GE

Grid Solutions

PAO

Condenser Bushing 25-765 kV
Oil-to-Air - Oil-Impregnated Paper

PAO bushings are capacitance-graded bushings with an oil-impregnated paper core. They meet ANSI/IEEE C57.19.01-2000 and C57.19.01-1991, standard performance characteristics and dimensions for outdoor apparatus bushings.

They are designed for use in power transformers and can be installed up to a 45° maximum inclination (up to and including 138 kV) or 30° (161 to 765 kV) off vertical. Design, components and manufacturing technology promote an average lifetime in excess of 30 years under normal operation conditions.

Manufacturing of Capacitance-graded Bushings

The main electrical component is the condenser body, manufactured using a continuous sheet of pure kraft paper, wound around a central conductor tube. During the winding process a series of aluminum foils are coaxially inserted between the paper layers, to achieve the best possible distribution of the radial and longitudinal electrical gradients between the central tube and the flange, which is grounded.

The winding is made by computer-controlled 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 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 head is filled with a nitrogen cushion. This process is automatic and computer-controlled.

* Catalog UNDER revision, some details may change, confirming compliance and design with the IEEE standard.

Standards

- ANSI IEEE C57.19.01-2000
- IEEE C57.19.01-1991

Key Benefits

- Bushings with longer lifetime and higher reliability
- Possibility to use bushings under extreme weather condition (lower pour-point value)
- Oil level visible from any side up to 161 kV

Imagination at work

PAO Bushings Main Features

ANSI/IEEE Standards condenser bushings

- Range from 25 to 765 kV
- Oil-impregnated paper
- Air side: porcelain or composite insulator
- Oil side: epoxy resin insulator (25 to 345 kV) or porcelain insulator (500 to 765 kV)
- Partial discharge: max. 5 pC at 1.5 $U_m/\sqrt{3}$
- Provided with power factor tap (25 to 69 kV) or voltage tap (115 to 765 kV)
- Draw lead for 400-800 A, 25 to 765 kV
- Draw split rod for bottom connection for 1200 A, 25 to 69 kV
- Bottom connection for 1200 A application, 115 kV and above
- Head made of special UV filter prismatic glass with oil level indicator (25 to 161 kV) or fitted with metal oil reservoir and level gauge (230 to 765 kV)
- Flange made of cast aluminum alloy
- Standard installation angle, max. of 45° off vertical (up to and included 138 kV) or max. 30° off vertical (161 to 765 kV)
- other installation angles available on request
- Transformer-Breaker Interchangeable (TBI)

Fig. 1: Bushings 230 to 765 kV

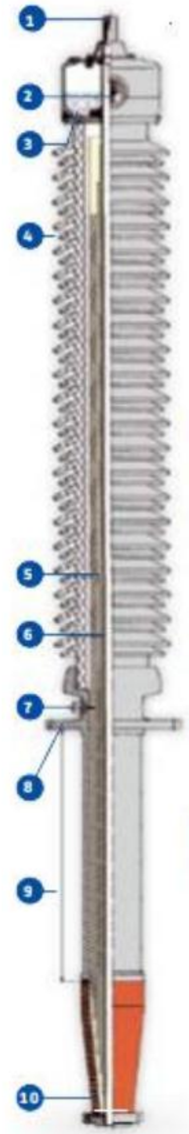


Fig. 2: Bushings 25 to 161 kV

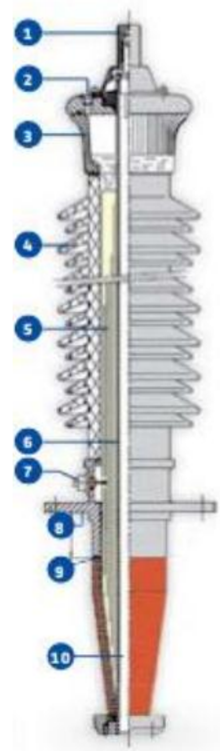


Fig. 1: Bushings 230 to 765 kV

1. HV Terminal
2. Metal oil reservoir
3. Oil level indicator
4. Porcelain
5. OIP Condenser
6. Winding tube
7. Voltage tap
8. Flange
9. CT space
10. Epoxy resin or Porcelain envelope

