

Composite Insulators are Gaining Ground

Applications of silicone composite insulators in Switzerland

■ Dr. Konstantin O. Papailiou

This paper presents the newest applications of silicone composite insulators which are finding increasing use not only in Switzerland, but also in the power industry worldwide. These applications include interesting designs for railway overhead lines, medium voltage lines, and 400 kV high voltage overhead transmission lines. Moreover, solutions are presented for high-voltage outdoor equipment, which have recently been conceived and manufactured with housings made of Silicone hollow core composite insulators.

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The concept of the composite insulator was actually developed in the USA around 1948. This technology was not really taken seriously until the seventies, when great advances were achieved in fibreglass-reinforced materials, which form the load-bearing core of the composite insulators and in the polymers of which the weathershed are made. The superior insulation behaviour of the silicone in the presence of pollution [1] and the insensitivity of the composite insulators to breakage when subjected to impact loads during operation, have made a particular contribution to the wide acceptance composite insulators have gained. It was these factors that enabled the initial hesitance of many users to be rapidly overcome.

As far as can be reconstructed, the first composite insulators manufactured in Switzerland were hollow core insulators with a silicone weathershed and were used as housings for cable terminations. A short time later these were followed by solid core composite insulators based on the same concept, which were used as line post insulators in the newly-developed catenary support structures in the Lötschberg railway tunnel. It wasn't long until further applications

appeared. Some of these were, for example, long-rod composite insulators for overhead lines up to the highest voltage levels and interphase spacers, primarily on medium voltage lines. Hollow core insulators for current and voltage transformers as well as for bushings and test capacitors were also realized in this period, albeit in modest quantities. At the beginning of the nineties the composite insulator industry experienced a "quantum leap". Positive long-term service experience, well supported and widely distributed research results, well-founded standardization efforts, a favourable trend in the material prices, but also the closing down of local facilities for the production of porcelain insulators were the main contributors to this development. These events led to the fact that today in this area, there are two innovative, upcoming and now internationally successful companies in Switzerland which are making considerable investments in order to be able to continue to play a future major role in a composite insulator industry which is experiencing a strong growth world-wide.

Composite Insulators in Catenary Systems

As already mentioned, one of the first applications of silicone composite insulators from Swiss production was their use

Address of the author:
Dr. Konstantin O. Papailiou, Sefag AG
Werkstrasse 7, 6102 Malters

in the catenary support structures of the BLS (Bern-Lötschberg-Simplon Railway) [2]. The BLS operates one of the two cross-Alps railways in Switzerland, the Lötschberg-Simplon line. As early as 1979, and notwithstanding the fact that the catenary system itself was a new design [3], the courageous decision was made to use silicone composite insulators in the project to double the track through the Lötschberg railway tunnel. The goal was to avoid the complicated and costly cleaning of the porcelain post insulators which had been used up till then, a procedure which had to be carried out annually inside the tunnel and even semiannually in the entrance areas. Due to the fact that the silicone composite insulator had been designed to have the same connecting dimensions as the otherwise-used porcelain insulator, the other existing, proven components of the tunnel catenary support structure were able to be used without any problem (Fig. 1).

The thoroughly positive service experience confirms the correctness of the decision to use silicone composite insulators in all the tunnels of the BLS. A large part of the 40 km of tunnels has now been fitted with this type of insulator. Although insulator washing has been completely stopped, not a single one of the 4000 silicone composite insulators has caused a fault.

Composite Insulators as Interphase Spacers

Interphase spacers are fitted mainly at the points on overhead lines at which, either for reasons of design or due to external influences, there is a danger that the required distance between the conduc-

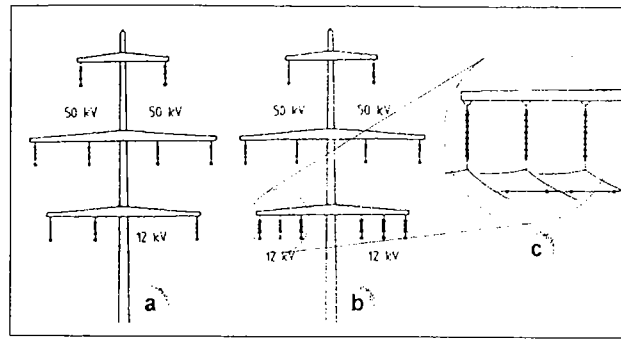


Figure 2: Silicone composite insulators as interphase spacers

- a Medium voltage line without interphase spacers
- b,c Compact medium voltage line with interphase spacers

tors of two phases will not be maintained, a situation which would lead to a short-circuit and hence an interruption in service. As early as 1990, a CIGRE questionnaire [4] brought to light that around the world, 32 power utilities had around 13000 interphase spacers in operation at practically all voltage levels. Some of them had been in active service for many years (up to 20 years at the time of the questionnaire). Almost a third of the interphase spacers registered in the above report are installed in Switzerland in the application as shown in Figure 2.

