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Subject:

Characteristics And Service Attention Of SF6* Gas When Used In Electrical Switchgear

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ABSTRACT:

The use of SF6 in switchgear is increasing. This paper examines questions of quality of the gas used, methods of handling and means of testing.

*To facilitate composition, the standard chemical symbol for sulphur hexafluoride, which should be written SF_6 not SF6, is disregarded except in chemical formulas or other substances.

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introduction

Electrical equipments employing SF6 as an insolutor and as an arc extinction fluid are becoming increasingly widespread on the market. Not only do they exploit the oustanding properties of this gas, but they benefit also from the great improvements made over recent years in the quality of the work carried out by manufacturing and control departments. This progress has led to the almost universal appearance of:

- intensive mechanical endurance tests : strength test concern at least 10,000 operations,
- climatic behavior tests to verify behavior in cold, hot and humid climates,
- electrical endurance tests of contacts, by repeated breaks of various currents representing the service life of the unit.

The behavior of a unit also depends on the manner in which its insulation age. The following discussion describes the methods employed during manufacture to ensure that the gas keeps its essential properties during operation with the least possible maintenance.

insulation quality

As for a solid, the insulation provided by a gas depends both on its quality and on its quantity.
In a circuit-breaker in service, the quality of a gas results from two factors :

- the purity of the filling gas,
- the alteration of its composition caused by the electrical arc at the moment of breaking of short-circuit currents.

At the filling stage, CEI and ASTM standards specify the maximum allowable limits for certain impurities.
For example :

- air : 500 ppm by weight,
- moisture : 15 ppm by weight.

In effect, moisture is highly destructive to the rigidity property of any insulator, and its continuous elimination implies :

- the installation of expansion and drying devices for the compressed air of air blast circuit-breakers,
- periodic treatment of the circuit-breaker oil.

For equipment insulated with SF6, moisture is harmful from several standpoints :

- condensation during temperature drops, sharply reducing dielectric capacity,
- decomposition of the gas by the electric arc, generating corrosive products for a wide range of materials.

The moisture content can be measured before filling and after sampling of each compartment by chromatography (see " SF6, physical and chemical properties " by André Fihman).
Nevertheless, filling with a gas, however dry and pure it may be, can only lead to perfect insulation conditions if care is taken to eliminate the impurities contained in the enclosure to be filled. This is done by creating a vacuum within this enclosure, ranging from 10^{-2} to 10^{-1} torr. This range is generally adequate as shown by the following example.
Consider a unit designed for operation under 3 bars pressure, in which the residual quantity of air under 10^{-1} torr vacuum is 6 ppm (weight). Assuming that this air is saturated with moisture at 20° C, the moisture concentration will be 0.06 ppm (assuming that no water is present in the liquid phase).

However, another phenomenon must be taken into consideration : desorption of materials employed. Every material is susceptible to penetration by gases which surround it in the natural state (air and moisture) ; plunged in another medium (e.g. SF6), the accumulated gases are liberated.
Tests have been carried out in order to compare the effectiveness and the ease of implementation of different drying processes : duration and level of preliminary vacuum, temperature of materials, flushing with very dry gases, use of various adsorbents such as molecular sieves, activated alumina etc. The latter method has proved especially valuable in view of its adsorption capacity, not only for moisture but also for gases produced by repeated breaks of heavy currents. This property means that the initial high purity of the gas can be maintained and that therefore the quality of the insulation is not affected ; a long life-time can thus be assured.
It should be noted, however, that these precautions need to be observed only at the moment of filling, in other words, mainly in the assembly plant.

effect on the human organism

Newly delivered, SF6 is a neutral gas and has the same effect on humans as nitrogen or CO2. Being five times heavier than air, it concentrates in the lower parts of the premises. It is nevertheless necessary to avoid smoking or using an electric (or gas) heater, because at these temperatures SF6 can give by-products which react on the organism.
In certain rare cases, it may be necessary to dismantle a circuit-breaker chamber on the site. Despite the presence of adsorbents, the compartments may contain gases or powders, produced by repeated arcs, which must not be inhaled or touched.

