Detecting Equipments of Salt Contamination of High-Voltage Insulators

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1. Introduction

The paper discusses the performance and characteristics of the detecting equipments of high voltage insulators.

Because of the special geographical condition of our country, many of large capacity steam-plants and their substations are located near the seaside. The design of out-door high-voltage insulator must be proof against contamination with the salt of fly-ash together with some acid-reacting substance deposited on the surface of the insulator.

The well known practical methods to guarantee the insulators from various contamination above mentioned, are as follows;

(i) Over insulation (ii) periodic hand-wiping (iii) periodic washing at energized and deenergized condition (V) dry cleaning (Vi) silicon coating

In this paper, we will discuss only (iii) (Vi), since these methods are mostly used at the ultra-high voltage substations and lines in our country. The portable-washing facilities of insulators are often used at some transmission and distribution lines, and the dry cleaning method of the energized insulator is used only at the lower class of line-voltage.

If the particles of sodium-chloride are deposited on the insulator, a conducting surface film is formed by existence of the moisture, and surface leakage current of the insulator increases remarkably.

The measurement of leakage-current characteristic or the detection of the effective quantity of the above electrolytic material are important to determine a period or frequency of insulator washing.

According to the paper by Mr, J, S, Forrest, leakage current takes the form of a number of kicks or surges, and the performances are evaluated by counting these surges. But their characteristics are always changed due to the variation of relative humidity.

Therefore, if the effect of the humidity can be eliminated from the surface leakage current under the contaminated condition, this relation will be more simple. As for our apparatus, Dc-high voltage is supplied to the pilot insulator only at the time when relative humidity arrives to the set point, and the magnitude of leakage current on the surface of the insulator depends upon the condition of salt contamination or industrial pollution. As it is well known, if the insulator is coated with silicon compound, it forms a thin film with the exceptional water repellency and the enveloping action of the silicon compound exclusive of the dirt parts of it. The surface leakage current of the insulator treated with the compound is extremely reduced by the superior surface resistivity of the insulator.

When moisture exists on the surface of the insulator recently treated, these characteristics will be maintained against intermittent droplet rather than a continuous flow, as long as the silicon compound retains its ability.

When the surface of the treated insulator is heavily contaminated, the large continuous conducting spot or path may be formed by moisture, since the compound ceases working. The useful life of silicon compound is proportional to the coated volume, and the next treatment should be done at one or two years' interval

The following apparatus for determining the next treatment of silicon compound are developed at our seminar room.

2. Detecting apparatus of salt-contamination of insulator

2.1 Various detecting methods and apparatus of salt-contamination on the surface of high voltage insulator in our coutry.

Table 1 shows the detecting methods and apparatus of salt-contamination in our country.

Table-1 Detecting method and apparatus of salt-contamination on insulator

Type of apparatus	Explanation and reference
Predictive apparatus of salt-contamination on insulator	Electrical Laboratory, Tokyo 1959. Japanese I. E. E. National Convention Record No. 223
Detecting tube of salt-contamination	Chugoku-Electric Power Co, Japan
Portable detecting tube of salt-contamination on insulator	Nippon Gaishi Kaisha, Nagoya, Japan 17th April 1962. Technical Papper No. 37084
Simplified measuring apparatus of salt-contamination on insulator	Central Reserch Institute of Electric Power Industry Tokyo
Type DC-M. detecting apparatus of salt-contamination on insulator	Nagoya Institute of Technology & the Chubu-Electric Power co., Inc. S. MUTO & T. Yoshimoto ; Electric Power, (Japanese) 45, p 1606 (1941)

These methods are different in each principle or use, show the detail explanations of table 1.

2.2 Characteristics of the leakage-current on the insulator

If the particle of sodium chloride under contaminated condition absorbs moisture, the insulator surface is covered with a conducting liquid film. The magnitude of leakage-current depends upon relative humidity in atmosphere.

The relation between the surface conductance and relative humidity is shown by the following Chirkov's equation.

$$\sigma_s = 10^{-c} exp\left(\frac{P}{Ps}\right) d \quad \cdots\cdots(1)$$

Where c and d are the factors depending on the materials, and P/P_s is relative pressure. Therefore, surface conductance is determined by relative humidity, and increase in film thickness results in increase in conductance.

