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Pollution behaviour of insulators with spiral shaped sheds

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Abstract

The paper reviews the experimental investigation of the performance of insulators with spiral shaped sheds under laboratory and field conditions. The study carried out in different countries and author' own measurements are presented. It was shown that the pollution flashover voltage of spiral shaped insulators is lower than that of insulators with standard sheds. The poorer performance of spiral shaped insulators is caused by the formation of non-uniform surface layer along the leakage path.

1 Introduction

Insulators with spiral shaped sheds are similar to a screw. The sheds round their core are similar to the screw-thread. These insulators were produced in France [1], Soviet Union [2] and are still manufactured in Czech Republic [3]. Their application is rather limited but in some countries like Czech Republic, Slovakia or Finland they are used in 110 kV lines, distribution lines or railway traction. Such profile is also used for the silicone rubber housing. The spiral polymer sheds are attached to the core therefore their production is very simple.
The insulators with spiral shaped sheds have been applied since 40 years. Their flashover performance was studied in 1960s and 1970s. In the Soviet Union the attention was paid to their aerodynamic properties because these insulators were applied in arid regions with small amount of precipitations [4, 5]. The spiral insulators were tested under natural conditions in Germany [6,7], Sweden [7] and Poland [8]. The very broad investigations were carried out in Czechoslovakia [9, 10].
The above cited papers presented usually the results of pollution test carried out on different insulators. Therefore, one paragraph in this paper shows the brief review of that works with a special attention on the performance of insulators with spiral shaped sheds.

2 Different types of spiral insulators

The first spiral insulator was patented by Stroup in 1928 (**Fig. 1**). The second solution, a cap and pin insulator with special shaped shed was patented in 1932 (**Fig. 2**). Cron designed a long rod insulator with spiral shaped sheds in 1954 [12].
The long rod spiral insulators have different shed profiles and different lead angle. There are two parallel rain-pipes on the shed of CT-35 insulator (**Fig. 3a**), there is only one rain-pipe on the shed of LPS 75/11 insulator (**Fig. 3c**). The spiral shaped sheds increase the length of water flow and the water amount on the insulator. Special attention was given on the (hypothetical) improvement of voltage distribution along the leakage distance of spiral insulators. It was explained that the voltage distribution on the insulators with standard sheds is more non-uniform due to great difference between shed and core diameters [2, 8].

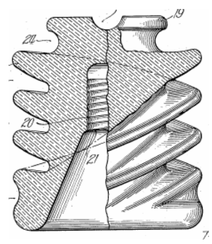


Fig. 1 The Stroup insulator with spiral shaped sheds [11]

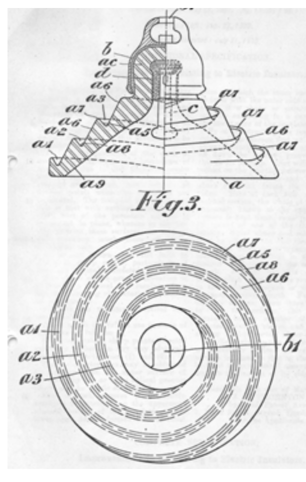
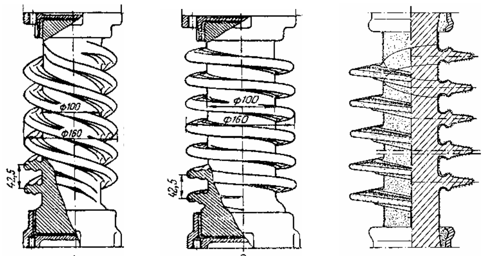


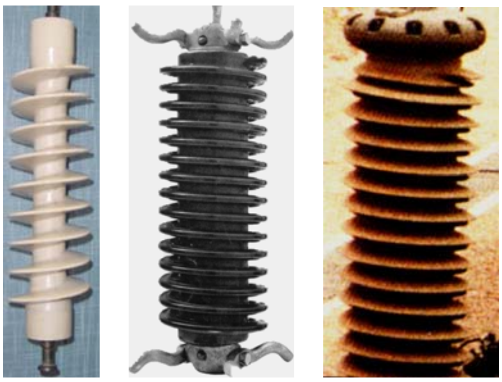
Fig. 2 The cap and pin insulator with a spiral rain-pipe on the shed [12]

Insulator Spirelec SSB 10054 has special caps (**Fig. 4b**). Due to this solution, at the same overall length, its dielectric length can be longer than the dielectric length of insulators with standard flanges.



a b c

Fig. 3 The profiles of spiral insulators:
a; b – soviet insulators of series CT-35 [6];
c – polish insulator LPZS 75/11



a b c

Fig. 4 Spiral insulators, a – polish composite insulator made from epoxy resin; b – czech porcelain insulator SSB 10054 Spirelec;
c – polymer housing

