Experience with Silicone Composite Insulators in the Tunnels of the BLS Lötschberg Railway

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1. What do you know about the BLS Lötschberg Railway?

The BLS Lötschberg Railway is a private company - the main shareholder is the Canton of Bern - which operates a small, standard gauge railway system. Technically and operationally, this system is fully integrated into the system of the Swiss Federal Railways SBB. The main line of the BLS Lötschberg Railway, the Lötschberg-Simplon line, forms the second transalpine railway of Switzerland, after the Gotthard line of the SBB. In the years 1979 to 1992 the BLS Lötschberg Railway was expanded to double track, and now has the same capacity as the Gotthard line.

As early as 1906 when work on the Lötschberg Railway was started, the programme decision was made to electrify the new railway line with single phase alternating current at a voltage of 15 kV and a frequency of 16 $^2/_3$ Hz. Since commencement of operations in 1913 trains on the BLS Lötschberg Railway have been driven by electricity.

The BLS Lötschberg Railway has a track length of 240 km. Of this over 40 km, or more than one sixth, is in tunnel.

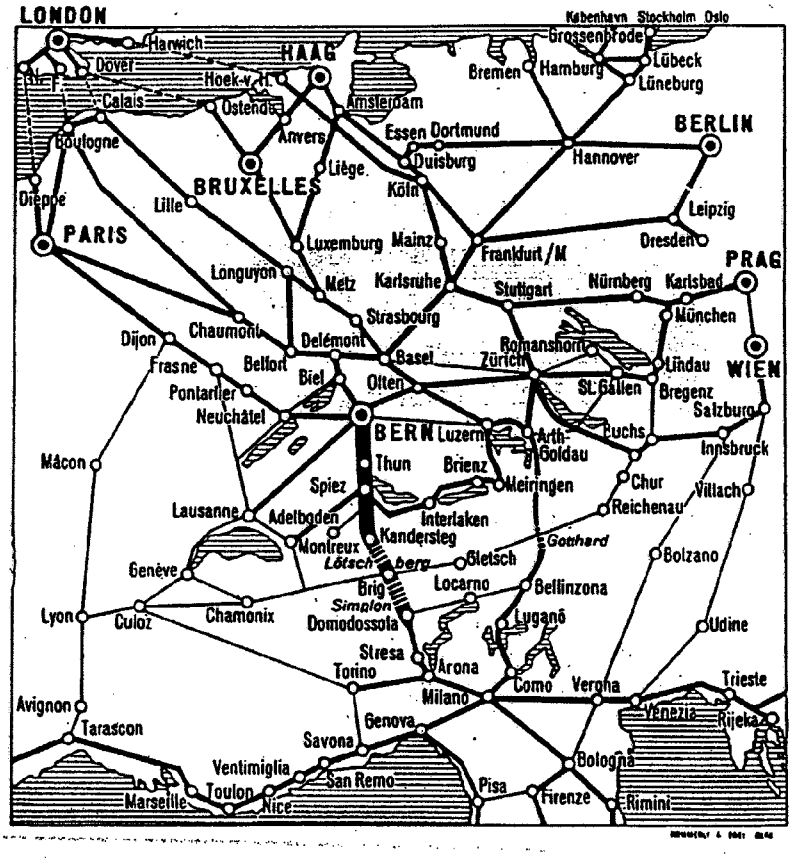
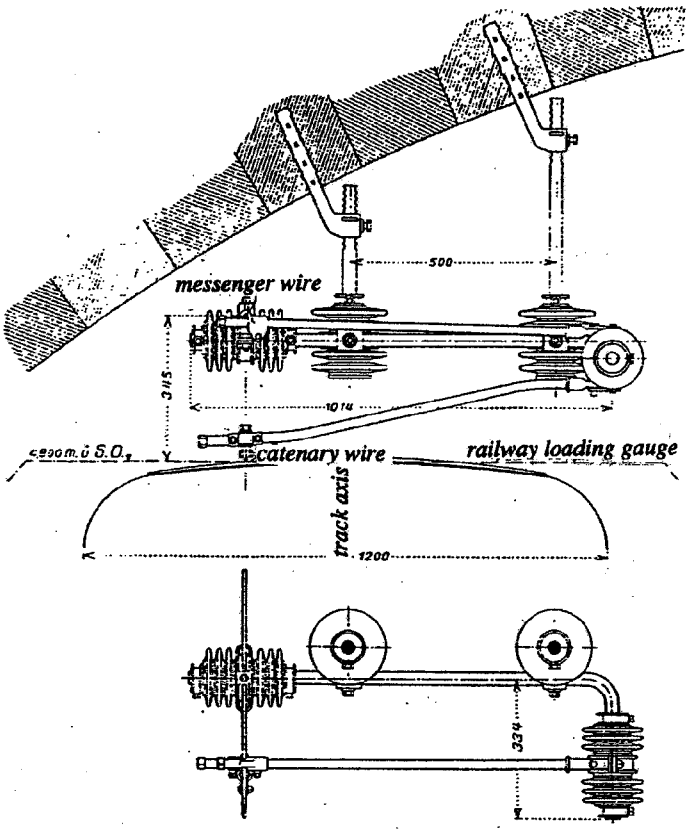