As in any industrialized country in Switzerland too, it is becoming increasingly difficult to obtain rights of way for routes for new lines. A possible solution to reduce the seriousness of this problem is to increase the power transmission capacity of existing lines, such as by installing a second circuit. In the case in question the crossarms of the concrete poles were originally designed to guarantee the required air clearance between the conductors at mid-span for one 12 kV circuit (Fig. 2, a). So appropriate interphase spacers made of silicone composite insulators were designed, and installed between the conductors at approximately

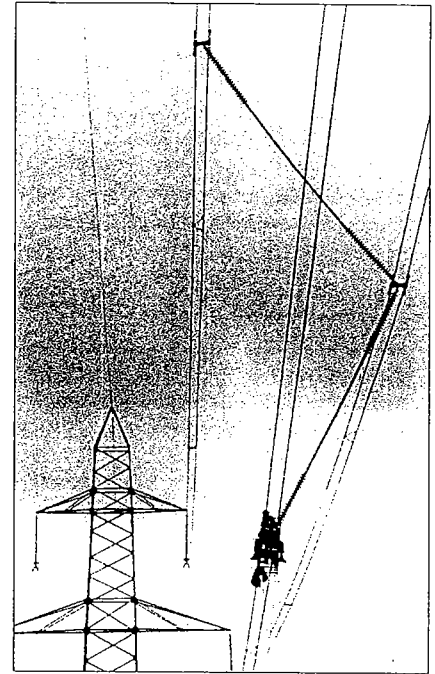


Figure 3: Fitting 400 kV interphase spacers on the Vorab line

40 m intervals in order to maintain the required conductor separation (Fig. 2, c), thus allowing a configuration as shown in Figure 2, b. This solution was only possible using silicone composite insulators, which are very light compared with porcelain insulators and thus do not add severe bending stresses upon the conductors during dynamic loads (ice shedding, short circuit). [5].

Interphase Spacers Prevent Conductor Galloping on a 400 kV Line

The highest-elevation 400 kV line in Europe is located in Switzerland on the Vorab glacier. Because of the extraordinary climatic conditions prevailing there, conductor galloping set off by shedding ice has regularly been the cause of service failures on one section of this line during the winter months (short circuits