3 Review of former research

3.1 Research in Soviet Union

In the Soviet Union the attempt was led on the hypothetical better rain washing effect and the lower contamination accumulation on spiral insulators as compared to standard long rods [4]. The study of a few spiral insulators in a wind tunnel have shown that the lower contamination accumulation was on the insulator with smaller lead angle (**Fig. 3b**). The insulators were contaminated by a cement dust in a tunnel with the wind velocity of 5 m/s. Next, the leakage current and flashover voltage were measured in a fog chamber (**Table 1**). The results were compared with measurements carried out with the reference insulator CT-35. The reference insulator with six standard sheds had the same height, core and shed diameter as the spiral insulators.

Table 2 shows that the highest flashover voltage of 65 kV was measured for screw insulator with the smallest lead angle. However, the flashover voltages for other spiral insulators were lower than for insulator with standard sheds. These results have shown that the flashover voltage of spiral insulators can be lower than that of standard insulator with similar length of leakage distance.

The field test carried out in arid territory under the voltage of 35 kV confirmed that the performance of spiral insulators can be similar to insulators with alternating sheds (sheds with different diameters) [5]. The shortest time to flashover of spiral insulator was 28 months and that of insulator with alternating sheds 34 months. The leakage distances of both type insulators were similar, 60 cm for spiral insulator and 68 cm for insulator with alternating sheds.

Table 1 The results of pollution test of spiral insulators and standard insulator CT-35 after contamination in a wind tunnel [4]

Number of insulator acc. **Fig. 3**	a		b		Standard insulator CT-35	
L (cm)	60		65		57	
Surface state	U_p kV	I mA	U_p kV	I mA	U_p kV	I mA
After contamination	47	75	65	40	60	40
After washing trial	50	45	66	35	59	20

L – leakage distance. The overall height of insulators amounted 42 cm

3.2 Research in Czechoslovakia

In Czechoslovakia, the line insulators were tested in salt fog, in steam fog and according to flow on method with methylcellulose [9], the post insulators were tested in salt fog [10]. **Table 2** compares the test results of Spirelec insulators with other line insulators in salt fog.

Table 2 Test results of line insulators in salt fog [9]

Insulator type	Leakage distance cm	Test voltage kV	Withstand salinity g/l
VKL 75/14	186	85	10
VKLS 75/21	335	85	>226
NVKL 75/27	277	85	28
9 VZC 2025	376	85	>226
8 VZC 2010	240	85	7
Spirelec 2 SSB 10054	441	85	14

The pollutants used for the solid layer consisted of 100 g Kieselghur, 10 g Aerosil (dispersed silica dioxide) per 1 litre of water. **Fig. 5** shows the pollution characteristics of 4 selected insulators obtained in steam fog.

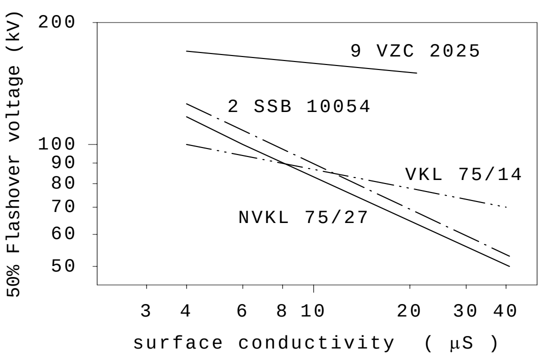


Fig. 5 Pollution characteristics of 4 selected insulators obtained in steam fog [9]

The results of flow on tests with methylcellulose layer are shown in **Fig. 6**.

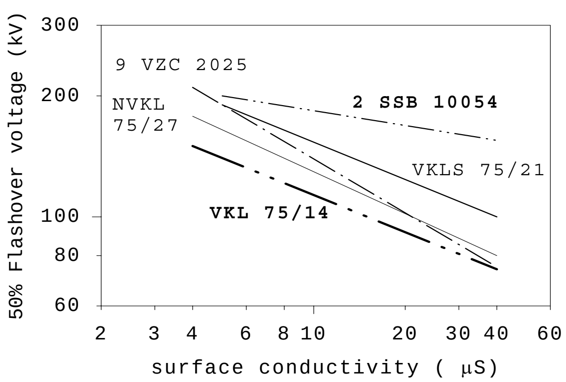


Fig. 6 Pollution characteristics of insulators obtained according to flow on method with methylcellulose layer [9]

Three post insulators with alternating sheds (insulator numbers 1, 2 and 4 in **Table 3**) with one post with uniform sheds (insulator number 3 in **Table 3**) and of the post with spiral sheds (insulator number 5 in **Table 3**) were tested in salt fog with a salinity of 40 g/l. The flashover voltage divided by the leakage distance or divided by the height of insulation is shown in **Table 3**.