Fig. 2: Bushings 25 to 161 kV

1. HV Terminal
2. Filling plug
3. UHV lter glass
4. Porcelain
5. OIP Condenser
6. Winding tube
7. Voltage tap
8. Flange
9. CT space
10. Epoxy resin or Porcelain envelope

Bushing Designation PAO.138.650.800

PAO	ANSI type Condenser Bushings, Oil-impregnated paper (OIP)
138	Insulation class in kV
650	BIL in kV
800	Rated current in A
DL (BC)	Draw Lead (Bottom Connection) installed

Air Side

The air side insulator is made of porcelain, light grey MUNSELL 5B4 7.0/0.4 (ASA 70). It can be provided with a resin fiberglass envelope covered by silicone sheds upon request. The typical creepage distance is suitable for very highly 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 815-1986 recommendations. A one-piece porcelain or multiple-piece porcelain, in order to meet standard or special requirements, is used for bushings. Multiple pieces are glued using epoxy resin, without use gaskets. The final porcelain is considered as a single piece (it passes tests IEC 233, clause 6).

Oil Side

The oil side envelope is made of a molded epoxy resin for bushings up to 345 kV and porcelain for higher voltage ratings. 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. As an added advantage, the epoxy resin easily accepts metal attachments, as required, to meet design requirements. The under flange sleeve length for the CT pocket is provided in accordance with ANSI/IEEE Standards.

Top Terminal

The top terminal is made of silver plated copper. Bushings rated 400/800/1200 A have a removable HV terminal (fig. 24-7 and 25-8). This terminal is connected to the copper inner terminal lug by means of multiblade contacts and is secured to the bushing head by screws.

Current Ratings

There are three connection alternatives for the conductor:

- Draw lead connection for 400 and 800 A (fig. 13-3 and 14-4)
- Draw split rod for bottom rod connection for 1200 A, 25 to 69 kV
- Bottom connection using a rigid conductor for 1200 A and above (fig. 15-5)

Using suitable accessories, any bushing rated 400 or 800 A (draw through lead installed) can be converted to 1200 A (bottom connected) and vice versa.

Fig. 3: 400 A draw lead terminal

Fig. 4: 800 A draw lead terminal

Fig. 5: 1200 A inner lug

Fig. 6: 1200 A draw split rod for bottom connection

Draw Through Lead Interchangeability

Current ANSI Standards address the dimensions, mounting holes and connections at and below the bushing flange. Bushings, for the same class, may vary slightly in external height creating few problems due to differences between various manufacturer's draw lead cable lengths and inner terminal lug connectors. This issue has been addressed by means of a "split-lug" draw lead connector (see fig. 13-3 and 14-4) that provides universal interchangeability to most bushing.

This eliminates the need to use an exact replacement bushing or to remove and replace the existing lug from the draw lead to mate with the bushing cap of the replacement bushing.

Draw Rod Installation

The draw rod connection (split-conductor) allows an easier and quicker bushing installation and removal as well. By simply connecting and pulling the split-conductor through the bushing, it is possible to install a 1200 A rated bushing (commonly bottom connected) in the same manner of a draw-lead type bushing, saving time and money in commissioning and maintenance activities (need to drop down the oil in the transformer tank).

Head and Oil Level Indication

Bushings up to and including 161 kV have a cylindrical oil head reservoir, prismatic in shape, made of borosilicate glass, and containing a UV filter (fig. 24-7). This head design allows easy oil level checks, even from a distance and at any angle of sight. Bushings at 230 kV through 765 kV have a metal head reservoir and are provided with a prismatic glass oil level indicator to verify proper oil levels (fig. 25-8). The metal components of the head are made of cast aluminum alloy.

