D6	D7	R7	D10	D11	L2	L3	L4	L5*	L6	L8	T1	N.	F
Type		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	N.	mm
PNO 420.1425.	1600	250	450	500	40	380	60	–	460	210	290	4000	3525	80	1140	3799	170	25	12	24
	2000				60		–	–				4026		150		–				
	3150						–	–								–				
PNO 420.1550.	1600	250	450	500	40	380	60	–	500	210	290	4510	4035	80	1140	4309	170	25	12	24
	2000				60		–	–				4536		150		–				
	3150						–	–								–				
PNO 550.1675.	1250	340	500	560	40	500	60	–	550	210	290	4666	4051	80	1236	4465	170	25	12	24
	2000				60		–	–				4702		150		–				
	3150						–	–								–				
PNO 550.1800.	1250	340	500	560	40	500	60	–	550	210	290	5126	4510	80	1401	4925	170	25	12	24
	2000				60		–	–				5162		150		–				
	3150						–	–								–				
PNO 550.1800.	1250	340	500	560	40	500	60	–	550	210	290	5566	4951	80	1401	5365	170	25	12	24
	2000				60		–	–				5602		150	1401	–	170	25	12	24
	3150						–	–						150	1401	–	170	25	12	24
PNO 765.2100.	1250	540	711	780	30	700	70	540	750	230	400	6090	5445	80	1370	5850	260	30	12	32
	1600																			
	2000																			
	2500				60		–					6115		125		–				
	3150																			
PNO 1050.2400.	1250	800	1100	1170	30	700	70	800	850	260	500	7135	6490	80	2315	6820	300	40	24	32
	2000																			
	2500															–				
	3150																			

** Valid for K min.*

Dimensions

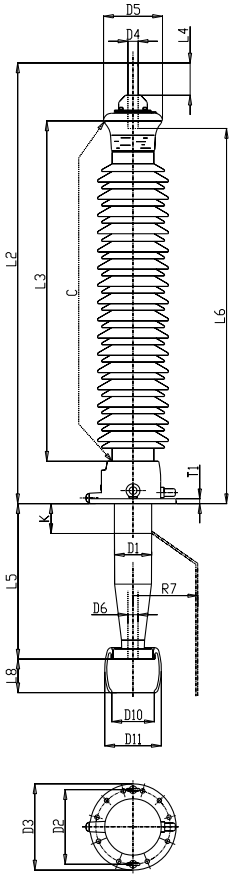


Fig. 14: 72,5-170kV bushing head type H1 or H2.

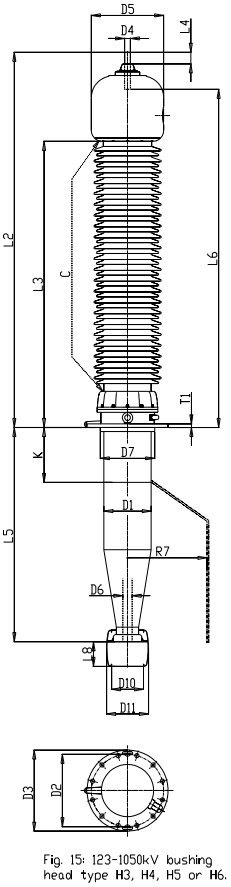


Fig. 15: 123-1050kV bushing head type H3, H4, H5 or H6.

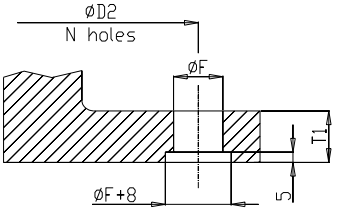


Fig. 16: flange fixing holes

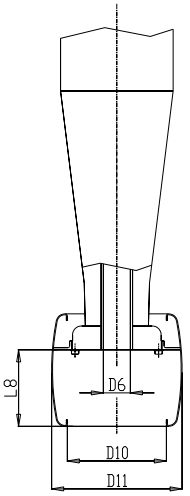


Fig. 17: 72,5-1050kV bushing tail: draw lead connection

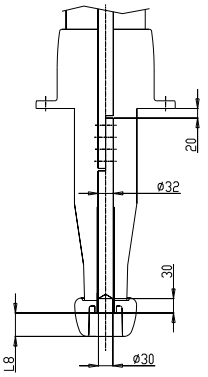
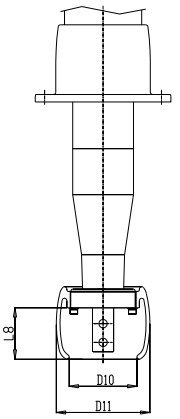


Fig. 18: 72,5-170kV bushing tail: draw rod connection



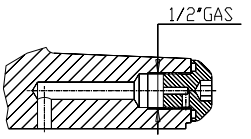
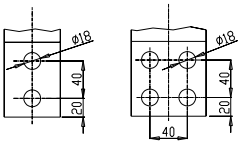


Fig. 22: bucholz relay connection



2 or 4 holes connection detail

Fig. 19: 72,5-1050kV bushing tail: bottom connection

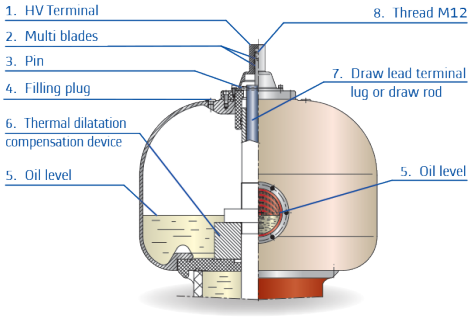


Fig. 20: H7 head type (draw lead or draw rod 765 to 1050 kV)

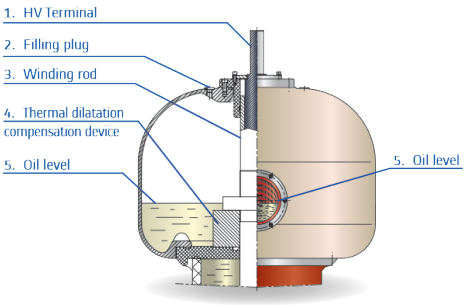


Fig. 21: H8 head type (bottom connection 765 to 1050 kV)

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