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AM/cm

To : Messrs. R. Bonvin, S. Hérin, J. Hofmann, G. Indreas, P.G. Innocenti, I. Kamber, B. Kuiper, S. Milner, H. Riege

From : A. Messina

Re : Tests on Leclanché's and ICAR's capacitors for the line of the Kicker magnet

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After the failure of the first four capacitors delivered by Leclanché, two things were noted; a) a breakdown against the ground at the center of the box, b) the burning of some packets in the same area. Two lines of action were therefore decided upon :

a) The increase of the thickness of the paper for insulation against the ground (Russian type, reinforced type, new model).

b) A more detailed study of the behaviour of the packets.

The first point had to be carried out by Leclanché, the second was to be developed together. This note concerns only our collaboration with Leclanché for the second part.

The proposed capacitor from Leclanché is made up by two groups in parallel with 28 packets in series. Each packet has a capacity of 360 nF and the total capacity of the capacitor is then $c = \frac{360 \times 2}{28} = 25$ nF. Each packet must hold $80/28 \cong 2.86$ kV. It was decided to discharge groups of 6 packets in series for a total capacity of 60 nF at a voltage of $\frac{80 \times 6}{28} = 16.66$ kV.

1) First test at CERN (1 group at 6 kV)

A group of 6 packets, taken from a still apparently good part of a dead capacitor, was put into a plastic box full of mineral oil supplied by Leclanché. The whole lot was degassed for three days in the NPA workshop. A large production of bubbles was observed and the degassing was probably not complete when the box was taken out.

A dumping resistor of 0.3Ω (100 series, in parallel, of three 10Ω, 2 W, resistors), in order to obtain the negative overshot of 50°/o required, was added and the spark gap, adjusted at 6 kV.

When the system was put into operation, a large production of bubbles was present at one terminal and after three hours, at 100 s/m, the block was destroyed. The analysis of the group made at Leclanché showed the burning of the paper in the area of contact between the electrode and the aluminium foil. It must also be noted that in the capacitors tested something similar had occurred. Mr. Louis at Leclanché was not discouraged by this attempt because a) in handling the group the electrode could have been damaged, b) it is very difficult totreat again a packet after its exposure to air. Therefore the test had to be repeated with a group, handled and treated carefully at Leclanché. The packets had not to be taken from an old dead capacitor but chosen from the packets ready for the new capacitors.

2) Second test at Leclanché (2 groups at 18 kV)

At the same time, Mr. Louis had put 6 groups from dead capacitors without exposing them to air in an old box of accumulator.

The test started the day of our meeting about our first attempt. It began only with two groups because the charging resistors were not available at Leclanché as well as the dumping ones. The two groups ran for three days under these conditions: the time neeessary for us to furnish the charging resistor and the dumping ones (utilizing the resistive strip used by G. Indreas in his tests of the septum, with a cooling system made of copper plates). So three days later we put all six groups into operation; one of the last four failed shortly afterwards as well as one of the previous two. During the pulsing of the two groups a large production of bubbles was again observed, but the life was much longer than expected. This test was put into operation only for a week in order to confirm our first test and because new packets were not available. It was an intermediate attempt while we were waiting for the new packets (no conclusive answer could have been drawn from packets perhaps damaged).

3) Test at CERN (1 group at CERN)

The group of 6 new packets, treated and handled by Leclanché, was now available and put into operation in the same conditions as the first one.

We started at 7 kV at 120 s/m for two hours, then the voltage was increased to 12 kV for another two hours and finally to 17 kV. The test was left running for a whole afternoon and night at 100 s/m: the following morning the group was dead.

4) Tests at Leclanché (6 groups at 18 kV)

In order to test some more new packets, a new capacitor was opened and 6 groups of 6 packets were prepared and put into operation again with material furnished by CERN (charging resistors, dumping resistors, power supply).

This decision was justified by the necessity to test the packets in their actual conditions of work. The disadvantage of this configuration was the fact that the failure of one group would have affected all the others. This test was stopped in fact because the oil became very dirty after a few days (700.000 shots).

At this time no significant conclusion could have been drawn a) the conditions being not respresentative; b) the number of packets and of shots being too small. It was then agreed to test 27 groups. Again the whole material had to be supplied by CERN, the groups had to be treated by Leclanché. Each group had to be put into a metallic box separately.