As the general characteristics, the magnitude of surface leakage-current obtained with increasing relative humidity in atomosphere, is different from the magnitude of surface leakage-current obtainod with decreasing relative humidity. Chirkov confirmed that this effect was probably due to the hysteresis in variation of film thickness with relative humidity.

These hysteresis characteristics of surface leakage-current on the insulator treated with silicon compound, are developed by us for determining life of silicon compound coated on a insulator.

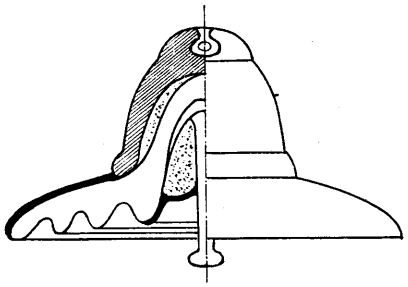


Fig. 1 Cross section of pilot insulator, upper half-side of surface and near the pin of insulator, are coated with metallic Zn.

2.3 Detecting apparatus of constant humidity type

2.3.1 Cyclic characteristics of relative humidity in atmosphere and surface leakage-current on a insulator

Fig-1 shows the pilot insulator of suspension type, which was used for the detecting equipment of salt contamination.

Upper half-side of its surface and near the surrounding portion of the pin are metallic-coatinized with zinc. When constant DC-10KV was supplied on the pilot-insulator under contaminated condition, the magnitude of surface leakage-current of it, varied as following curves shown in Fig-2.

The parameters of these curves in Fig-2 show the degree of contamination on the surface of the pilot insulator. As the materials of artificial method of salt contamination, we used the mixture of NaCl and polishing powder, respectively 1:2 by weight. Now, if we plot the relation between the leakage current and the quantities of salt at same relative humidity (for instance 80% or 70%) from the Fig-2, we can obtain the curves A and B in Fig-3.

