

ILC R&D Board Task Force on High Gradients (S0/S1)

Definition of Cavity Tests

L. Lilje

Version: 27-Jul-06

1.1 Introduction

One goal of the task force must be to define a test procedure which results in a data set comparable between the laboratories. Due to the significant differences in infrastructures the test procedures differ significantly today.

Several limitations can be observed in superconducting cavities. They will be very briefly described in the following to make the definition of the testing procedure more transparent¹.

- Field emission
 - Electrons are emitted from the surface (at e.g. protusions and dust particles). These are accelerated and generate Bremsstrahlung.
 - Field emission can lead to a thermal breakdown due to the heating of the electrons impinging on the surface.
 - Detection:
 - Exponential increase of surface resistance with increasing accelerating field
 - X-ray monitoring shows exponential increase with higher accelerating fields
 - Temperature mapping shows typical traces
- Thermal breakdown
 - Foreign material inclusions or particles on the surface heat up due to the microwave current. This heats up the surrounding niobium over its critical temperature and causes a runaway situation.
 - Detection:
 - Temperature mapping shows well identified hot area
- Multipacting
 - Resonant electron loading leads to the dissipation of heat at localised spots (e.g. equator two-point multipacting at 17-21 MV/m in TESLA shape)
 - Usually this can be processed by applying low RF power for some time
 - Detection
 - Temperature mapping shows localised spots (e.g. at equator)
 - X-ray monitoring shows signal in certain range of the accelerating field

¹ A more detailed description of limiting effects in superconducting cavities can be found in H. Padamsee, J. Knobloch, and T. Hays, RF Superconductivity for Accelerators, John Wiley & Sons, 1998.

- ‘Q-drop’ without X-rays
 - This mechanism is not yet fully understood, but is probably related to the oxygen concentration in the niobium surface layer. It can be cured by a low-temperature ‘in-situ’ bakeout at 120°C.
 - Detection
 - Exponential increase of surface resistance with increasing accelerating field
 - X-ray monitoring shows no signal
 - This is sometimes very difficult to differentiate from field emission in case there is a ‘small’ level of field emission as well.
 - Temperature mapping shows typically several hot spots in the high magnetic field region.
- ‘Q’-disease
 - Hydrogen contamination of the niobium during the surface preparation process (e.g. from electropolishing, etching or centrifugal barrel polishing) leads to very low surface resistance at low fields.
 - Detection:
 - This usually occurs after the cavity is kept in a critical temperature region of 80-120 K for several hours.

To diagnose these limiting mechanisms and localise the source several diagnostic methods are available:

- Measurement of the passband modes
 - To calculate the fields in the various modes, one assumes that the accelerating field is constant in each cell (‘Field flatness is o.k.’). I.e. there is no mechanical deformation which could lead to false information.
- Temperature mapping
- (X-ray mapping)

1.2 Define tests needed on a nine-cell cavity

A standard set of data from a vertical, low-power test for nine-cells to be obtained contains:

- A check for hydrogen contamination of the niobium material (Q-disease)
 - o Stay at 100K for 8 hours during cooldown
 - o As this test significantly extends the testing time for some labs, this can be omitted after confidence has been gained, that the processes do not contaminate the niobium with hydrogen.
- Q(T) measurement
 - o Gives information on the BCS part of the surface resistance. A high BCS resistance results from a contamination of the superconducting layer.
- All 9 passband modes have to be measured
 - o Help to localize the problem to pairs of cells
- Checks of frequency spectrum for possible detuning
 - o Deformation would lead to a unusable information from the passband modes measurement
 - o If the measurement is doubtful a bead-pull measurement needs to be done in warm conditions
- Temperature mapping (T-mapping)
 - o As outlined above the T-mapping can help to differentiate between the various mechanisms. There are two options:
 - Full rotating T-mapping of nine-cells
 - Usually the efficiency is lower as the thermal contact of the sensors with the niobium surface is less good.
 - Fixed T-mapping
 - Either at full nine-cell (lot of sensors) or cell pair under suspicion (implies additional cold test with passband mode measurement)
 - Sensors have very good contact. Good efficiency.

Further information to be provided with the data above includes:

- Continuous pumping during test or closed
 - o If closed, pressure and temperature before closing valve
- Cooldown speed
- Temperature difference over cavity during cooldown
- Method of low-power processing
 - o pulsed or continuous wave (cw)
- Coupler type
 - o fixed or variable