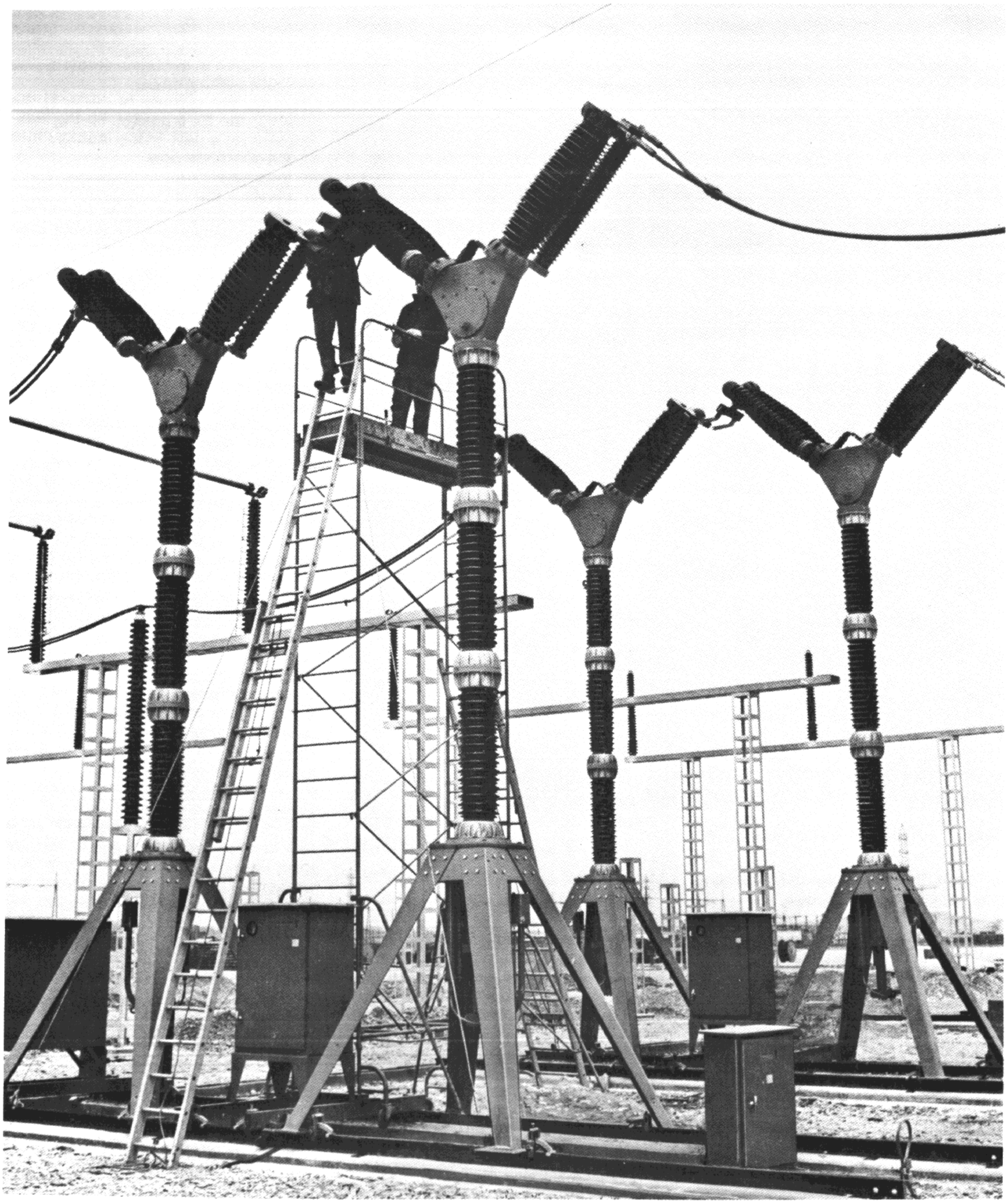

Figure 3 - Circuit-breaker FA4 420 kV

Figure 2 - Circuit-breaker FB 24 kV

For each different type of equipment it is necessary to choose the most suitable method of examination.