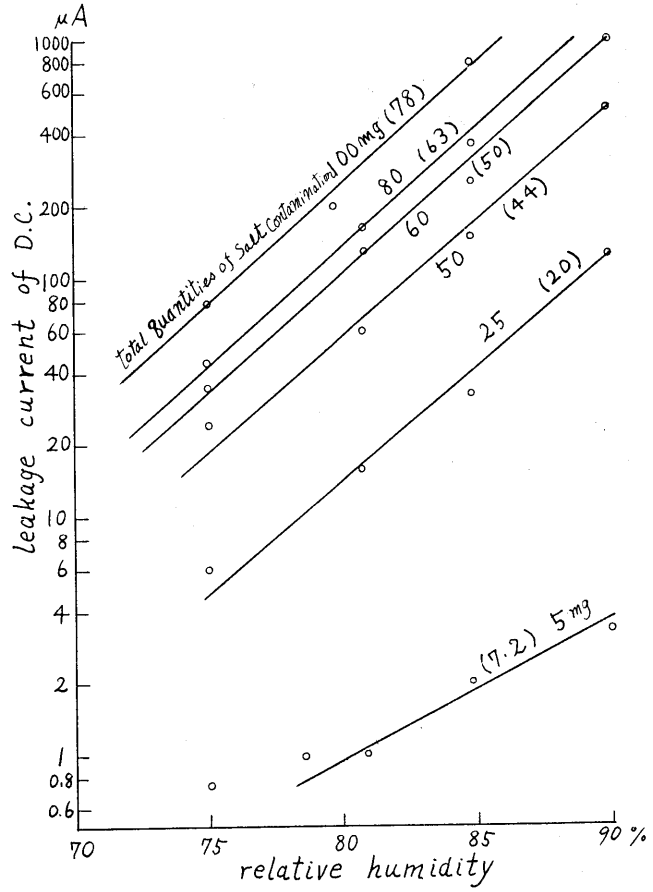


Fig. 2

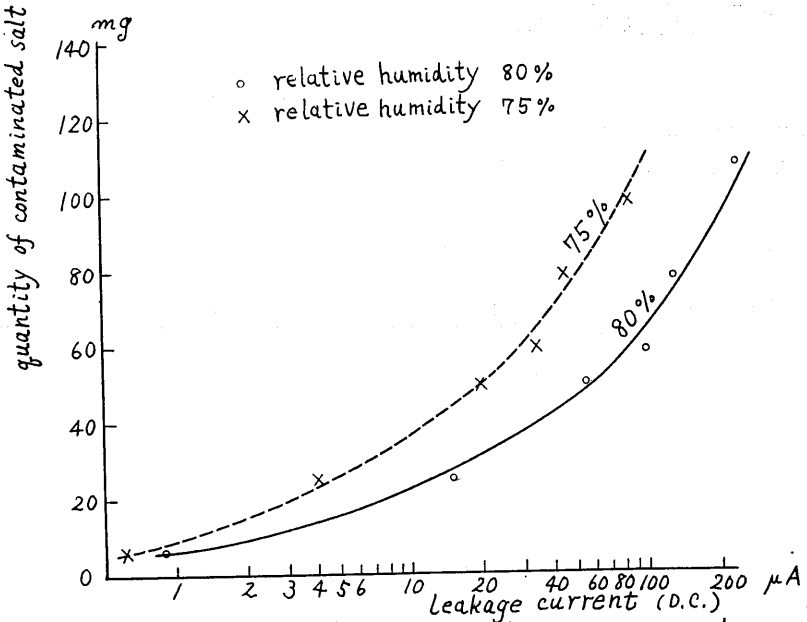


Fig. 3 relation between the leakage current and quantity of contaminated salt.

2.3.2 Hygrometer equipped with upper and lower current-contacts

If we measure surface leakage-current of the pilot insulator at the relative humidity (for instance 80%) from the horizontal axis in Fig-3, we can obtain the equivalent quantities of salt of the contaminated layer on the surface of the pilot insulator from the curve A in Fig-3. For these purposes, a special hygrometer equipped two contact, L and H, was developed. If relative humidity in atmosphere of the pilot-insulator arrives at a lower set point (for instance 70%), the lower contact L is made on, and DC 10KV- SOURCE is ready for working.

Relative humidity in atmosphere increases and the needle of hygrometer attains to a higher set point (for instance 80%), at once making a contact, and DC source is supplied on the pilot-insulator in several seconds. Therefore, DC leakage-current of the pilot-insulator is measured at only the time when relative humidity in atmosphere attains to 80%.

According to our experiment, the values of leakage current of the pilot insulator are different in both cases which relative humidity in atomosphere attains to the set point from the lower side or higher side.

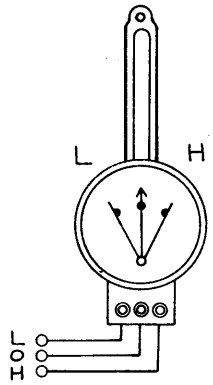


Fig. 4 Hygrometer with L& H contacts

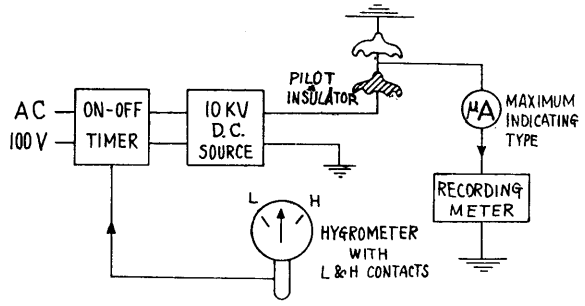


Fig.5 Model M-10 Detecting apparatus of salt contamination

It is sure that we must accept the cause approached to the set point from the lower side in the humidity change above mentioned.

For this reason, we must use the special hygrometer equipped two contacts, L and H shown in Fig-4.

Fig-5 shows the block-diagram of model M-10, the detecting apparatus for salt contamination.

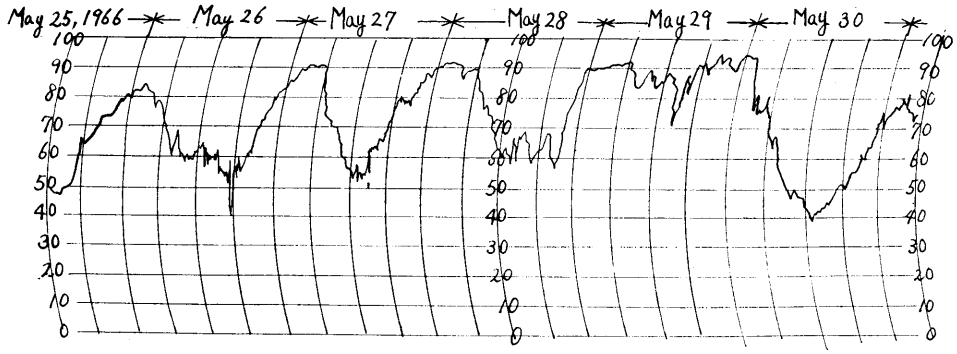


fig 6 Periodical change of relative humidity at the out-door of Yokkaichi steam-power-station

