

Performance degradation in several TESLA 9-cell cavities due to weld imperfections

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1. INTRODUCTION

Six TTF [1] cavities (S7 to S12) from one fabrication line exhibited premature quenches at accelerating gradients of 10 to 14 MV/m and a slope in the $Q(E)$ -curve (Fig. 1). Except S12, which was heat-treated at 800 °C, all cavities were heat-treated at 1400 °C. With temperature mapping the origin of the insufficient performance could be traced back to defects in the equator welds. A recently made cavity (S28) with improved welding technique could be excited to 24.5 MV/m without a continuous Q-drop.

1. TEMPERATURE MAPPING RESULTS OBTAINED ON CAVITY S9

Measurements in all coupled modes [2] showed that cavity S9 had only one bad cell, the middle cell, with a limit of 10 MV/m while all others reached gradients of more than 19 MV/m. The heating which was observed with a fixed temperature mapping system (Fig. 2) mounted to cell 5 is shown in Fig. 3 for two highlighted field values. The quench was found on the weld.

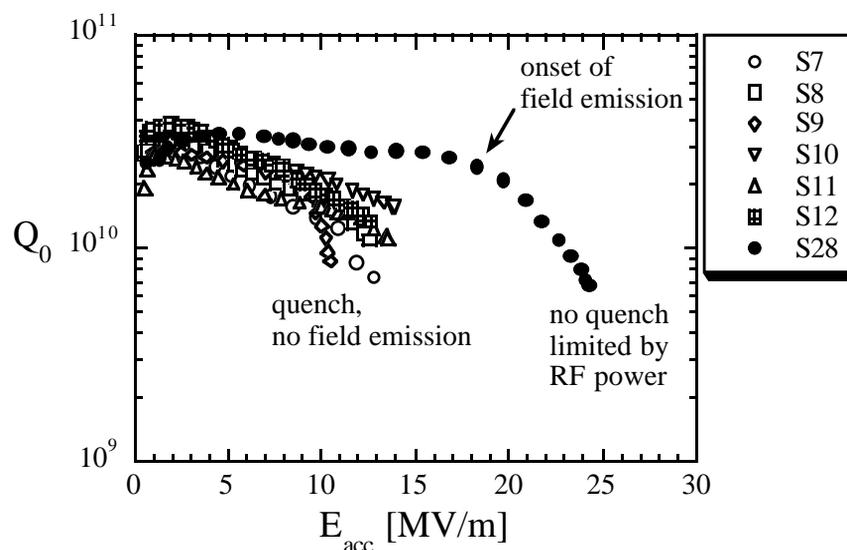


Fig. 1: Summary of the vertical test results on the S-cavities before (S7 to S12) and after (S28) improvement of the welding technique.

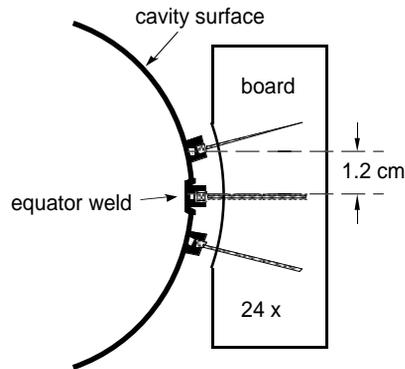


Fig. 2: Fixed temperature mapping system for studying losses close to the equator region.

