RECOVERING INSULATIONS OF LARGE ELECTRICAL MACHINES

NEW PROCEDURE IN SUBMARINES

BY

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Introduction

The 'O' and 'P' Class submarine was designed in the early 50's and H.M.S. *Porpoise*, the first of class, was built in 1956. Since then, the deterioration of the main generator insulation in submarines of this Class has been a 'continuous sore' to the Submarine Command. So much so that a considerable amount of operational time has been lost.

Currently accepted methods of recovering main generator insulations have in the past been actioned by a total strip and removal of the armature. This recovery process took not less than fourteen days to achieve and involved about one thousand manhours working in shifts. In July 1976, a presentation was made by the First Submarine Squadron to D.G. Ships/DPT(S/M) proposing an *in situ* cleaning method. As a result of this, the Ayrodev process was investigated and finally agreed for a controlled trial in H.M.S. *Ocelot* utilizing Atmosphere Monitoring.

Insulation Deterioration

The main generators of the 'O' and 'P' Class submarines were designed and produced by English Electric Co. of Stafford and are coupled to an ASR1-16 VMS diesel by flange mounting and the void closed by wrapper plate. Both are shock and sound insulated. The distance between the engine frame and the main generator lower yoke is only nine inches and the whole engine/generator is situated in the engine-room compartment.

Inevitably there is a carbon build-up within the generator due to brush wear. However, when oil from the engine and oily atmosphere from the compartment have intruded, the generator insulations have dropped dramatically. Invariably, the low insulation (having dropped from over 50 megohms to a few hundred kilohms) has been found to be due to a build-up of carbon/oil mixture on the field and armature structures involving a tracking to earth in this area.

The currently accepted method of measuring insulation is by use of the megger thus measuring a pure insulation resistance to earth. However, some commercial firms are now using methods which take into account the capacitive effect of the machine. These methods measure Tan Delta and Polarization Index of the machine and give a better indication of the quality of the insulation.

Tan Delta

If using a Marconi Bridge, the winding is regarded as a capacitor, the electrodes being, on one side, the winding and, on the other, the frame, with the insulation structure (with or without the varnish) as the dielectric. The chemical changes taking place during the process are reflected in changes in the electrical parameters, and it is these that are monitored. A winding can be shown diagrammatically as in FIG. 1.

If a d.c. voltage is applied across A and B, there is an initial surge as the

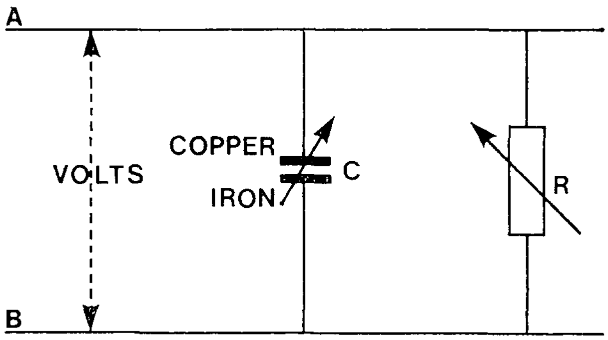

FIG. 1

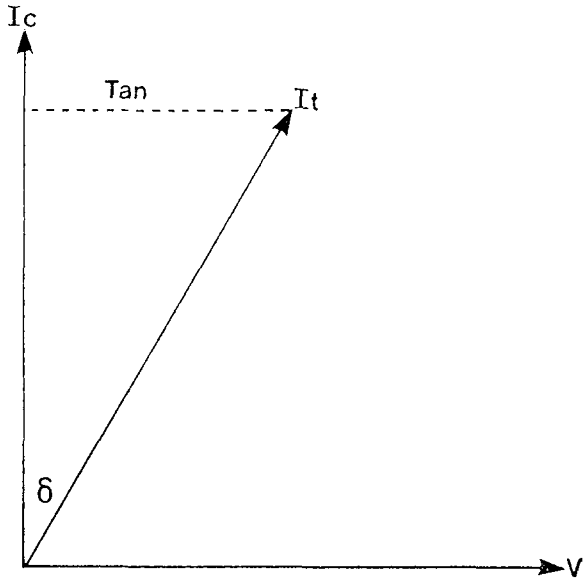

FIG. 2

condenser charges up and then the current stabilizes at a value inversely proportional to the value of R. This is the basis of the megger method of testing.

If an a.c. voltage is applied, however, another factor comes into operation due to the losses in the dielectric structure. If C were a perfect capacitor with no losses, the current would lead the voltage by 90°, i.e. there would be no phase displacement, and the current flowing through the circuit would be due to the resistive component R only, and would be equal to the d.c. current.

However, with a.c., the capacitor first charges up (as before) on the positive half-cycle, discharges, and then becomes charged again on the negative half-cycle. But, as no capacitor is perfect, some of the energy is absorbed into the dielectric, resulting in a phase displacement. The absorbed energy is dissipated in the form of heat within the dielectric. The higher the energy absorption, the greater will be the phase displacement angle so giving an indication of the dielectric absorption: a small displacement angle indicating a good dielectric, and a large displacement angle indicating a poor dielectric, independent of R. In other words, it is possible to have a poor insulation for a.c. conditions although a good d.c. insulation is shown on a megger. The vector diagram (FIG. 2) will make this clear.