Fig. 7: Head of bushings 25 to 161 kV

Fig. 8: Head of bushings 230 to 765 kV

Flange

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

- Lifting holes
- Power factor tap, for bushings 25 to 69 kV (fig. 22-9)
- Voltage tap, for bushings 115 to 765 kV (fig. 23-10)

Fig. 9: Power Factor Tap

Fig. 10: Voltage Tap

Gaskets

Made of Viton® (a fluoroelastomer which has better properties than nitrile, i.e. resistance to higher temperature and excellent resistance to oils, aggressive fuels and chemicals), O-ring type. They are compatible with both the fluid inside the bushing and transformer mineral oil. The air side gaskets are sealed to carefully protect against polluting weather elements.

Fig. 11: Cemented Porcelain

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

Assembly

The coupling between porcelain and metallic parts is made of Belleville spring washers placed into the bushing head. Bushings of 138 to 765 kV are always assembled using cemented porcelains.

The cement used is a quick setting monocalcic-aluminized type. All cemented surfaces, potentially in contact with the external environment, are silicone sealed.

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

Tests

All bushings have electrical characteristics and are tested in compliancwith ANSI/IEEE C57.19.00-2000 and C57.19.00-1991 standard general requirements and test procedure for outdoor power apparatus bushings.

Design Tests

- Dielectric Withstand Voltage Tests
  - Low-Frequency Wet Withstand Voltage Test
  - Full-Wave Lightning Impulse Withstand Voltage Test
  - Chopped-Wave Lightning Impulse Withstand Voltage Test
  - Wet Switching Impulse Withstand Voltage (345 kV)
  - Low-Frequency Dry Withstand Voltage Test with PD measurement
- Mechanical Tests
  - Draw-Lead Bushing Cap Pressure Test
  - Cantilever Strength Test
- Thermal Tests

Routine Tests

- Capacitance and Power Factor Measurement
- Low-Frequency Dry Withstand Test with PD Measurement
- Tap Withstand Voltage
- Mechanical Tests

Packing - Transportation

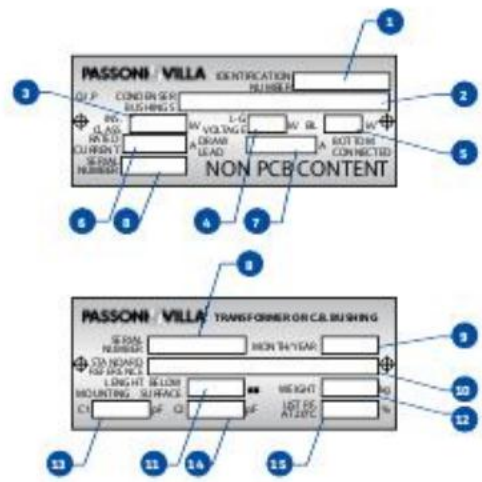
Thanks to a special device to prevent the diffusion of the nitrogen cushion out of the head into the lower end of the bushing, each bushing can be packed and shipped secured in the horizontal position.

This insures minimal crate dimensions and reduced transportation costs.

Nameplate

Each bushing is provided with a nameplate, containing complete electrical data and the serial number, in accordance with the requirements of ANSI Standards. The nameplate, made of aluminum, is secured to the ange with rivets and includes:

Fig. 12b: Nameplate



1. *Identification number*
2. *Bushing code*
3. *Insulation class*
4. *Rated maximum line to ground voltage*
5. *Rated impulse withstand voltage*
6. *Rated continuous current for draw lead type*
7. *Rated continuous current for fixed conductor, bottom connection type*
8. *Serial number*
9. *Month and year of nal tests*
10. *Standard references*
11. *Length below mounting surface*
12. *Weight*
13. *Capacitance C1*
14. *Capacitance C2*
15. *Power factor value at 20 °C*