Figure 1: Location of the BLS Lötschberg Railway in Europe

2. The Catenary System of the BLS and its Electrical Insulation

The overhead catenary system of 1913 was equipped with double porcelain insulators, i.e. two insulators connected in series. The arrangement of the tunnel suspension structures can be seen in Figure 2. The total creepage distance of these insulators was only about 40 cm.



Especially in the tunnels, this creepage distance proved insufficient to guarantee the long-term dielectric strength of the catenary system. Due to the fact that brake dust combined with the high humidity led very quickly to an adhesive, relatively well-conducting contamination of the porcelain surface, the insulators had to be cleaned at regular intervals.

For decades this cleaning was carried out tediously by hand while increasing traffic on the line made the time between trains shorter and shorter. In the last few years the cleaning has been mechanized by means of a hot-water, high-pressure washing system. By using a silicone spray it was also possible to reduce the adherence of the contamination layer to the porcelain surface, thus making the cleaning process easier.

In order to avoid the risk of flash-overs, the cleaning had to be carried out annually, and in the entrance areas of the Lötschberg Tunnel even semi-annually. Over the years, several unsuccessful attempts were made to lengthen the cleaning interval. Each time the result was serious interruptions in service due to multiple occurrences of insulator flash-overs.

3. Technical and Economic Considerations in the Design of the New Catenary Conductor Insulators in the Tunnels of the BLS Lötschberg Railway

In connection with the doubling of the track of the BLS Lötschberg Railway at the end of the seventies, a new catenary system was developed [1]. For the catenary suspension structures in the tunnels components which had already been operating successfully with the Swiss Federal Railways SBB were selected. One of these was a porcelain solid core post insulator which was already in use in the Simplon tunnel. A short time later however, the company Dätwyler AG in Altdorf developed a silicone composite insulator having the same coupling lengths and endfittings. Table 1 shows the most important technical data of the two insulator types.

	SILCOSIL post insulator Sefag Art. SSRF 80/10-596	Porcelain insulator SBB Art. 377.00.07
Test voltage	according to IEC for 36 kV insulators	
Coupling length and endfittings	identical	
Max. bending amplitude at the insulator base (Nm)	2500	2500
Number of sheds	10	8
Creepage distance (mm)	1115	700
Weight (kg)	14	30

Table 1: Technical Data of Insulators for Tunnel Support Structures

The bad experiences with the unsatisfactory dielectric strength of the catenary system which, as described above, dated from the early beginning of the BLS Lötschberg Railway moved us to make every effort to insulate the new tunnel catenary in such a way that insulator washing would never again be necessary. For this reason, and as we had already had good experience with cable terminations using the same silicone technology, we gave Dätwyler AG cable works in Altdorf the incentive for the development of a silicone composite insulator. About 1989 this development was taken over by SEFAG AG in Malters, which manufactured the SILCOSIL insulator and incorporated further improvement in its design. In comparison with the porcelain insulator having the same coupling length and endfittings, we expected the following main advantages:

- The surface of silicone rubber in comparison with the surface of porcelain (and also of glass or epoxy resin) is more resistant to the build-up of layers of contamination. In addition, silicone rubber is in comparison with other materials much more hydrophobic. Silicone rubber is also very resistant to chemical and physical influences. The properties of the material silicone rubber are described in detail in [3] and [4].

- Silicone rubber is elastic without having to add softening agents. It can be cast into molds very well and adheres to other materials. These properties allow the engineer a great degree of freedom in the design of an insulator. That is why it was possible to construct the silicone composite insulator with two sheds more than the porcelain insulator and over 50% more creepage distance - and still maintain the same outer dimensions.

- Further advantages, which most importantly make installation much easier, are the impact strength and the 50% lower weight than the porcelain insulator.

In November 1979, at the same time as the development of the silicone composite insulator described above, a long-term test was started in the Lötschberg Tunnel with three 30 kV cable terminations each having two IXOSIL silicone rubber sealing ends made by Dätwyler AG in Altdorf. The significant dimensions of these sealing ends are equivalent to the dimensions of the SILCOSIL composite insulators described above.

