A STATISTICAL ANALYSIS OF THE RISK OF DUST CONTAMINATION DURING ASSEMBLY OF RF SUPERCONDUCTING CAVITIES

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I) INTRODUCTION

It is a well known fact that great care in surface preparation of superconducting cavities is an indispensable prerequesite to obtain good performances of these delicate objects. That is also why cavities are mounted in a dust free environment. More recently, the noxious effect of dust particles on electron emission has been demonstrated at Saclay by a dedicated experiment .[Ref 4, 5].

It is of great practical importance to assess which step of the surface preparation are crucial for the success of the cavity, and a partial answer to this question can be based on statistical grounds. Indeed, since its creation in 1986, the "Groupe d'Etudes des Cavités Supraconductrices" (GECS) has accumulated large statistics on cavity results. This data set is extremely homogeneous : all cavities are single cell cavities at 1,5 GHz, made from the same kind of niobium (Heraeus, RRR $\leq$ 200), by the same company (ATEA). Moreover, all cavities have been prepared with the same surface treatment, by the same technicians, following a rigourously defined process.

It is the purpose of this paper to exploit this data base on statistical grounds, trying to assess the influence of incidents during mounting on ulterior cavities performances. Another interesting and closely connected question is to determine to what extent a cavity can be qualified as intrinsically good or bad, in other words : are the performances of a cavity solely determined by its fabrication, or by the care of its surface preparation and mounting ?

II) SELECTION OF THE STATISTICAL SAMPLE

Even if incidents during cavity assembly do not result in measurable dust contamination, it is often suspected that they degrade the results. We tried to quantify this statistically by studying more than 65 standard RF tests performed on 18 different single cell cavities at Saclay, with or without incidents during mounting. In compiling statistics, all tests were rejected where some accident occurred during the RF test : a leak during the test, anomalous heating of antenna or couplers, a quench in the couplers or any breakdown in the RF system. In addition, any test which obviously exhibited the "Q-desease" [ref. 1] were rejected. Only standard tests were selected.

The standard procedure consists of attaching antennas and couplers to the cavity in a clean-room, and then leak testing it. Chronologically, the leak test was first performed in the RF test area, in laminar air flux, under a plastic "clean tent" which covers the whole insert part of the cryostat. It is now performed directly in the clean room, and this has been the case with approximately half of the tests considered. If this leak test is negative, the cavity, with ends temporarily closed, is carried to the clean tent (if it is not already there), and is opened for a short while as it is connected to the vacuum system of the insert. The cavity is then pumped, lowered into the cryostat, cooled, and tested under RF. This procedure is hereafter designated as "no problem", which means of course that no incident was detected.

The cases considered as "problems" are : leaks necessitating changes in gaskets or any unusual reopening of the cavity or particular difficulties in adjustments and tuning of antennas or couplers or any prolonged manipulations of the metallic parts in contact with the cavity openings.

Two results were obtained for each RF test : the curve Q0(Eacc) as first obtained, hereafter termed as "before processing", and the same curve "after processing", i.e. after all RF and/or helium processing.

III) RESULTS.

Figures 1 to 4 show the distributions of the threshold fields for electron emission Eth. When quench is attained without electrons, the maximum accelerating field : Emax is quoted. The mean threshold of electronic onset <Es> is calculated by taking into account only tests limited by electron emission (Eth).