The significance of tan δ is mainly applicable to high voltage machines and is a general indication of the quality of the insulation structure and the stability or otherwise of a winding.

Polarization Index

This test is again intended to assess the condition of the insulation structure of large high-voltage machines. The method is to measure the insulation resistance at 500 volts, keeping the winding at this pressure for ten minutes.

Polarization index is defined as:

$$\frac{R \text{ at } 10 \text{ minutes}}{R \text{ at } 1 \text{ minute}}$$

For insulation values of the order of 100 megohms or so and for machines up to about 300 hp, there is little difference between the readings, resulting in a P.I. of one. However, with a large machine, particularly with a very high insulation resistance, there will be a gradual creep upwards of insulation resistance and this is what is measured.

This test is primarily intended for large mica-insulated machines where a P.I.


FIG. 3—ACCESS TO FORWARD HALF OF GENERATOR


FIG. 4—SPRAY PROCESS AND AFTER ACCESS TO GENERATOR

of three is considered to be good, but it is a useful check on quality for all machines. On large machines, any increase in insulation resistance reading giving a P.I. greater than one is an indication of high quality insulation structure; whereas, on normal machines, the fact that the P.I. is one should not condemn it provided that the insulation resistance itself is adequate.

The Ayrodev Process

Now with technological advances in the chemical field with new solvents, the removal of the offending carbon/oil deposit can be achieved by the use of an *in situ* wash through, thus avoiding stripping the machine down to bottom yoke level and removing the armature.

Breakdown insulation and tan δ readings are taken well in advance to ensure that the quality of the insulation is good enough to allow improvement by the wash-through process.

A front and back strip of the generator down to shaft level for access to the field windings and armature (FIG. 3) is carried out by squadron base staff. The process is simple and effective employing a wash (sprayed on) using the two proprietary solvents Meggawash and Meggaboost and a final finish of Air Drying Devoloc Varnish (FIG. 4). About four to six hours is required for the Meggawash process, followed by about 24 hours for the Meggaboost. The dry-out time between sprays is usually two to four hours, and insulation and tan δ readings are taken at approximate intervals to check progress.

The total quantity of Meggawash used is approximately 15 to 20 gallons, and a similar quantity of Meggaboost. Three coats of Air Drying Varnish are sprayed on to the armature and field coils: the first coat is Devoloc Grey, the second coat is Salvameg Blue, and a final coat of the grey. The Salvameg Blue enables the operator of the spray to see where he has not covered during the final application.

Toxicity Monitoring

Atmosphere monitoring was an important necessity during the use of the method in the confined space of a small submarine. This was done by the

Institute of Naval Medicine and their work is described in detail in the next article in this *Journal.*

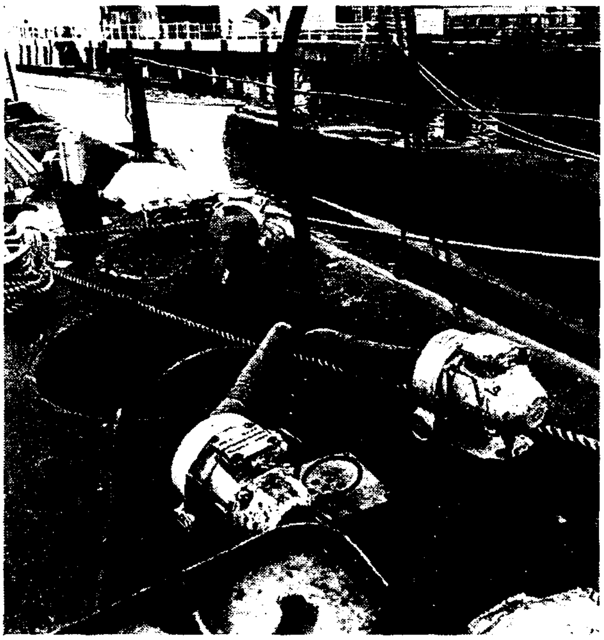

FIG. 5—POSITION OF D.B. FANS AND ASSOCIATED TRUNKING

The Future

The recovery of insulations in excess of 100 megohms and overall insulations of 80 megohms shows a marked improvement in insulation over current methods. The overall time taken was six days compared with sixteen days for a full generator strip. This makes this process very attractive where saving of operational time is paramount. No toxicity problems were encountered and, if the ventilation requirements (FIG. 5) are met, there is no danger from the white spirit fumes. It should also be noted that the process gives a considerable saving in base staff labour, leaving them free for other commitments normally shelved during a generator strip. The process is also considered to be cheaper.

While the process looks to be a considerable advance in recovering insulations over the accepted method, the proof of the method will be in sustained high insulations over an extended period. *Ocelot*'s main generator insulations are still in excess of 50 megohms some six months after, and this augurs well for the future. The process is thought to be a major breakthrough in recovering the insulations of rotating machines and has recently been used in the SSBNs, SSNs, and by the Royal Dockyards.

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