More than 16 years later, one of the terminations is still in test service and is subjected to periodic measurements. The measurement results can be seen in Table 2:

Duration of test (years)	**Relative humidity (%)**	Test voltage ± 138 kV DC	**Leakage current (µA)**
2	95		300 - 450
4	100		300 - 430
6.5	90		500 - 650
8	78 - 86		200 - 240
14	80 - 96		250 - 430

Table 2: Long-term Test with Silicone Composite Insulators in the Lötschberg Tunnel; Measurement Results since the Start of Testing in November 1979

The following conclusions can be drawn from the test results:

- The insulating capacity of the test insulators is still sufficient with a large safety factor even after 14 years of operational service in the Lötschberg Tunnel. Their condition is practically the same as it was after 2 years of service. The scatter of the measured leakage current is determined largely by the humidity of the air. Higher humidity levels allow the leakage current to rise slightly.
- The hydrophobic properties of the surface and the elasticity of the material of the silicone composite insulators prevent a further build-up of the contamination layer.

These test results give us the confirmation that the expectations we have put in the silicone composite insulator have been fully met. We can be certain that our tunnel catenary supports which are fitted with this type of insulator will never again require any expenditure for insulator washing.

We are aware that these gratifying results also have their price, as silicone composite insulators of the type described are indeed somewhat more expensive to procure than the equivalent type in porcelain. But when we consider the savings in maintenance costs over the entire service life of the insulators, the additional initial investment for the silicone composite insulators is more than compensated.

In the course of the last fifteen years the BLS Lötschberg Railway has, with the exception of a few short tunnels, equipped the greater part of its over 40 km of tunnel trackage with silicone composite insulators. In our system there are currently some 4000 silicone composite insulators type IXOSIL made by Dätwyler AG, Altdorf, and the follow up-type SILCOSIL made by SEFAG AG, Malters in service. We have been able to do away with insulator washing completely.

The operational experience supports us in our decision to use the silicone composite insulator in the tunnels of the BLS Lötschberg Railway. Up to the present day we have not experienced a single outage in service due to an insulator fault - and as every operational breakdown which can be prevented enables unnecessary costs to be avoided, the economy of operation of our catenary systems is greatly improved.

Bibliography:

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[3] K.O. Papailiou: *Silikon in der Hochspannungstechnik,* Bulletin SEV/VSE 81(1990)15, pp. 33 - 37 (also available in English)

[4] K.O. Papailiou, Walter Fluri, Anton Wermelinger: *Erfahrung mit Einsatz von Verbund-Isolatoren,* Bulletin SEV/SVE 81(1990)19, pp. 11 - 18 (also available in English)

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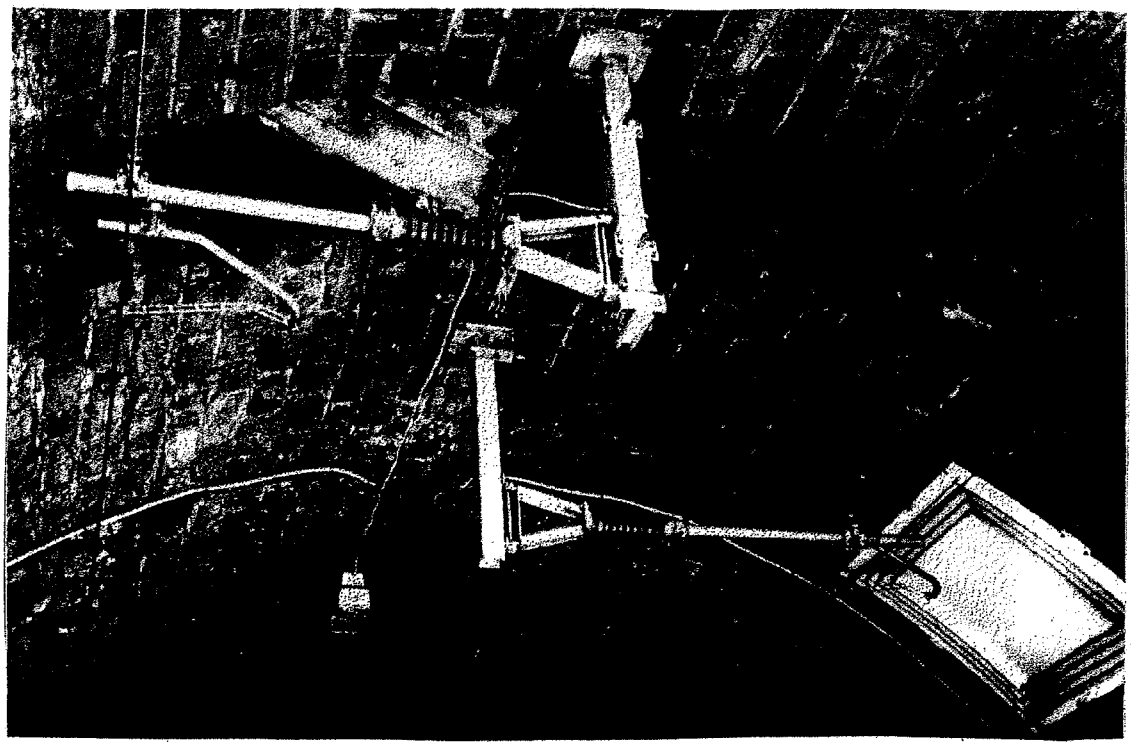