We could find periodic variation of relative humidity at yokkaich isteam power-plant where this apparatus is installed for the field test, and this result is shown in Fig-6.

Now, if we set a higher contact at 80% relative humidity, and set a lower contact to 65%, for instance, we can measure leakage current of the pilot insulator at 80% relative humidity after passing through 65% making a contact once or twice in a day. Leakage current is recorded automatically, and indicated by the demand-meter and equivalent quantity of salt in the contaminated layer on the surface of the pilot insulator is obtained from Fig-3.

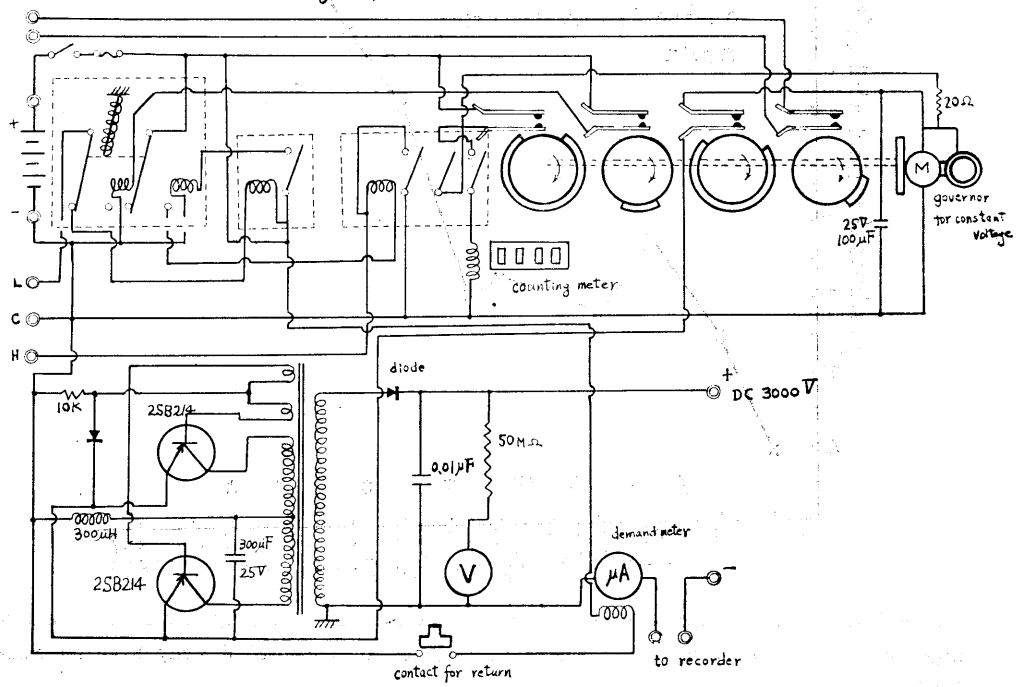
2.3.4 Model DC-M3 apparatus

The detecting apparatus model DC-M10 above mentioned contains DC 10KV-voltage source and this voltage is suitable for the standard pilot insulator shown in Fig-1.

The another apparatus, however, must be designed smaller and driven by a dry-cell for use at transmission line.

The model DC-M3 shown in Fig-7 is designed for this purpose, contains DC 3 KV source.

Fig 7
Type D.C. -M3 Detecting apparatus of salt contamination



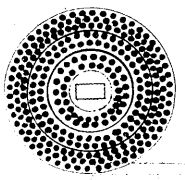


Fig 8 Reformed pilot insulator one-third of lower half side of the surface are metallic coating; black spot show metallic parts

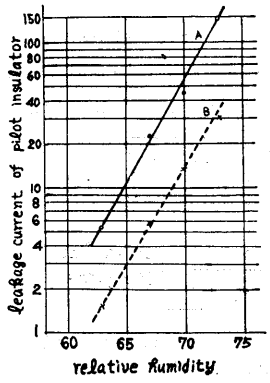


Fig. 9

Comparatible characteristics between relative humidity and leakage current of two pilot insulators, A and B.