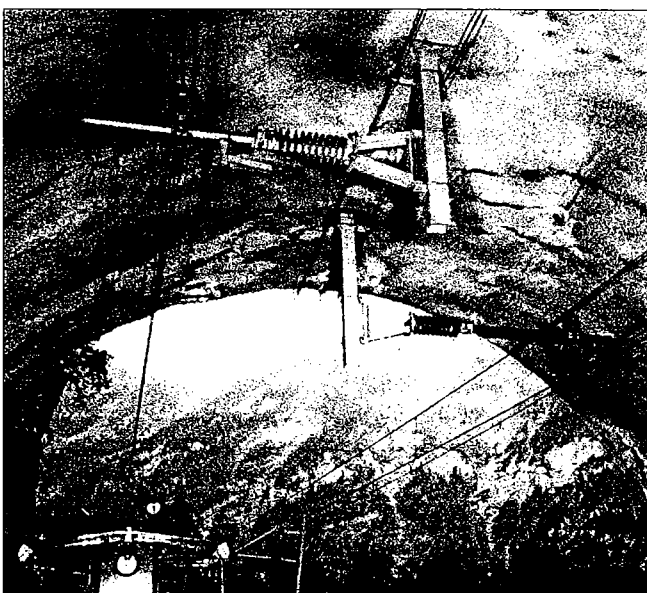


Figure 1: Tunnel catenary support structure with silicone composite insulators

Photograph taken near the southern entrance of the Lötschberg Tunnel

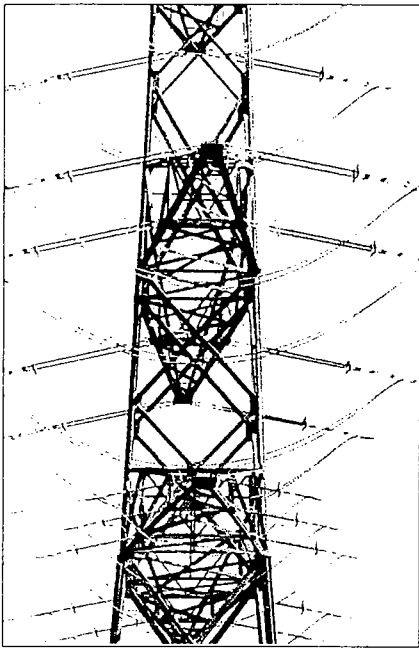


Figure 4: Silicone composite insulators on 400 kV line

as well as conductor damage due to twisting and clashing together of the conductors). Due to the ruggedness of the terrain, repair of these failures has only been possible with extreme efforts of the maintenance crews. For this reason it was decided to install interphase spacers in this section which are capable of maintaining the required phase geometry even in the presence of extremely dynamic stresses. For the following reasons, only composite insulators came into consideration in the solution of this complex problem: their relatively light weight does not place an undue load on the conductors and their elasticity is able to cope with the high displacements without any trouble (computer simulations have confirmed eyewitness reports that earlier, sudden ice drops caused conductors to jump up to 20 m vertically). Figure 3 shows the installation of interphase spacers at the specific span of the Vorab line, which had been selected on the basis of its extreme galloping conditions.

The individual interphase spacers which are fitted between two conductors are about 10 to 12 m long and, including the special hardware which allows longitudinal displacement and twisting of the conductors, weigh about 100 kg. They each consist of four or five silicone composite insulators having a shank diameter of about 80 mm. In the meantime, the interphase spacers have been in operation for some five years without a single fault occurring in the section earlier regarded as highly damage prone.

400 kV Lines with Composite Insulators and Environmentally Friendly Tower Configuration

Environmental demands on high-voltage transmission lines have increased constantly in recent years both in qualitative and quantitative respects. For example, today it is of prime importance when planning an overhead line to pay attention to the achievement of a pleasing and environmentally tolerable tower configuration. A large power company in Western Switzerland has reached this goal in an exemplary manner with its new 400 kV lines. In this case the wide use of silicone composite insulators brought positive results (Fig. 4). The composite insulator with a connection length of 3.0 m can be manufactured in a single piece and is almost 1.5 m shorter than the previously used porcelain insulator strings, each with three long rod insulators type LG 85/22/1470.

Figure 5 shows graphically the positive effect on the tower construction because of the shorter length of the suspension insulators. Shorter insulators allow the use of shorter crossarms without the risk of flashover due to reduced clearances to the tower as a result of the swinging of the conductors. This has the further effect of reducing the torsional loads in the cross-

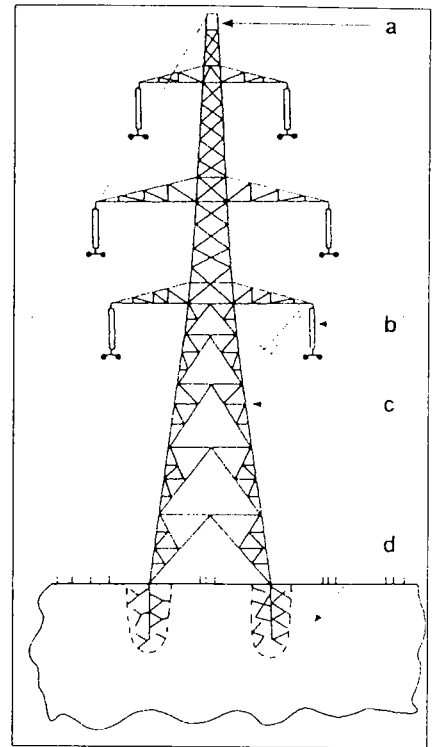


Figure 5: Influence of insulator length on the tower design

- a shorter earth wire peak
- b shorter crossarms, thus lower torsional stresses
- c lower loads, hence less steel and more pleasing appearance
- d reduced bending and torsion moments allow smaller foundations