Figure 3 :
Tunnel catenary support structure with silicone composite insulators near the southern entrance of the Lötschberg Tunnel. Version for twin track tunnel. At the lower right of the picture the electrical insulation of the vaulted ceiling by means of a 10 mm thick polyethylene plate can be seen.

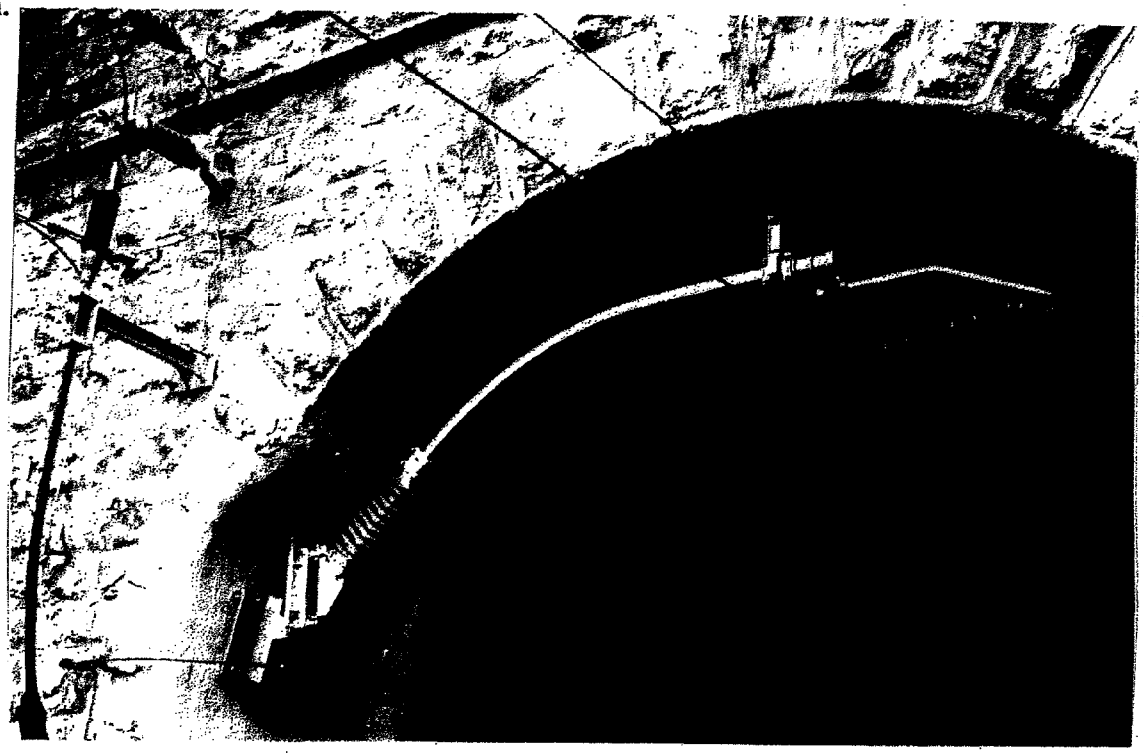

Figure 4:
Tunnel catenary support structure with silicone composite insulator in a single track tunnel of the BN Bern - Neuenburg line. At the extreme left a 30 kV silicone cable sealing end can be seen.