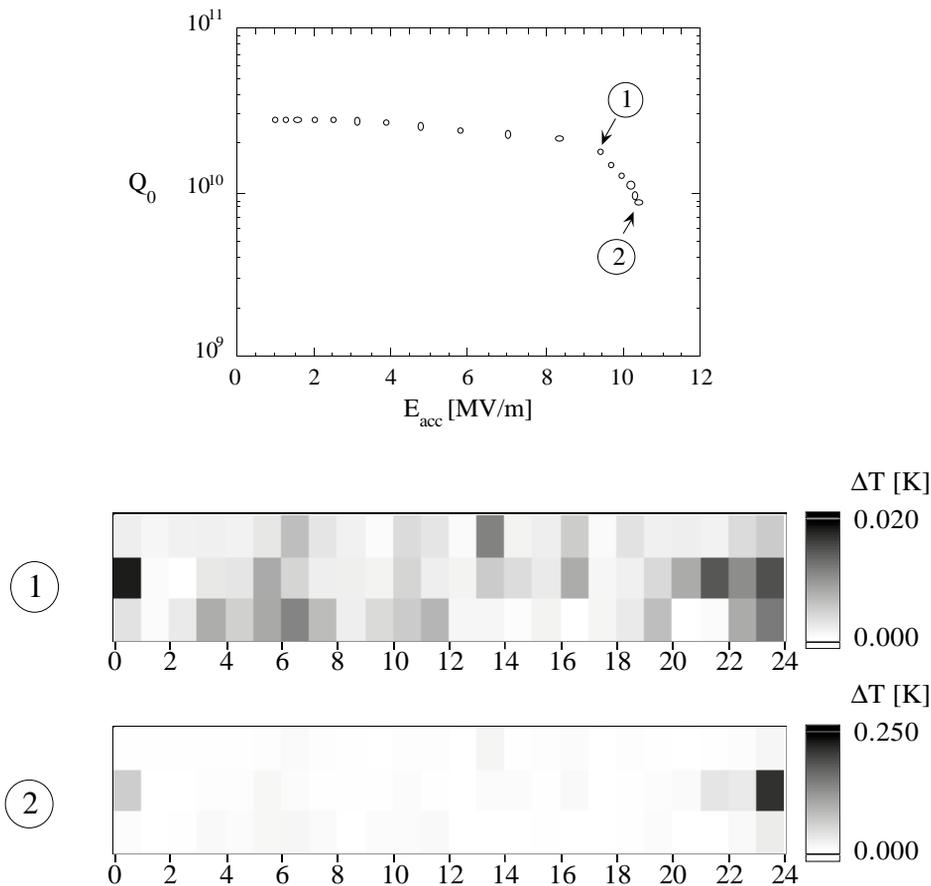


Fig. 3: Performance of cavity S9 and temperature maps at two highlighted points. The hot spot visible in the lower map is causing the quench

The temperature rise of some thermometers as a function of the magnetic field B on the surface is presented in Fig. 4. For a constant surface resistance a temperature rise proportional to B^2 is expected. An example of this kind of heating is shown for a thermometer above the equator at position of board 14. In contrast to that several thermometers on the equator weld show a B^n dependence with $n = 5$ to 8.

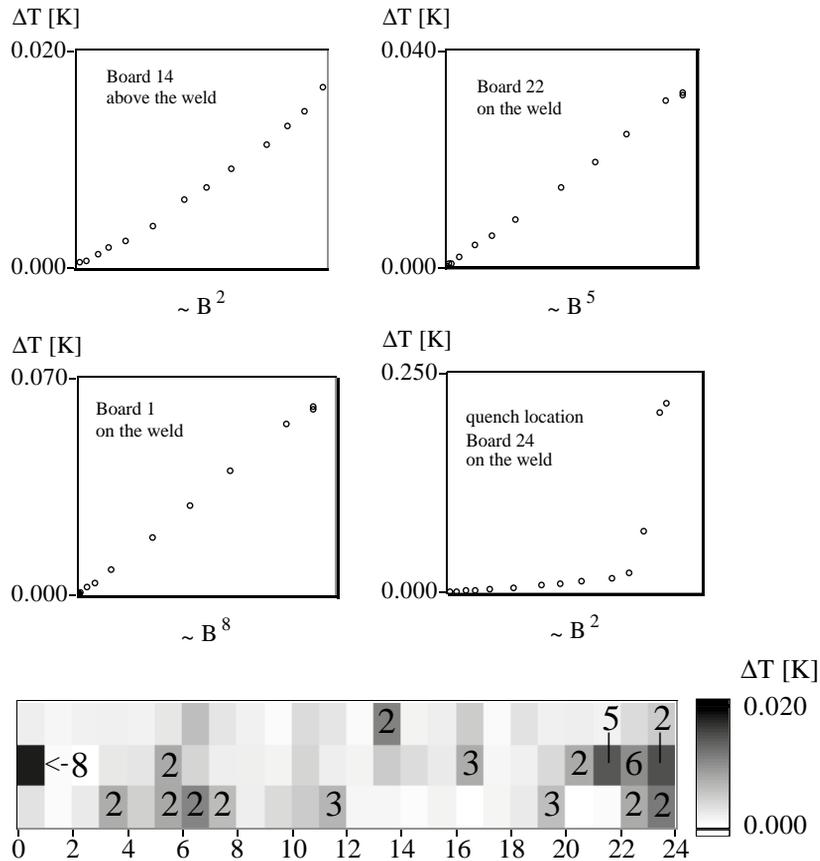


Fig. 4 Heating of some selected thermometers mounted to cell 5 of cavity S9 in dependence of the magnetic field B at the surface and distribution of the exponent n describing the B^n dependence of the temperature rise. Only on the weld $n > 3$ is found.

3. TEMPERATURE MAPPING RESULTS OBTAINED ON CAVITY S12

In cavity S12 all cells are limited close to 13 MV/m. The observed Q slope is related to an increase of the surface resistance with the square of the magnetic field B (Fig. 5). A rotating temperature mapping system [3] was used to localize quench locations. In four different cells on the equator weld defects responsible for quenches were found and equipped with the fixed temperature mapping system which has a 100 times higher sensitivity in superfluid helium since the thermometers are glued to the niobium surface. Only the four detected hot spots on the weld showed a B^n dependence with $n = 3$ to 5.