A --- pilot insulator shown in fig. 1

B --- pilot insulator shown in fig. 8

The reformed pilot insulator whose upper side and one-third of lower side area of the surface consists of the metallic coating, is used in this apparatus, and it is shown in Fig-8. Therefore, the total leakage paths of the pilot insulator are reduced to about one-third length of the standard pilot insulator in Fig-1.

The characteristics between relative humidity and leakage current of these two pilot-insulators are comparatively shown in Fig-9.

2.3.5 Results of field test with the apparatus

As the field test, this apparatus was set on the tower of transmission-line of Shinnagoya-Otaka 70KV system near Nagoya-harbor, and the test was done during ten months from June 1963 to March 1964.

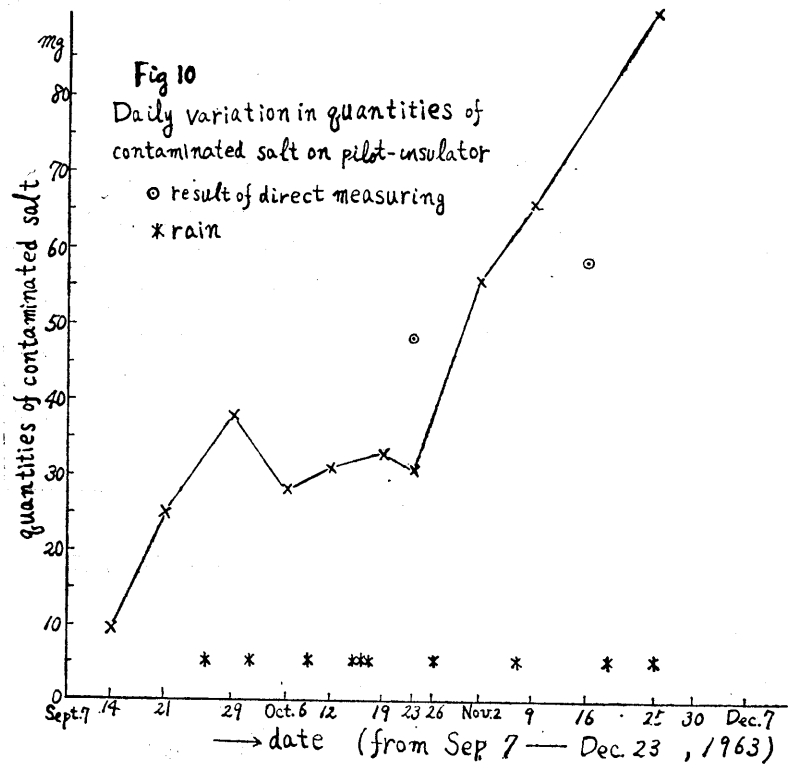


Fig-10 shows the result of the field test which the equivalent quantity of salt obtained from this apparatus is compared with the equivalent quantity of salt measured directly from the same type insulator.

2.4 Hysteresis-loop characteristics between the leakage current and relative humidity

The recording method of hysteresis-loop characteristics of surface leakage current of the insulator under contaminated condition is shown in Fig-11.

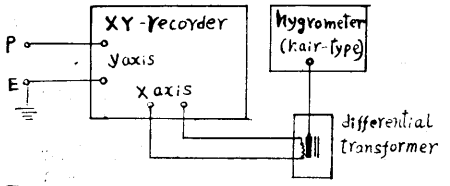


Fig11 block diagram of measurement for looped characteristics

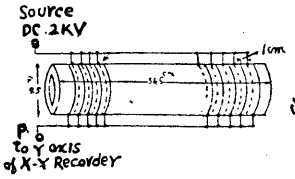


Fig 12 Cylindrical pilot insulator for detecting

Input voltage to the X-axis of a X-Y recorder is linear to relative humidity in atmosphere, and input voltage to the Y-axis is proportional to the magnitude of surface leakage current of a insulator.