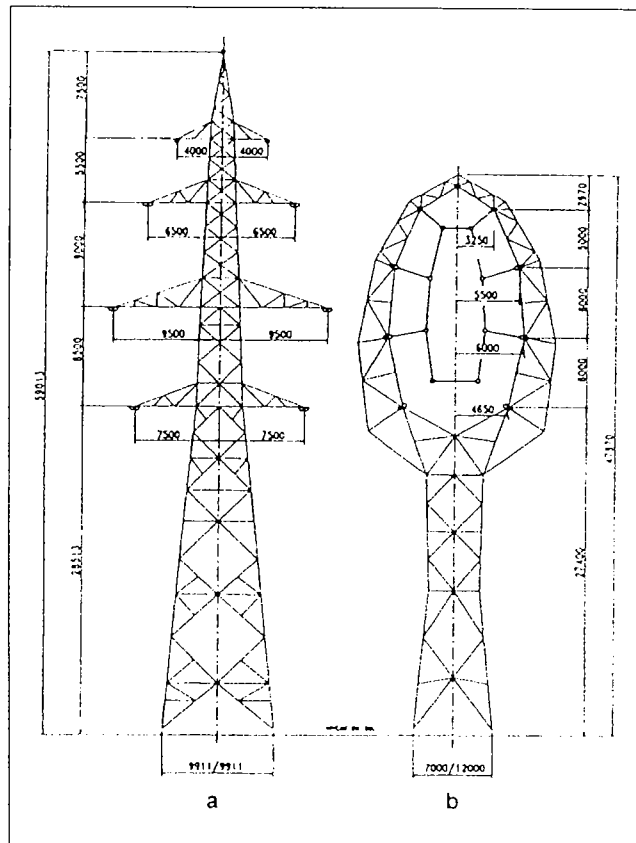


Figure 6: Size comparison of tennis racket tower and conventional tension tower



Figure 7: Is it going to be a direct hit?

arms and on the whole tower, which permits a lighter construction with a more pleasing appearance, and lower costs.

Tennis Racket Tower with Composite Insulators

In the planning of the 400 kV line in Western Switzerland described above it was of absolute importance to conceive a design with a minimum space requirement and minimum right-of-way width. This led to the development of the so-called tennis racket tower (pylône raquette) [6]. For weight considerations, the realization of the tower top was only possible using silicone composite insulators. By fitting composite insulators under tension between the conductors at the tower top, the distances between conductor and tower are able to be kept constant. The tennis racket tower is 19% shorter and 10% lighter than a comparable conventional

tower. It requires a 37% narrower way-leave, which translates into 50% lower right-of-way costs (Fig. 6).

Composite Insulators are a "Hit" on the Golf Course!

One of the questions posed in a Cigré questionnaire on the utilization of composite insulators world-wide [7] asked about reasons for giving this type of insulator preference over proven conventional insulators made of glass or porcelain. Interestingly, at that time about 20% of users, particularly from the United States, had chosen composite insulators because of their resilience against bullet shots and vandalism. The problem of shots has recently become more pronounced in Switzerland as well, whereby here the projectiles tend more to be golf balls which have been "shot" past the hole! In one instance near a golf course in the Zurich area, the porcelain insulators previously used have been replaced by composite insulators because from time to time they had fallen victim to the golfers (Fig. 7).

Composite Insulators in Outdoor Substations

Switchyards are the nerve centres of every power grid and so the users' expect and demand a correspondingly high degree of operational safety. It is therefore not surprising that with the growing faith in composite insulators - particularly due to the good experience made in their application in overhead lines world-wide - great interest has developed in recent years in their application in outdoor substations. Today, if the

customer so desires, it is possible to design complete substations in silicone composite technology (Fig. 8).