Table 3 Salt fog test results of post insulators [10]

Insulator	1	2	3	4	**5**
Shed number	12	15	16	14	**38**
Leakage distance (cm)	327	381	310	338	**367**
Shed distance (mm)	95	70	50	80	**25**
U / L (kV/cm)	0,68	0,69	0,53	0,64	**0,55**
U/ H (kV/cm)	2,2	2,71	2,35	2,06	**2,01**

L – Leakage distance; H – Insulation height;
U – flashover voltage; Insulator number 5 – insulator with spiral sheds

It is interesting to note that only with the methylcellulose layer the flashover voltage of spiral insulator was higher than flashover voltage of other insulators. The flashover voltages of spiral insulator in salt fog and in steam fog were the lowest ones. These results were noted in spite of the fact that the leakage distance of spiral insulators was longer than that of other insulators. The spiral insulators behaviour is very good in the case of very thick pollution layer.

3.3 Research in Germany

The field test of 18 different insulator types was carried out under a voltage of 125 kV and industrial pollution in 1969-1973 [6]. The insulation height of 110 kV rated insulators was 107 cm. The number of flashovers as a function of leakage distance is shown on **Fig. 7**. This function can be drawn as a triangle setting by insulators numbered as 6, 17 and 18. The point representing flashover numbers on spiral insulator (point 2 on **Fig. 7**) is situated outside that triangle. In spite of very long leakage distance, the flashover number on spiral insulator was similar to flashover number on insulators with standard sheds but with nearly two times shorter leakage distance.

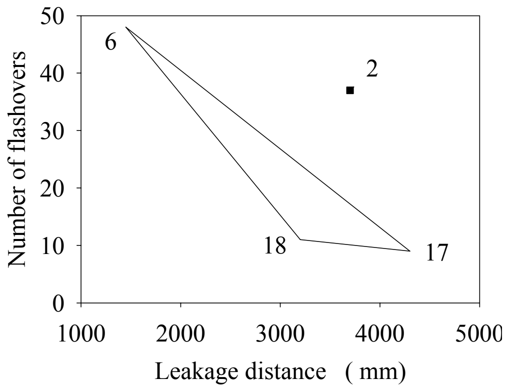


Fig. 7 Flashover number as a function of leakage distance of support insulators. Point 2 - Insulator with spiral sheds [7]

3.4 Research in Sweden

20 different cap and pin and long rod insulators were studied. Two insulators with spiral sheds were marked as 5a and 5b in **Table 4** (Table 4 shows only a part of results published in [7]). From the flashover number observed during the field test the specific leakage distance was calculated for each insulator which gave the same flashover number for all insulators. Regarding the specific leakage distance the spiral insulators were placed on positions No. 16 and 20. In contrast to the poor behaviour it can be noted that pollution accumulation on spiral insulator number 5a was rather good. In this respect it was classified on the fourth position.

Table 4 Order of merit related to leakage distance of insulators [7]

		Insulator ranking with regard to		
Insulator number	Specific leakage distance mm/kV	Leakage distance	Insulator height	ESDD
6a	10,4	1	4	5
8a	10,8	2	8	2
1a	11,7	3	6	1
...	...	...	...	...
4b	15,5	15	17	12
5a	**15,6**	16	9	4
2d	15,9	17	20	11
8b 2	15,9	18	7	3
9b	16,7	19	13	-
5b	**19,0**	20	14	-

No 5a and no 5b – spiral insulators

3.5 Research in Egypt

Pollution tests of four polymer insulators including a spiral shaped one were carried out in 1986 [14]. First, the insulators were exposed to natural contamination for 3 years. Then, ESDD and flashover voltage in a clean fog were measured. The contamination density on spiral insulator was similar to the contamination density on insulators with standard sheds. The flashover voltage of naturally polluted spiral insulator was the lowest one. However, its electrical strength with artificial pollution consisted of kieselgur and dispersed silicone dioxide was the highest. It is worth to note that the flashover voltage of spiral insulator SSB 10054 contaminated with the same pollutants was lower than the flashover voltage of insulators with standard sheds. Its electrical strength with methylcellulose was higher than that of other insulators (Czech results).