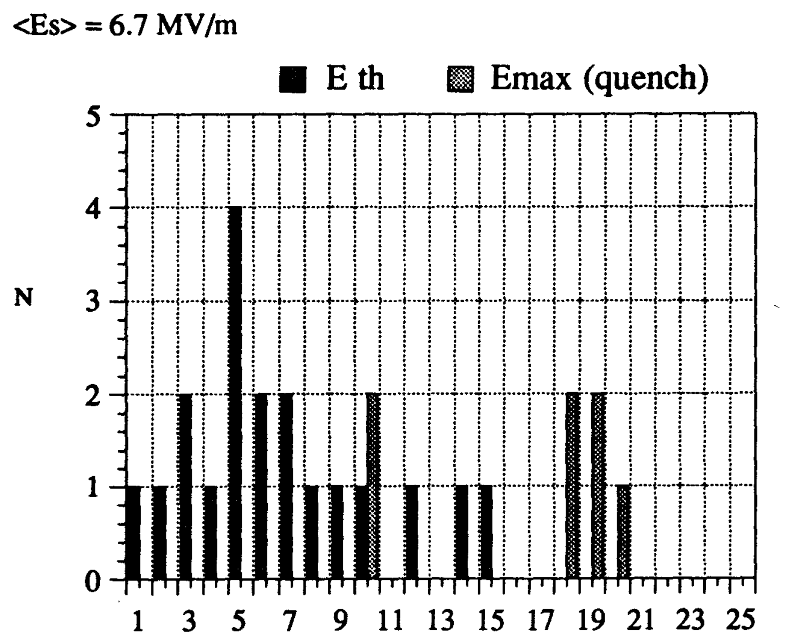

Figure 1 : Results of tests, with problems during assembly, before processing

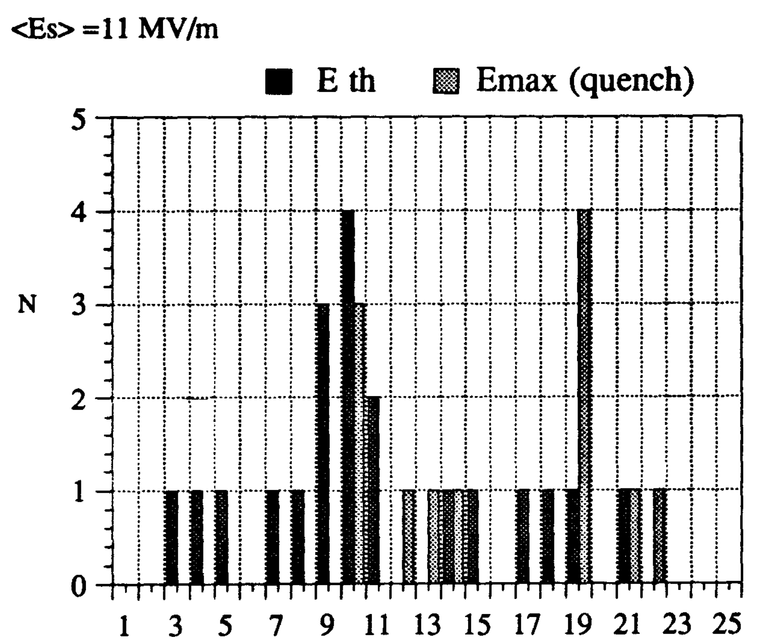

Figure 2 : Results of tests, with no problem during assembly, before processing

<Es> = 9.7 MV/m

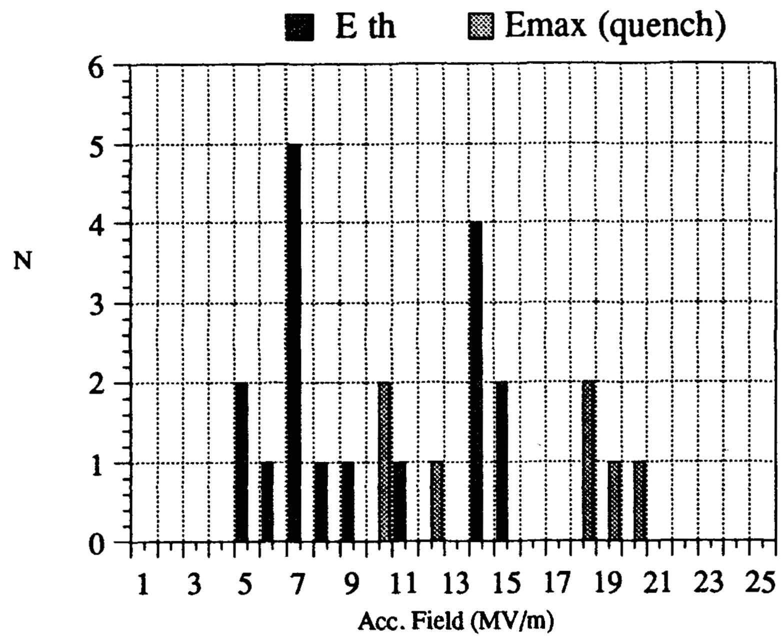

Figure 3 :Results of tests, with problems during assembly, after processing

<Es> =11.4 MV/m

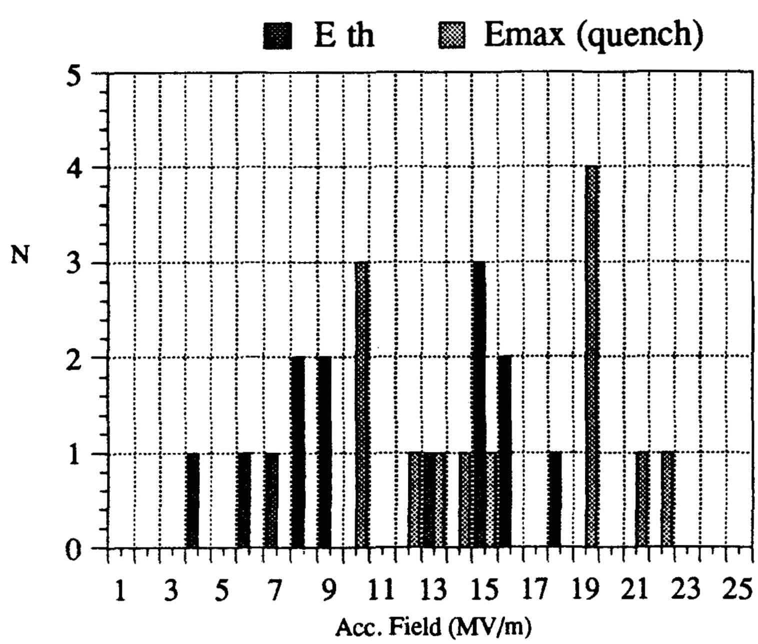

Figure 4 : Results of tests, with no problem during assembly, after processing

As these results show, problems during assembly obviously lead to a statistical reduction of the emission threshold by more than 4 MV/m before processing. This effect is somewhat lower after processing, but the difference is still about 2 MV/m. One can note that it is nevertheless possible to get good results , i.e. to reach a quench at high accelerating field without any electron, even in case where problems did occur. This is probably due to the fact that only a very small part of the surface of a cavity is sensitive in terms of electron emission.