At high voltage (figure 2) the equipment consists of compartments completely assembled and pressurized in the plant. The use of cast housings enables a reduction of the number of openings to the strict minimum (bushings, operating components, filling and assembly openings). Their small size and moderate weight facilitate handling and transportation to premises with an SF6 - free atmosphere, enabling accurate determination of leaktightness.

Finally, the small volume of the enclosures enables compensation of part of the leaks by diffusion of the gas stored in the adsorbents.

The technology and the precautions taken during assembly of the units have made it possible to give leaktightness guarantees with a safety factor greater than 10.

At very high voltage, the large volumes involved give rise to an increased number of parts and of assembly operations. On the other hand, an identical amount of gas lost gives rise to a far lower pressure drop than in the case of medium voltage equipment. Furthermore, it is almost always necessary to execute part of the assembly on the site (figure 3).

The total allowable leakage rate is made up of different elements in this case.

Example of a pole of an FA2 circuit-breaker.

This pole includes approximately as many gaskets as parts forming the leaktight compartment.

Let N be the number of parts, Fj the leakage rate for a gasket, Fp the leakage rate for a part, Ft the leakage rate for the complete pole :

we thus have :

$Ft = N (Fj + Fp)$

Since it is more difficult to obtain the same leaktightness for a gasket than for a part, we require :

$Fp = Fj/10 \therefore Fj \approx Ft/N$

This leads to the requirement of 10^{-5} atm. cm^3/sec per gasket and 10^{-6} atm. cm^3/sec per part. Although the probability of leakage is related to the length of the gasket, this method gives valid results which have the advantage of being easy to obtain.

By subdividing the allowable leakage rate, one eliminates the possibility of compensating the excessive leak of a joint by greater leaktightness of the remaining parts of the equipment. This is why the safety factor for this type of equipment has been taken as 3. In fact, 95 % of leaks at gaskets are less than 10^{-6} atm. cm^3/sec. Note that this value is the result of special surveillance concerning the state of the bearing surfaces of the gaskets and of the appearance of the latter.

The use of double gasket with an intermediate tap makes it possible : (fig. 4) :

- to collect of the leaks of the inner gasket for measurement of its tightness (a particularly practical method for tests after on-site assembly),
- to protect of the inner joint from external contamination.

The individual leaktightness of each part is checked by a helium test for solid parts, or by the ammonia test for welded parts. At the junctions, the leaks are measured by a halogen detector.

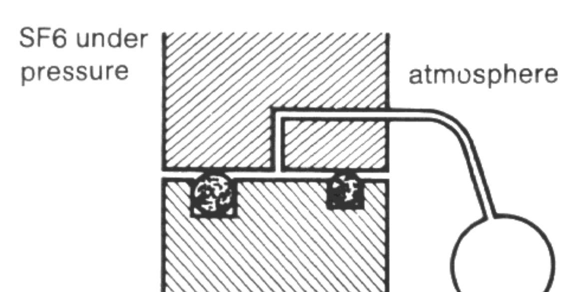

Figure 4 - Double gasket principle

The gases have nevertheless an unpleasant odor and are easy to detect long before their concentration reaches a dangerous threshold.

insulation quantity

The dielectric properties of SF6 (insulation and break) depend on the amount of gas contained in the given enclosure. A drop in pressure (at constant volume) may have two causes :
- temperature,
- leaks.

temperature

Temperature variations change the pressure of the gas but not its density, and hence have not effect on its properties. Consequently, for an observation to be meaningful, it is important to take temperature readings when making pressure measurements (figure 1). Moreover, since the action of adsorbents is variable with temperature, they can cause a sudden drop in pressure ; this means that it is necessary to limit the amount placed in each compartment.