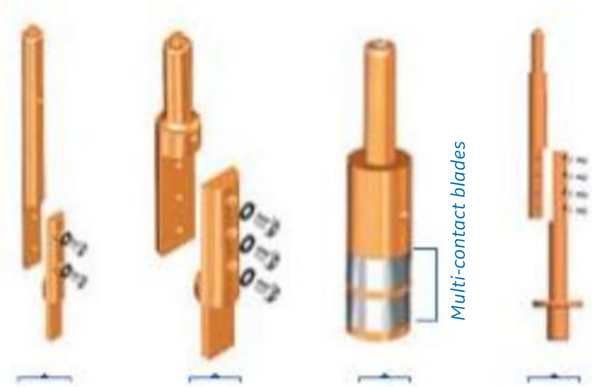


Fig. 13 *Fig. 14* *Fig. 15* *Fig. 16*

Fig. 13: Split draw lead terminal 400 A (25 to 69 kV)
Fig. 14: Split draw lead terminal 800 A (25 to 765 kV)
Fig. 15: Bottom connection 1200 A and above (115 to 765 kV)
Fig. 16: Botttom connection 1200 A and above (25 to 69 kV)

PAO Range from 25 to 765 kV: Ratings / Dimensions

Type	Figure	IEEE C57.19. 01-	Nominal System Voltage	BIL	Rated conti-nuous current	Arcing distance	Creepage distance	Weight	Maximum altitude	K (CT pocket)	L	L2	L3	L4	L1	D1
Type			kV	kV	A	Inches	Inches	Lbs	Feet	Inches	Inches	Inches	Inches	Inches	Inches	Inches
25.150.400	26	1991	25	150	400	17.12	37.1	90	9900	21	52.68	25.98	6.50	12.91	26.70	3.54
25.150.1200	26	1991	25	150	1200	17.12	37.1	110	9900	21	55.48	25.98	6.50	...	29.50	3.54
25.150.2000	26	1991	25	150	2000	17.12	37.1	117	9900	21	58.26	25.98	6.50	...	32.28	3.54
25.150.3000	26	1991	25	150	3000	17.12	37.1	174	9900	21	62.47	28.15	8.27	...	34.32	3.94
34.5.200.400	26	2000	34.5	200	400	17.12	37.1	92	9900	21	54.68	25.98	6.50	12.91	28.70	3.54
34.5.200.1200	26	2000	34.5	200	1200	17.12	37.1	112	9900	21	57.48	25.98	6.50	...	31.50	3.54
34.5.200.2000	26	2000	34.5	200	2000	17.12	37.1	132	9900	21	59.48	25.98	6.50	...	33.50	3.54
34.5.200.3000	26	2000	34.5	200	3000	17.12	37.1	143	9900	21	61.65	28.15	8.27	...	33.50	3.94
46.250.400	26	1991	46	250	400	24.02	67.8	103	9900	21	63.98	33.27	6.50	20.20	30.71	3.94
46.250.1200	26	1991	46	250	1200	24.02	67.8	128	9900	21	66.77	33.27	6.50	...	33.50	3.94
69.350.400	26	2000	69	350	400	29.94	92.87	117	9900	21	73.91	39.19	6.50	26.10	34.72	3.94
69.350.1200	26	2000	69	350	1200	29.94	92.87	145	9900	21	76.69	39.19	6.50	...	37.51	3.94
69.350.2000	26	2000	69	350	2000	34.45	98.0	220	9900	21	84.78	45.28	6.50	...	39.50	5.12
69.350.3000	26	2000	69	350	3000	34.45	98.0	254	9900	21	86.55	47.05	8.27	...	39.50	5.12
115.550.800	27	1991	115	550	800	42.32	149.84	308	3300	23	99.49	56.49	6.69	47.24	43	5.125
115.550.1200	27	1991	115	550	1200	42.32	149.84	330	3300	23	99.30	56.30	6.50	...	43	5.125
115.550.2000	27	1991	115	550	2000	42.32	149.84	380	3300	23	100.48	57.48	7.68	...	43	5.125
138.650.800	27	2000	138	650	800	52.16	175.6	348	3300	23	113.08	66.33	6.69	57.09	46.75	5.75
138.650.1200	27	2000	138	650	1200	52.16	175.6	348	3300	23	113.08	66.33	6.69	...	46.75	5.75
138.650.2000	27	2000	138	650	2000	52.16	175.6	482	3300	23	113.08	66.33	6.69	...	46.75	5.75
161.750.800	27	1991	161	750	800	59.06	200.79	494	3300	23	126.43	76.18	8.66	66.93	50.25	6.89
161.750.1200	27	1991	161	750	1200	59.06	200.79	494	3300	23	126.43	76.18	8.66	...	50.25	6.89
230.1050.800	28	2000	230	1050	800	96.06	368.11	838	3900	23	177.39	120.51	15.10	111.26	56.39	7.87
230.1050.1200	28	2000	230	1050	1200	96.06	368.11	838	3900	23	177.39	120.51	15.10	...	56.39	7.87
230.1050.2000	28	2000	230	1050	2000	90.95	323.78	974	3900	23	177.39	120.51	15.10	...	56.39	7.87
345.1175.1200	28	2000	345	1175	1200	106.5	399.7	1236	9900	23	185.25	134.25	18.7	...	51	8.66
345.1175.2000	28	2000	345	1175	2000	106.5	399.7	1245	9900	23	188.01	137.01	21.46	...	51	8.66
500.1675.1200	28	2000	500	1675	1200	146.85	558.50	2332	3300	23	250.23	185.23	28.54	...	65	13.39
500.1675.2000	28	2000	500	1675	2000	146.85	558.50	2486	3300	23	250.23	185.23	28.54	...	65	13.39
765.2050.800	28	2000	765	2050	800	202.36	767.71	5720	3300	23	326.73	241.73	26.18	232.28	85	21.26
765.2050.1200	28	2000	765	2050	1200	202.36	767.71	5720	3300	23	325.16	240.16	24.61	...	85	21.26
765.2050.2000	28	2000	765	2050	2000	202.36	767.71	5720	3300	23	325.16	240.16	24.61	...	85	21.26