In order to verify the possibility of using the capacitors at a lower voltage (60 kV) 9 groups had to work at a voltage of 14 kV. From the remaining 18, 9 had to be tested at Leclanché and 9 at CERN.

5) Tests at Leclanché (9 independent groups at 18 kV)

In order to decrease the noise for the people of Leclanché the test was mounted in the tunnel of Leclanché. A capacitor bank of 3 μF furnished by CERN was interposed between the power supply and the groups for a better use of the power supply. After an hour of operation I left the tunnel with Mr. Louis. When I came back, 1/2 hour later, the 9 groups were on fire. After the fire was put out, I saw one charging resistor burned in a few points. This could only have happened if the group had blown up. In fact the following day a check made by Mr. Louis showed that the other 8 groups were still O.K. and only that one had failed. The conclusion was then that one group had blown up, caught fire and propagated it to the rest.

6) Tests at CERN (8 groups at CERN)

The succession of facts was confirmed in the equivalent test put into operation two days later at CERN. Only half an hour after the test started at 18 kV and 100 s/m a first group began to smoke, big bubbles came to the surface of the oil and the start of a fire was noted. Of course the group was disconnected at that moment and the test continued with the others.

A second group failed after 2 hours, a third after 3 hours, a fourth after 4 hours and a fifth after 10 hours. The last three ran for another two days at 150 s/m without any trouble. One of them was taken to ICAR to measure the $tg\,\delta$ and c. The values

$$c = 56679\ pF \quad tg\delta = 28 \times 10^{-4}$$

are not indicative because the capacitor lost some oil, unfortunately.

7) Test at Leclanché (6 groups at 14 kV)

From the 9 groups to be tested at 14 kV only 6 were available. The test was not repeated in the tunnel for reasons of security (we also ran it only during the day).

The reasons for the failure of the previous tests seemed to be the bad contact between the electrode and the aluminium foil.

A new analysis of all the packets which failed in the capacitors and in the group showed upon a more accurate control signs of deterioration in the area of contact. These six groups were then very well pressed in order to avoid the formation of microsparks between the electrode and the aluminium oil. The test started at 20 kV and 275000 shots were fired. At that moment one group had a failure against the ground, the test was stopped and 4 groups were put again into operation at 14 kV. At our last meeting Leclanché had 110.000 shots in these conditions.

Conclusion

Out of all the tests done no conclusive results can be drawn : the only thing which can be said is that a few packets hold. Someone optimistic could say that in all the other cases some detrimental conditions were introduced, but till now nobody can assume that in the manufacture of the capacitors these conditions will disappear. I think it is necessary in any case to point out that at Leclanché the importance of the tests was not fully understood and that they have been carried out more in an attempt to keep us quiet than to learn something. This explains :

a) the continuous change of the conditions of tests;

b) the very little attention attached to the tests by Leclanché.

Till the end Mr. Louis seemed sure that the reason for the failures was to be found somewhere else (insulation against ground for instance). In general the attitude has been fatalistic on one hand and empiric on the other, because after each failure they started to try something else without being sure of the reasons for the previous failures.

Two socalled modified capacitors are now in operation here : one has done 2.000.000 discharges and the second 700.000. This is the first positive result since we started. Let us hope that the others will behave in the same way.

Visit to ICAR

The purpose of the trip was to measure the conditions of the prototype from ICAR, after 2.300.000 shots at 80 kV. The measurements were taken with a bridge for high voltage, 50 cl/s.

The results are the following :

V_p(kV)	c(pF)	100 tgδ	T_A	T_C
10	26 548	0.13	29.6	30.4
15	26 549	0.13	29.6	30.4
20	26 551	0.13	29.6	30.4
25	26 555	0.13	29.6	30.4

The figures measured at the departure were :

V_p(kV)	c(pF)	100 tgδ	T_A	T_C
10	26 507	0.16	20°	20°

A decrease in tgδ from 16×10^{-4} to 13×10^{-4} can be seen. Ing. Perucca explained to me that this was to be expected because during the first shots there is a sort of electrical purification of the capacitor. Now the tgδ should present small modifications and increase very much at the moment of the failure.

A series of checks at steps of 2 millions shots could help ICAR and us in forecasting the life of the series. For the end of August it was decided to have another check.