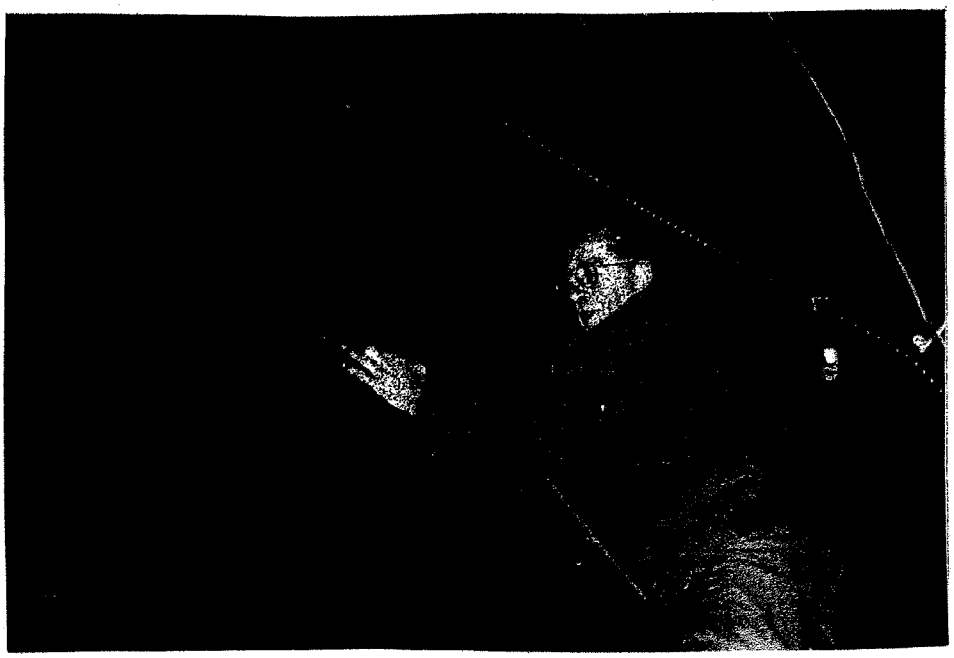

Figure 5:
30 kV cable section fitted at both ends with silicone cable sealing ends type IXOSIL made by Dätwyler AG, Altdorf. This cable termination has been suspended in the Lötschberg Tunnel at tunnel-km 0.4 since November 1979. It is in continuous service at a voltage of 15 kV/16 $^{2}/_{3}$ Hz. The picture was taken at the last inspection on 13th December 1993, that is after more than 14 years under test. The insulator had never been cleaned. In spite of this, the contamination layer does not adhere to the silicone and can be wiped off easily with a finger.

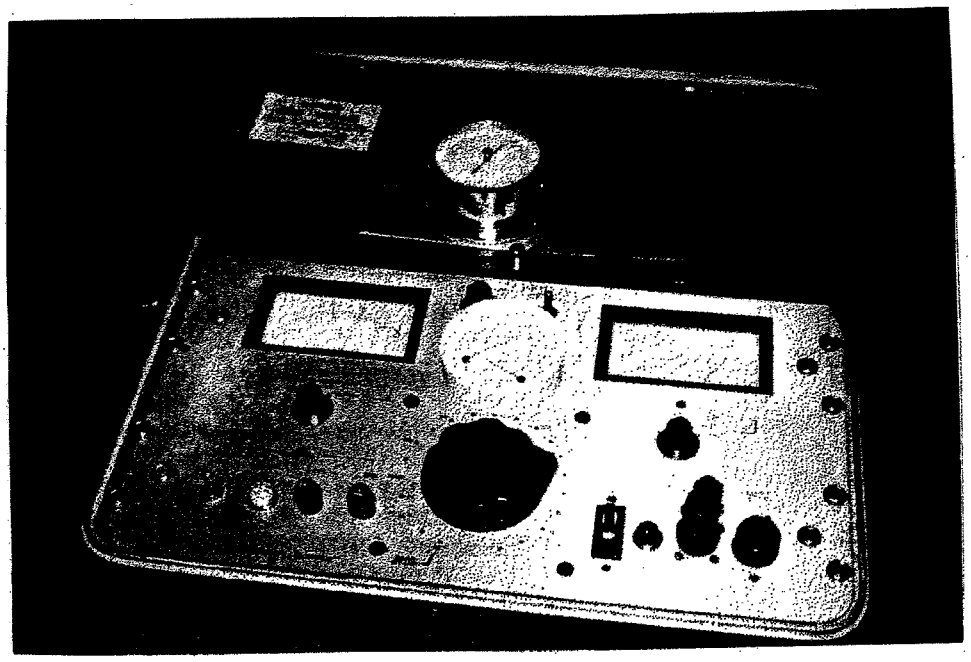

Figure 6:
DC voltage generator control panel of the mobile high voltage testing equipment of Dätwyler AG. The meters for the voltage and leakage current as well as for air pressure, relative humidity and temperature can be seen.