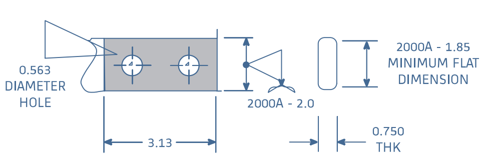


Fig. 17: Bottom terminal type 1

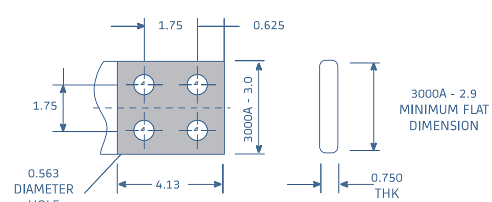


Fig. 18: Bottom terminal type 2

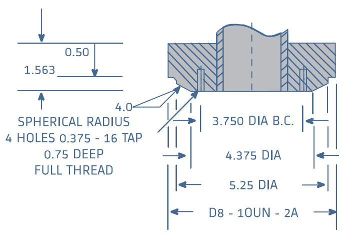


Fig. 19: Bottom terminal type 3

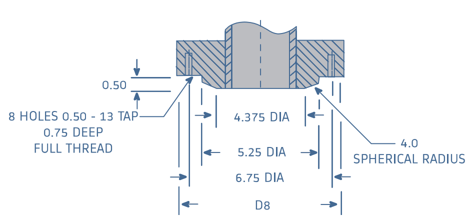


Fig. 20: Bottom terminal type 4

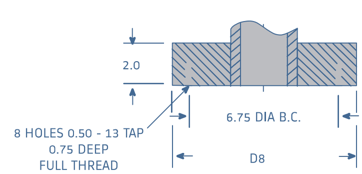


Fig. 21: Bottom terminal type 5

Type	D3	D4	D5	D6	d3	D8	s	n	F	D7 Top terminal thread size	L7 Top terminal min. thread	Terminal lug: figure d.r.	Bottom terminal thread size	Bottom terminal min. thread	Bottom terminal type	Installation d.l = draw lead b.c. = bottom connected
Type	Inches	Inches	Inches	Inches	Inches	Inches	Inches	N.	Inches	Inches	Inches	fig.	Inches	Inches	fig.	
25.150.400	7.25	8.875	6.70	3.54	1.38	...	0.625	4	0.875	1.5-12	2.125	13	...	...	...	d.l.
25.150.1200	7.25	8.875	6.70	3.54	...	...	0.625	4	0.875	1.5-12	2.125	16	1.5-12	2.125	...	b.c.
25.150.2000	7.25	8.875	6.70	3.54	...	...	0.625	4	0.875	2.0-12	2.5	...	...	...	1 (17)	b.c.
25.150.3000	9.25	11.42	6.70	4.53	...	...	0.625	6	0.875	2.0-12	3.0	...	...	...	2 (18)	b.c.
34.5.200.400	7.25	8.875	6.70	3.54	1.38	...	0.625	4	0.875	1.5-12	2.125	13	...	...	...	d.l.
34.5.200.1200	7.25	8.875	6.70	3.54	...	...	0.625	4	0.875	1.5-12	2.125	16	1.5-12	2.125	...	b.c.
34.5.200.2000	7.25	8.875	6.70	3.54	...	...	0.625	4	0.875	1.5-12	2.5	...	...	...	1 (17)	b.c.
34.5.200.3000	9.25	11.437	6.70	4.53	...	...	0.625	6	0.875	2.0-12	3	...	...	...	2 (18)	b.c.
46.250.400	8.25	11.437	6.70	4.53	1.38	...	0.625	4	0.875	1.5-12	2.125	13	...	...	...	d.l.
46.250.1200	8.25	11.437	6.70	4.53	...	...	0.625	4	0.875	1.5-12	2.125	16	1.5-12	2.125	...	b.c.
69.350.400	9.25	11.437	6.70	4.53	1.38	...	0.625	6	0.875	1.5-12	2.125	13	...	...	...	d.l.
69.350.1200	9.25	11.437	6.70	4.53	...	...	0.625	6	0.875	1.5-12	2.125	16	1.5-12	2.125	...	b.c.