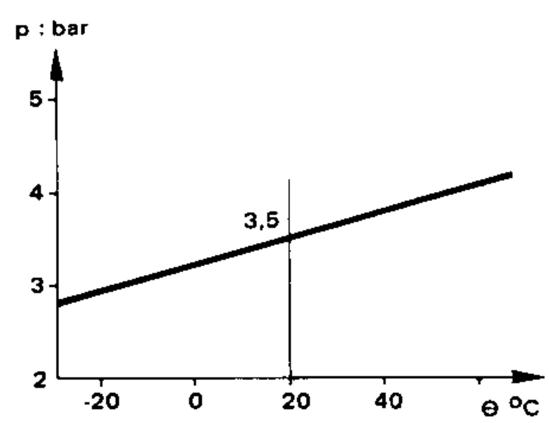

Figure 1 - Variation of pressure with temperature

leaks

Every enclosure is subject to leaks because absolute leaktightness cannot be attained. It is therefore necessary to define, independently of the cost criterion, a maximum allowable leakage rate which may be :

■ the annual loss of gas with respect to its initial weight,

■ the time elapsed between two successive injections of gas necessary for the unit to return to its original state.

This value must be subjected to a safety factor to take account of :
- measurement inaccuracies, since, despite the use of sophisticated methods and the presence of skilled personnel, one cannot hope under industrial conditions for accuracy better than ± 50 % of absolute values,
- the extrapolation of results obtained in a few hours, over several years during which moreover the leakage rate may be changing

The presence of the gas should not be assimilated to a leakage. A leak may not necessarily give rise to an accumulation of gas, owing to certain factors such as ventilation. Conversely, it is possible to detect the presence of a constant quantity of gas at a non-ventilated point without the occurrence of a leak. (Detectors are sensitive to the concentration of the gas and not its flow rate).

Hence it is necessary to measure and then to locate the possible leaks.

The main means for detecting leakages are the following :

■ pressure drop, if large leaks and small volumes are involved,

■ soapy water, for large leaks,

■ ammonia gas tests with alkali-sensitive paint,

■ helium tests, with mass spectrography,

■ tests with SF6 or freon, using halogen detectors.

The most widely used unit for leak measurements is the atmosphere - cm^3/sec. This is a flow of 1 cm^3 of gas at atmospheric pressure during one second. In fact, this unit is relatively large and one uses negative powers of 10 to assess the relative size of a leak

Apart from the relatively sophisticated unit employed for measurements in the plant, it is possible to use a small portable instrument whose sensitivity, while lower, is still adequate for on site inspection (figure 5).
EHV equipment is always equipped with a system insensitive to temperature variations, designed for remote 2 levels indication of density drop.

The principle of using a continuous complementary supply of gas from a high-pressure neighbouring reservoir, through a pressure regulator, has not been retained because, on top of the permanent risk of misadjustement of this accessory, this solution would only have displaced the problem of the maintenance operations.
To conclude these observations concerning sealing problems, it should be noted that other categories of equipment are also subjected to constraints of this nature :

- compressed air circuit-breakers necessarily require valve seals,
- the oil in reduced oil volume circuit-breakers can sweat without this being easily detectable at a distance,
- the use of vacuum poses problems different from those of SF6, but just as complex, and industrial realizations do not appear to have yet reached the performance levels necessary for EHV.