Bus Bar Post Insulators

An important application of composite insulators in outdoor substations is their use as post insulators for tubular bus bars. Figure 9 shows a 123 kV line post insulator in composite technology which has been in service for about five years. These post insulators have a fibreglass reinforced solid core with a diameter of 76 mm. This gives it a breaking strength of 8 kN for an overall height of 1150 mm. The primary reason for its application was that porcelain insulators having the same dimensions had experienced problems in the cementing of the base fittings [8]. In the meantime it has become

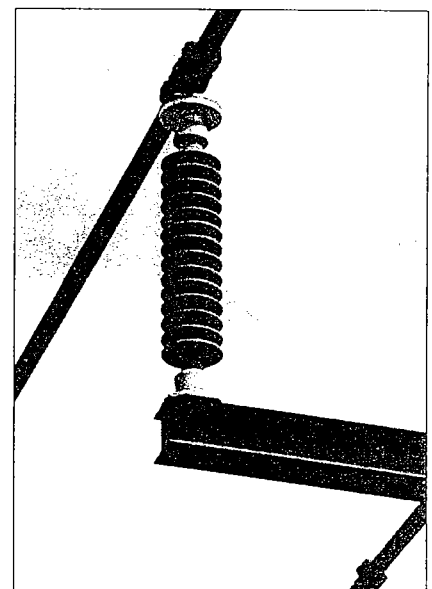


Figure 9: Post insulator for tubular bus bars (123 kV)

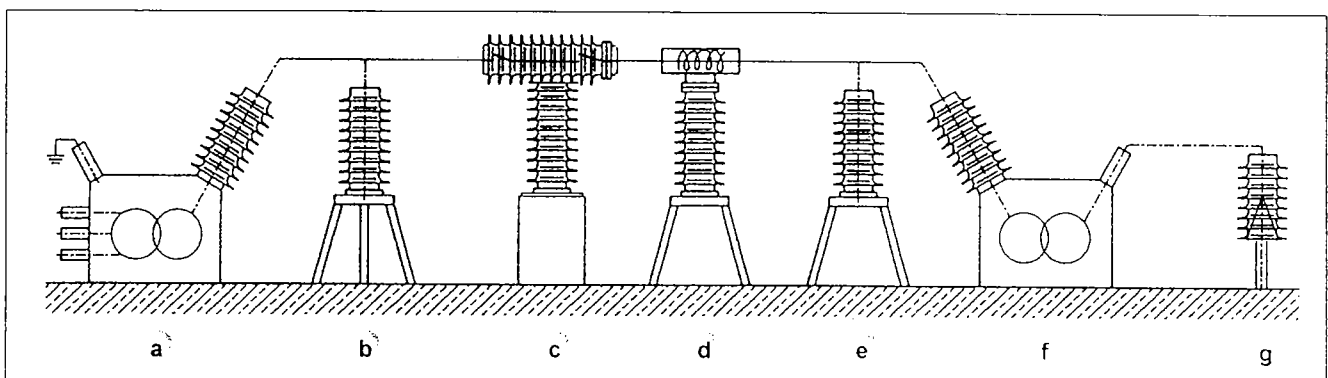


Figure 8: Possible locations in an outdoor substation where composite insulators can be used

- | | | | |
|---|---|---|--|
| a | voltage-controlled bushings for transformer (36/420 kV) | e | voltage transformer |
| b | surge arrester | f | voltage-controlled bushings for power transformer (420/170 kV) |
| c | live-tank circuit-breaker | g | cable termination (170 kV) |
| d | current transformer | | |

possible to manufacture single-piece composite post insulators also for voltages up to 400 kV and this will certainly result in new applications in this area.

Bushings

Increasingly, the design of high-voltage bushings is being influenced by higher demands on operational safety, damage-risk minimisation (to persons and property) and not least, by a greatly increased public environmental consciousness. The consideration of these factors led to a new conception of these important components on the basis of composite technology. By using superior materials, as well as having their manufacture well under control, it has been possible to satisfy the above-mentioned demands on the bushings. Fig. 10 shows 420 kV and 220 kV transformer bushings and Fig. 11 shows GIS Bushings for 123 kV in composite technology.

Surge Arresters

For the obvious reason of the danger of explosion due to overloading, surge arresters were one of the first electrical devices that were built with silicone insulator sheds. The advances in ZnO technology in arrester design, which replaced the spark-gap arrest-