There is a linear dependence on the average temperature rise of the fixed thermometers to the power dissipated in the mapped area [4] which is plotted in Fig. 6. Because only a small fraction of the 9 cell cavity S12 was mapped with the fixed temperature system, the additional dissipated power of the major surface (not mapped) is assumed to be caused by a constant surface resistance of 12 n Ω . Under this assumptions the dissipated power of

the cavity at different gradients was calculated and the $Q(E)$ -curve could be constructed. The result is shown in Fig. 6 and compared to the measured $Q(E)$ -curve. The "Q-slope" is identical in both results leading to the conclusion that the defects in the equator weld are not only responsible for the quenches but are also the origin of the observed "Q-slope".

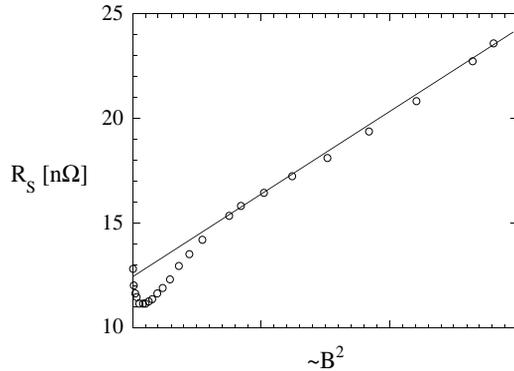


Fig. 5: Integrated surface resistance R_s at a bath temperature of 2.0 K as a function of the surface magnetic field B at the equator.

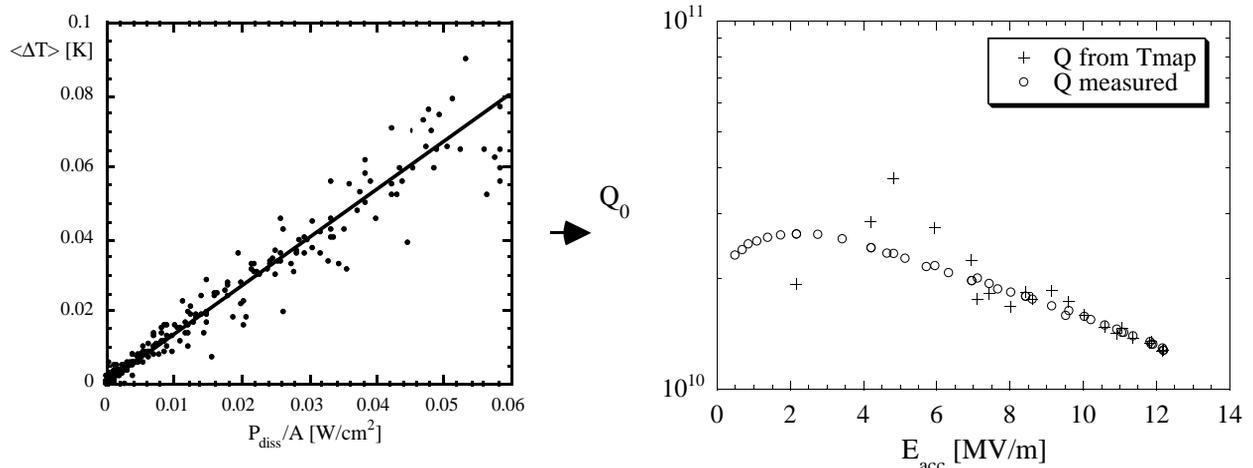


Fig. 6: Measured [4] linear dependence of the average temperature rise of the used fixed thermometers to the dissipated power deposited in the mapped area. With this dependence the $Q(E)$ -curve of cavity S12 could be reconstructed.

3. EDDY CURRENT SCANS OF THE EQUATOR WELDS

To further investigate the equator welds, an eddy current scanning apparatus was built [5]. In 3 of 5 cases a jump in the detector signal was observed when scanning along the defects in the equator welds. It was decided that only welds with no jumps in the signal during an eddy current check are accepted in the future.

4. RESULT OF THE NEW CAVITY S28

A new 9-cell cavity (S28) was made by the same company. Proper cleaning of the welding area by 2 μm chemical etching followed by rinsing in ultraclean water was done. A wiggled beam with first 50 % penetration and then overwelding with 100 % penetration was used at a vacuum in the 10^{-5} mbar regime leading to a smooth signal during an eddy current check. The RF performance of cavity S28 is shown in Fig. 1 and compared to the old results of cavities S7-S12. No quench was observed even at a field of 24.5 MV/m. No "Q-slope" was present.

5. CONCLUSIONS

Defects in the equator welds of cavities S7 to S12 observed with temperature mapping techniques are causing a local power dissipation increasing with the power of 3 to 8 of the magnetic surface field. The defects are responsible for an early quench and the observed "Q-slope". It is a fact, that this kind of defects could not be cured with heat-treatment at 800 °C or at 1400 °C. Also heavy etching of the inner surface (up to 350 μm) could not improve the RF performance. A cut out of such a defect and a microscopic investigation is not yet done. A cavity with improved welding technique showed no quench at a very high gradient and no Q-slope.

References

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