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Question 1.13:
Which functions are influenced by ageing of liquid insulation systems?
What are the possibilities to verify these functions?
Are alternative methods to measure ageing mirroring the functional properties?

Introduction

Factors related to degradation by ageing include not only operating years, but also individual equipment design, load history, maintenance history, and installation environment.
In addition, in order to evaluate the degree of degradation of equipment, investigations and tests based on degradation mechanism of insulation must be carried out.

- ✓ **Performance testing and dismantling studies of equipment that has operated for long periods of time are effective to grasp overview of equipment degradation.**
  In selecting equipment to be investigated, it is important to classify the equipment by its structure.
  In addition, it is desirable to conduct an analysis of the degree of degradation corresponding to the causes as the electrical, mechanical, and chemical stresses that the insulation materials have undergone during equipment operation, and caused by unwelcome events such as an intrusion and a contamination (air, moisture, particles) in liquid insulation materials.

- ✓ **Nondestructive diagnosis of the equipment is advantageous to investigate degradation condition of individual equipment in operation.**
  When conducting insulation tests of samples taken from inside the equipment, it is desirable to faithfully reproduce the environment inside the equipment (see below).
  At this time, insulation materials should be carefully collected, shading, avoiding intrusion, contamination and heat.

Which functions are influenced by ageing of liquid insulation systems?

It is well known that the conducting (dielectric breakdown voltage and resistivity) of liquid insulation materials and liquid-impregnated solid insulation materials decrease over the years.
However, insulation performance is not the only requirement for liquid insulation materials inside the equipment. Table I summarizes examples of functions influenced by ageing.
In power equipment designed for low electric field strength, the change in characteristics except for insulation performance will cause the equipment to reach the end of its life.
Therefore, the performance of liquid insulation materials that should be noted differs for each device.

Table I The influenced functions by ageing of liquid insulation materials

Equipment	Influenced functions	Indications
Transformers	Degradation in electrical insulation performance	Decrease in the BDV/PDIV Increase in the ECT
Power capacitors OF cables	Degradation in electrical insulation performance	Decrease in the BDV/PDIV
	Increase in losses	Increase in the tan δ
Capacitor voltage transformer	Degradation in electrical insulation performance	Decrease in the BDV/PDIV
	Deviation of transformation ratio	Change of the permittivity

What are the possibilities to verify these functions?
Performance testing (for functional testing of equipment) and dismantling investigations (for performance test of each material) are accurate and reliable for aging equipment investigations.
There are two types of criteria values for evaluating performance: the acceptance test values of equipment and the standard values of minimum performance required for equipment.
In order to know the trend of degradation of aged equipment, CEPCO had conducted dismantling investigations for several dozen aged equipment and their insulation performance were compared with the above two criteria values.

Target equipment was selected from the following perspectives related to degradation mechanism of insulation materials.

- Structural classification of equipment
  - Transformer example:
    Shielded type / Open type, Core type /Shell type, Disk winding / Cylindrical winding
- Operating years
- Temperature history
- Type of insulation material
- Manufacturer
- Presence of intrusion and contamination such as air, moisture and particle

Are alternative methods to measure ageing mirroring the functional properties?
Some existing aging measurement methods are not able to mirror functional properties.
One of the examples is the method of evaluating static electrification, which is the subject of our research.
Static electrification is a complex phenomenon between liquids and solids, but most conventional measurement methods can evaluate characteristics of insulating oil only.
For example, the conventional mini-static electrostatic charging tendency tester method uses a new membrane filter as a solid insulation material sample, although the insulating oil inside the transformer is used as the liquid sample.
For this reason, this method can not evaluate the functional properties of solid insulation materials.
Therefore, our paper "D1-10647" proposed a test method that can faithfully reproduces the phenomena inside a transformer as shown in Figure 1 by using both the insulating oil and the solid insulation materials inside the actual transformer as samples.

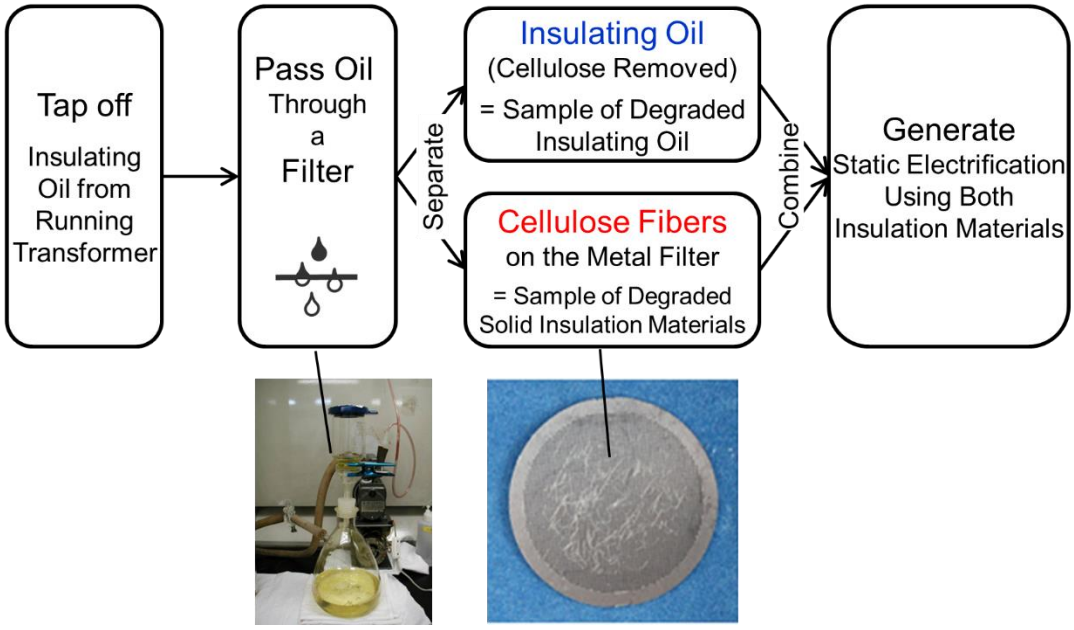

Figure 1 - Concept of the new test method for evaluating static electrification