69.350.2000	9.25	11.437	9.06	5.9	...	...	0.625	6	0.875	1.5-12	2.5	...	...	...	1 (17)	b.c.
69.350.3000	10.25	12.00	9.06	5.9	...	...	0.625	6	0.875	2.0-12	3	...	...	...	2 (18)	b.c.
115.550.800	13.25	15.75	9.06	6.7	1.625	...	0.875	6	1.25	1.5-12	2	14	...	...	...	d.l.
115.550.1200	13.25	15.75	9.06	6.7	...	5.75	0.875	6	1.25	1.5-12	2	15	...	...	3 (19)	b.c.
115.550.2000	13.25	15.75	9.06	6.7	...	5.75	0.875	6	1.25	2.0-12	2.5	...	...	...	3 (19)	b.c.
138.650.800	14.25	16.75	9.06	6.7	1.625	...	0.867	6	1.25	1.5-12	2	14	...	...	...	d.l.
138.650.1200	14.25	16.75	9.06	6.7	...	5.75	0.867	6	1.25	1.5-12	2	15	...	...	3 (19)	b.c.
138.650.2000	14.25	16.75	9.06	6.7	...	5.75	0.867	6	1.25	1.5-12	2.5	...	...	...	4(20)	b.c.
161.750.800	15.75	18.312	10.63	7.68	2	...	0.867	8	1.25	1.5-12	2	14	...	...	...	d.l.
161.750.1200	15.75	18.312	10.63	7.68	...	5.75	0.867	8	1.25	1.5-12	2	15	...	...	3 (19)	b.c.
230.1050.800	21.00	23.75	11.81	7.87	2.16	...	0.867	12	1.25	1.5-12	2	14	...	...	...	d.l.
230.1050.1200	21.00	23.75	11.81	7.87	...	8.25	0.867	12	1.25	1.5-12	2	15	...	...	4 (20)	b.c.
230.1050.2000	21.00	23.75	11.81	7.87	...	8.25	0.867	12	1.25	1.5-12	2.5	...	...	...	4 (20)	b.c.
345.1175.1200	21.00	23.75	14.96	9.84	...	8.25	0.867	12	1.25	1.5-12	2	15	...	...	5 (21)	b.c.
345.1175.2000	21.00	23.75	14.96	9.84	...	8.25	0.867	12	1.25	1.5-12	2.5	...	...	...	5 (21)	b.c.
500.1675.1200	25.00	28.34	19.68	13.39	...	8.25	1	12	1.25	1.5-12	2	...	...	...	5 (21)	b.c.
500.1675.2000	25.00	28.34	19.68	13.39	...	8.25	1	12	1.25	1.5-12	2.5	...	...	...	5 (21)	b.c.
765.2050.800	35.00	37.80	27.56	21.26	2.76	...	1.18	16	1.25	1.5-12	2	14	...	...	...	d.l.
765.2050.1200	35.00	37.80	27.56	21.26	...	8.25	1.18	16	1.25	1.5-12	2	...	...	...	5 (21)	b.c.
765.2050.2000	35.00	37.80	27.56	21.26	...	8.25	1.18	16	1.25	1.5-12	2.5	...	...	...	5 (21)	b.c.