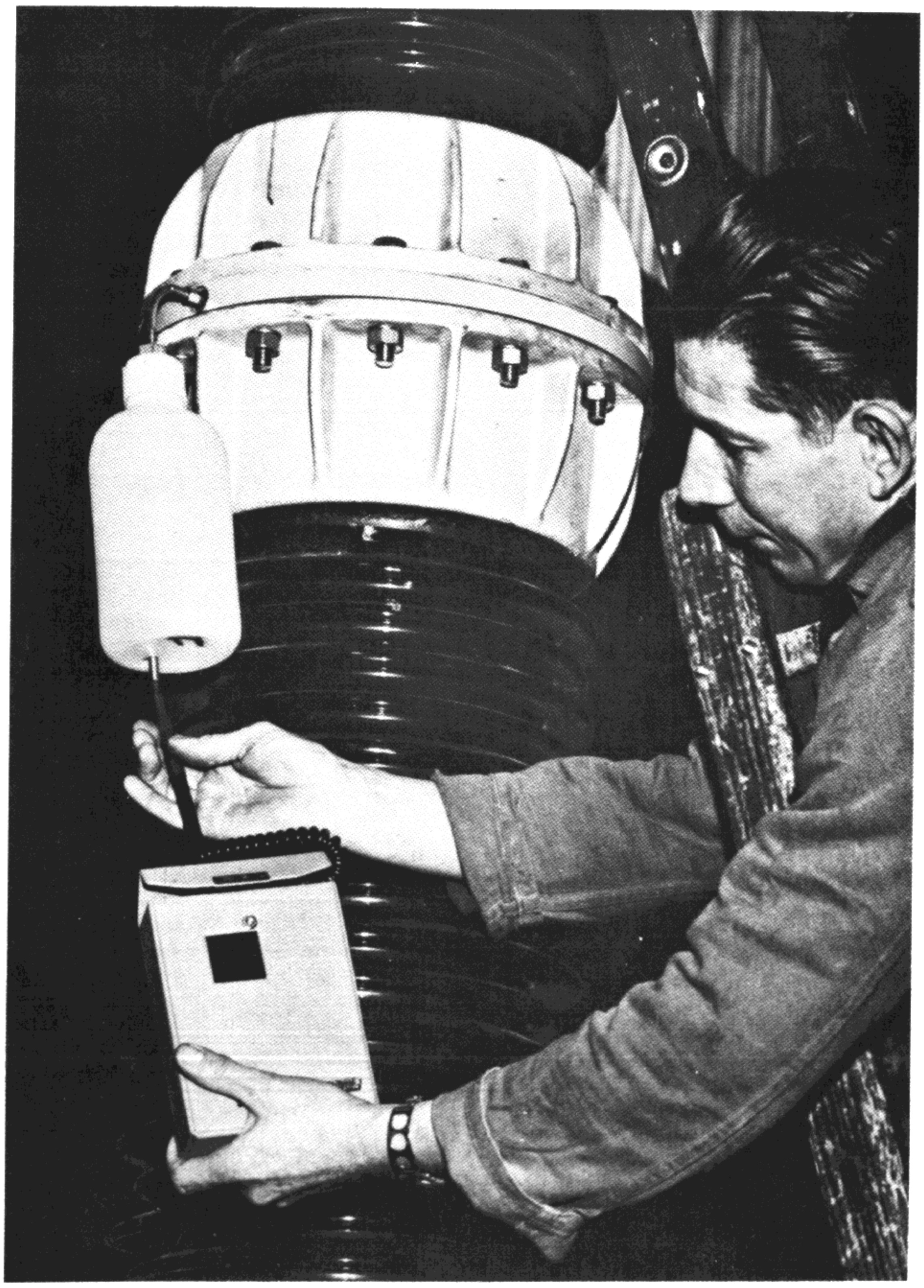

Figure 5 - Use of a portable detector

conclusions

The first units employing SF6 have now seen ten years of service during which the principles and methods of implementation have become increasingly well understood. However, their use in a grid implies various constraints which can only be examined separately in accelerated plant tests. Thus only time can tell to what degree the dependability of electrical switchgear has been improved by these measures.

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