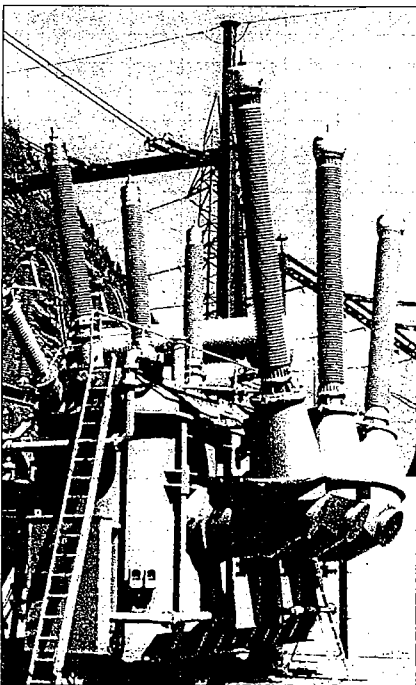


Figure 10: Composite insulator bushings on a 420/220 kV power transformer

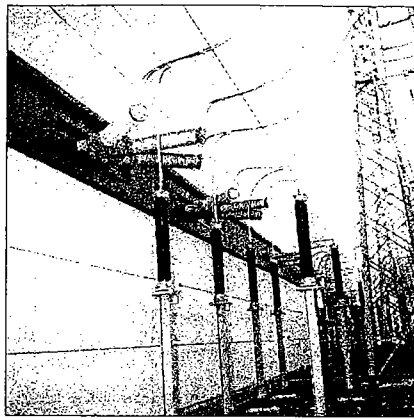


Figure 11: GIS bushings (123 kV)

ers, eased the realization of porcelain-free arresters. Today, ZnO arresters are manufactured either by applying the silicone sheds directly onto the active part, which is sometimes done for voltage levels up to 36 kV [9], or by using a fibreglass reinforced, silicone coated composite tube as an insulating housing for the arrester, which is possible up to the highest system voltages (Fig. 12).

Outdoor Terminations for Solid-Insulated Cable

The many users and supporters of high voltage cable with extruded, solid insulation were soon calling for terminations properly suited to the properties and possibilities of this type of cable. Push-on silicone terminations were developed in Switzerland as early as 1974 and were used with success at home and abroad (Fig. 13). Outdoor terminations with silicone insulation exhibit a high thermal stability and resistance against ozone, corona discharges, ionizing radiation, dampness, the effect of flame, industrial contamination, contamination in railway tunnels and near roadways with heavy traffic as well as the mechanical stresses which can occur in high-alpine and earthquake-prone areas. This gives them the qualities of low maintenance, operational safety and a high lifetime.

Current and Voltage Transformers

For a few years now, hollow composite insulators have been finding use as housings for the outdoor versions of current and voltage transformers (Fig. 14), and this in locations which put particular demands on the mechanical strength and elasticity of the device's case, such as when there is a risk of

explosion or where high mechanical stresses like earthquake, vandalism or high short-circuit forces are likely. Rare faults leading to a CT or VT explosion and hence causing considerable risk of injury or damage to persons and property [8] have in Switzerland recently led to an increase in the application of CT's and VT's using composite technology.

High Voltage Switches with Composite Insulators

For the various reasons already mentioned above there is also an increase in the use of hollow composite insulators in high voltage circuit breakers, including their associated control capacitors, and also recently in high voltage load disconnecting switches (Fig. 15). The possibility of fitting an optical fibre cable into the composite tube for the transmission of measuring and control signals, particularly in circuit breakers, is regarded as an additional advantage.

State of Standardization

In an earlier summary paper on experience with composite insulators [10], attention was already drawn to the efforts which are being undertaken under the auspices of international organizations (Cigré, IEC) to develop recommendations and standards for compos-

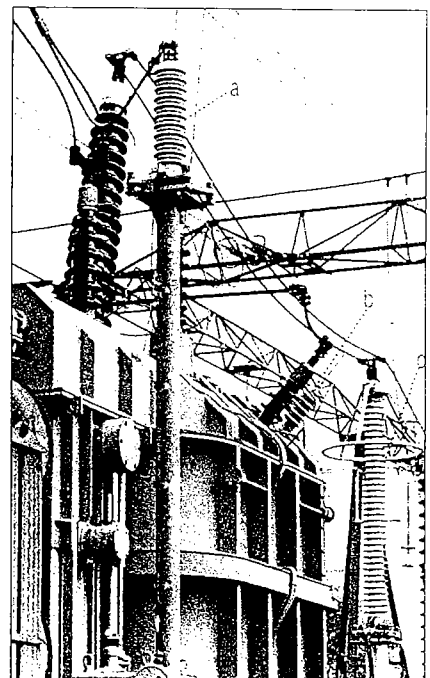


Figure 12: Transformer protection by means of arresters with silicone-sheds
a 44 kV arrester, b 24 kV arrester, c 170 kV arrester