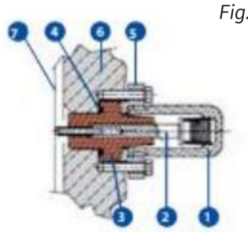


Fig. 22: Power Factor Tap (25 to 69 kV)

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

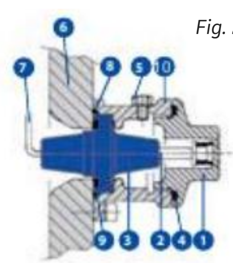


Fig. 23: Voltage Tap (115 to 765 kV)

1. *Closing and grounding cap*
2. *Measurement electrode*
3. *Insulation tap*
4. *Gasket*
5. *Filling plug*
6. *Bushing ange*
7. *Connection to internal layer*
8. *Gasket*
9. *Gasket*
10. *Tap external body*

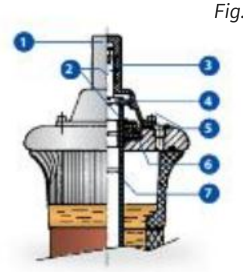


Fig. 24: Bushings' head 25 to 161 kV

1. *HV Terminal*
2. *Multicontact blades*
3. *Copper connector*
4. *Pin*
5. *Filling plug*
6. *Belleville washers*
7. *Winding tube*

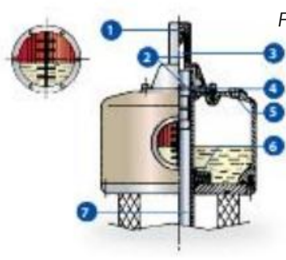


Fig. 25: Bushings' head 230 to 765 kV

1. *HV Terminal*
2. *Multicontact blades*
3. *Copper connector*
4. *Pin*
5. *Filling plug*
6. *Belleville washers*
7. *Winding tube*