We made a cylindrical hollow insulator with two groups' electrodes, arranged parallel and at a equal distance for our experiment as shown in Fig-12, and studied the characteristics of the contaminated surface of the above insulator, coated with silicon compound or not.

If we want to take the hysteresis-loop characteristics, relative humidity must be changed up and down.

For our experiment, we used a closed chamber and settled the detecting element in it, as shown in Fig-11.

We kept the relative humidity in the chamber equal to the relative humidity in atmosphere (for instant 70%) with opening the door, and blew steam into the chamber little by little.

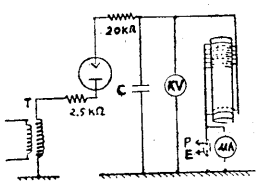


Fig 13 connecting diagram of the measurement of looped characteristics

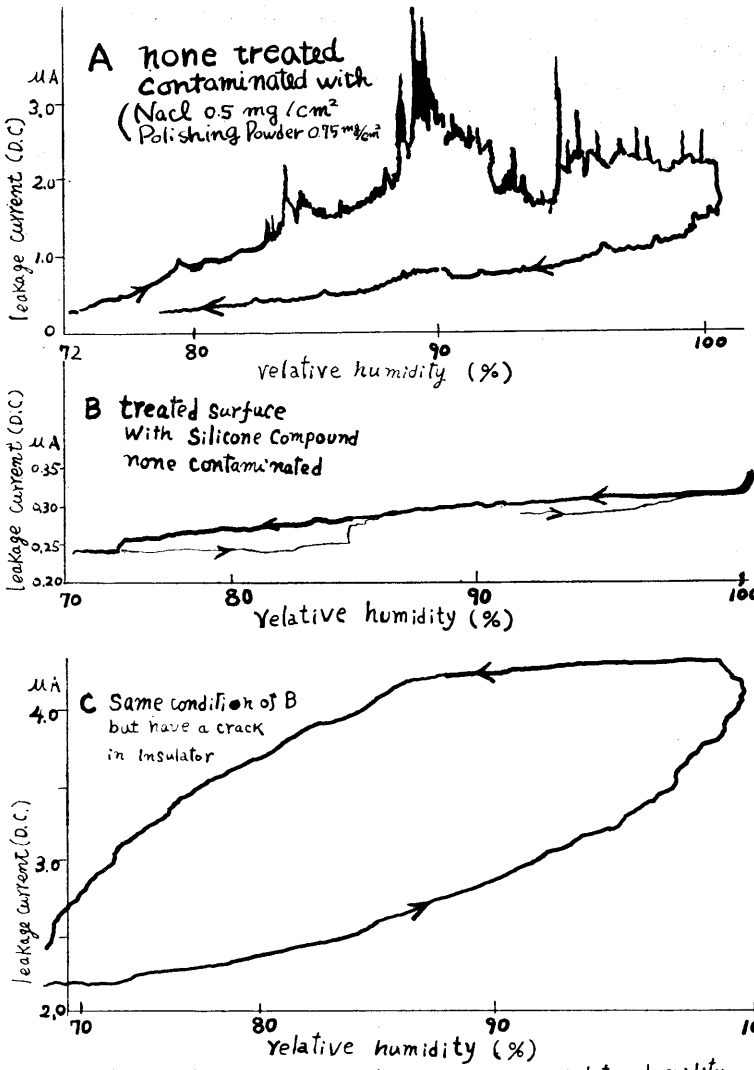


Fig 14 looped Charact. of leakage current by relative humidity

At the first step, relative humidity in the chamber increased slowly until 100%, and was decreased to 70% making use of the absorbent like silica-gel at the next half cycle.

Fig-13. shows the connecting diagram of cylindrical insulator and the voltage source of DC. 3KV, and Fig-14 shows these hysteresis loop characteristics.

The found results of these experiments are as follows,

(1) The area in the hysteresis loop depended upon the quantities of the absorbed moisture in the surface layer.

(2) The area in the loop became smaller for the insulator coated with silicon compound without contamination.

(3) The area in the loop became larger for the insulator coated with silicon compound with heavy contamination.

(4) The rotating direction and shape of loop mostly depend on the degree of retained ability or life of the treated silicon compound on the insulator.

Reference

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