4 Research carried out by authors [15]

The flashover voltages were measured according to flow on method using a 50 g/l kaolin suspension (**Fig. 8**). The dimensions of insulators used, a spiral insulator LPS 75/11, an insulator with stepped sheds LPZS 75/15, an insulator with alternating sheds LPZ 75/37 and insulator VKL 75/14, are shown in **Table 5**. The voltage was applied 2,5 minutes after the insulator was polluted by dipping into the kaolin suspension. Due to the flowing down, the layer thickness on the top of spiral insulator was thinner than on the bottom. Therefore, the discharges concentrated on its top (**Fig. 9a**). This non-uniformity of pollution layer caused the decreasing of flashover voltage. As a result, the flashover voltage of spiral insulator measured in kV per centimetre of leakage distance is the lowest (**Fig. 8**).
The measured flashover voltages and currents just before flashover in salt fog with the salinity of 14 g/l are shown in **Table 6**. The table presents the withstand voltage U_w, 50% flashover voltage $U_{50\%}$, the smallest I_{max} (Min I_{max}) and greatest I_{max} current (Max I_{max}) just before flashover, the withstand voltage divided by insulation height U_w/H and withstand voltage divided by creepage distance U_w/L. Again, the electrical strength of the insulator with spiral sheds is the smallest one. Similar to the previous experiment, in salt fog the electrical discharges were concentrated on the top of spiral insulator.

Table 5 Data of tested insulators

Insulator type	H (cm)	L (cm)	D / d (cm)	f
LPS75/11	59	146	17,4	3,25
VKL 75/14	107	186	14,6	6,45
LPZS 75/15	107	250	17,6	7,9
LPZ 75/37 W	108	284	15,2/12,0	9,9

H – the height of insulation; L – leakage distance; D/d – diameter of large/small shed; f – form factor

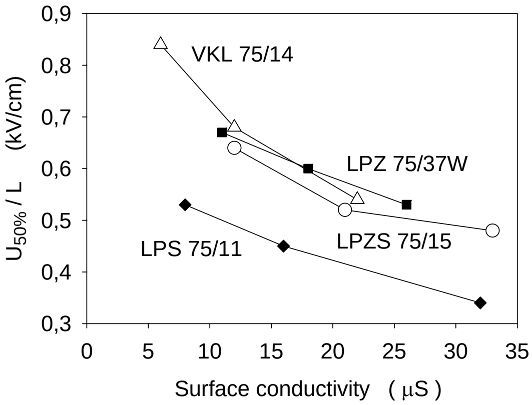


Fig. 8 Pollution characteristics measured according to flow on method

Table 6 Results of salt fog test with a salinity of 14 g/l

Insulator type	U_w	$U_{50\%}$	Min I_{max}	Max I_{max}	U_w /H	U_w /L
	kV	kV	A	A	kV/cm	kV/cm
LPS 75/11	28	30	2,26	2,76	0,47	0,19
VKL 75/14	63	65	0,83	1,07	0,59	0,34
LPZS 75/15	91	94	1,54	2,29	0,85	0,36
LPZ 75/47W	71	75	0,87	2,04	0,66	0,25

U_w - withstand voltage

5 Resume

The review of research carried out in few countries indicated that the pollution behaviour of spiral insulators is usually worse than that of insulators with standard sheds. The designer's intention, a uniform pollution on spiral insulators was in fact not fulfilled. The profiles of many spiral insulators facilitate the formation of dry band on their top. **Fig. 9b** and **Fig. 9c** show the development of discharges on insulator SSB 10054. First, the small discharges appear close to the top flange and gradually elongate to the bottom. This process was observed on insulators with different lead angle. The profile of spiral insulators should be modified in order to inhibit the flow of electrolyte down along the spiral.

The methylcellulose is very dense. Therefore, this contamination was able to produce a layer with the same thickness. The flashover voltage of spiral insulator SSB 10054 was higher than insulators with standard sheds because in this case the discharges were divided into many small sparks. The positive long experience with insulators Spirelec 2 SSB 10054 on 110 kV lines in Czech Republic and Slovakia result from a very long specific creepage distance 4 cm/kV used. In very heavily polluted environment the specific leakage distance should be greater than 3,1 cm/kV. The 110 kV lines usually serve areas with light pollution. Therefore, the insulation consisting of two insulators Spirelec is simply overdimensioned.

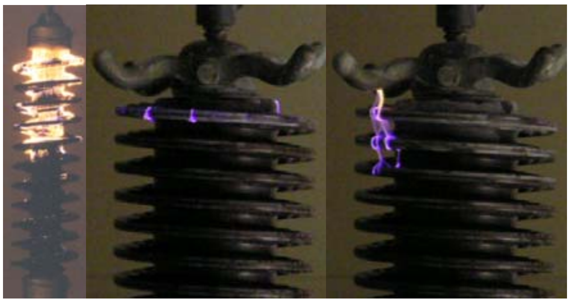


Fig. 9 Discharges on insulators with spiral sheds during flow on test. a – insulator LPS 75/11; b, c – insulator SSB 10054

6 Conclusions

The flashover voltage of insulators with spiral shaped sheds is usually lower than the flashover voltage of insulators with standard sheds

The spiral insulator performs inefficient due to formation of single discharges at the upper flange

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