Dimensions

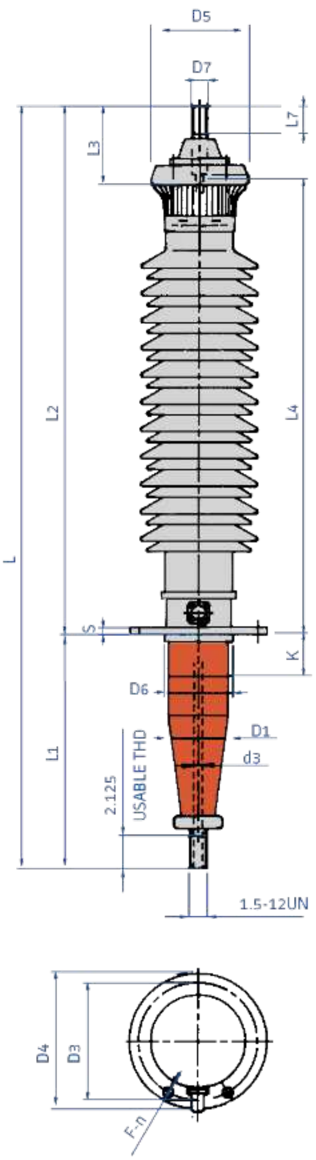


Fig. 26: PAO bushings 25 to 69 kV

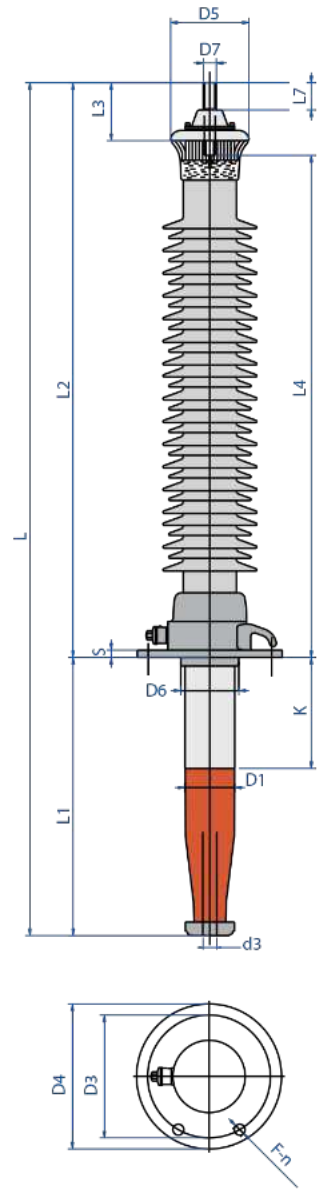


Fig. 27: PAO bushings 115 to 161 kV

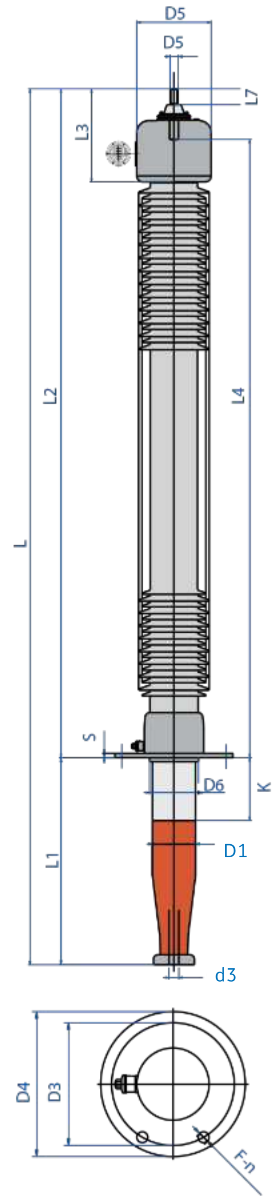


Fig. 28: PAO bushings 230 to 765 kV

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