The effect of processing can be summed up on using all the results (with or without problems) : we find a mean threshold <Es> of 8.9 MV/m before and 9.6 MV/m after processing, which seems to indicate that processing is only weakly effective. In fact, if one examines the results closely, one can observe that processing is very effective for most of the cavities, but that sometimes when a cavity is maintained at high fields, very strong emitters can appear, degrading dramatically the cavity performance.

This mean value of 9.6 MV/m was then used to check if good or bad results in terms of electron emission were something intrinsic for a cavity. For each cavity we have examined sequential pairs of tests (after processing), and we have plotted Eth2, the electronic onset treshold obtained in the second test, in function of Eth1, obtained in the first test. Fig 5 show the results of this analysis.The set of points can be divided in four different areas, considering a test as "good" if the electron emission threshold is higher than 9.6 MV/m, and "bad" if it is lower ; if both tests are good, the spot corresponding to this pair of tests will be located in the "GG" area, if the first is good and the following bad, "GB" and so on.

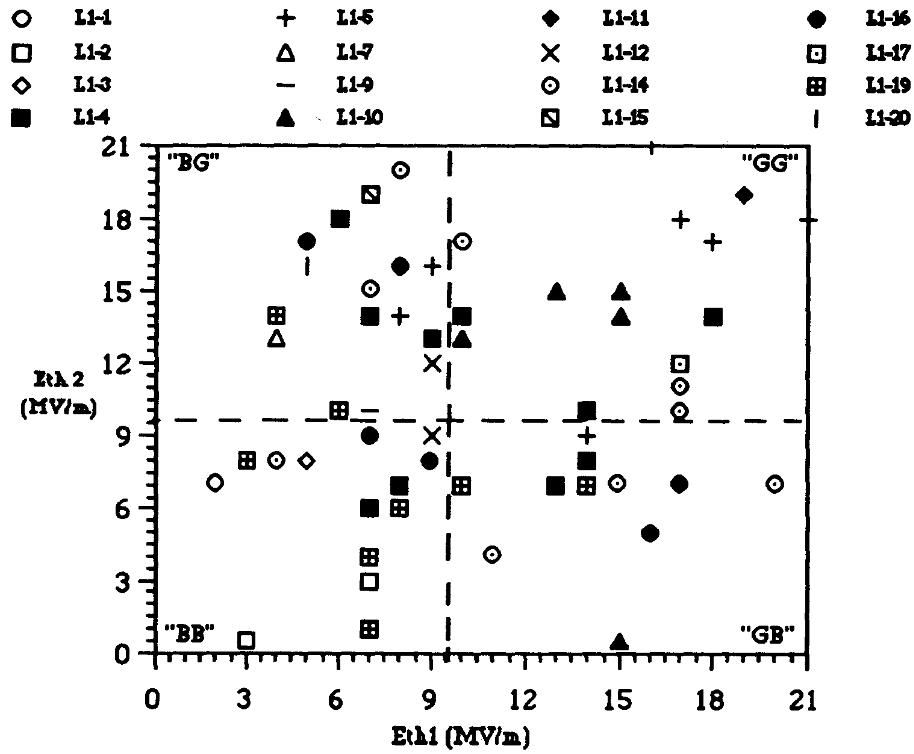

Figure 5 : Analysis of sequential pairs of RF tests: Eth2, the electronic onset treshold obtained in the second test, in function of Eth1, obtained in the first test. Dotted lines represent the mean value <Es> = 9.6 MV/m of electronic onset for the whole statistical sampling.

Within statistical errors, the set of spots distribute uniformly arround the mean value : no correlation appears between the results of successive tests. In a less formal way, one can say that none of the cavities that encountered a lot of tests are always "good" or "bad". (Note : if electron emission was something intrinsic for a cavity, the results would have been located mainly in the "BB" or the "GG" areas.)

Some other experimental facts tend to confirm these results : we all know now that working in a clean-room is an absolute necessity. The poorer results obtained in horizontal cryostats where mounting procedures are somewhat more complicated (in comparison with vertical tests) can also be partly due to the enhanced risk of getting particles in case of prolonged manipulations.

Several field emission studies on samples showed that particles form preferential emission sites [Ref 2, 3]. Recently, another experiment performed in our laboratory showed that metallic particles tend to be very strong emitters while insulating particles are not.[Ref 4, 5].

All the assembly steps, with unavoidable frictions between different parts are likely to produce metallic particles, and are very dangerous in terms of electron emission. As these steps cannot be avoided in the construction of an accelerator, efforts should be made from now on to minimize this danger such as simplified and reproducible assembly procedures, or even special tribologic surface treatment of the rubbing parts, etc...

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