

# PERFORMANCE OF 3.9-GHZ SUPERCONDUCTING CAVITIES\*

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## Abstract

We report on the performance of 3.9 GHz SRF cavities built and tested at Fermilab for use in the DESY FLASH facility. Comparisons of performance in various test scenarios are presented. We also report on analysis of expected maximum performance.

## INTRODUCTION

Four 3rd harmonic nine-cell 3.9 GHz superconducting cavities will operate at a gradient of 14 MV/m in the TM<sub>010</sub> mode and will be placed in TTF/FLASH. These cavities are designed to linearize the accelerating gradient of the accelerator, providing improved longitudinal emittance.

## TESTING SEQUENCE

Once fabricated, each 3.9 GHz cavity goes through a sequence of processing steps prior to high power RF being introduced to the cavity. This has been described previously [1]. Following initial processing, all cavities are tested vertically in the Fermilab's A0 North cave test area. This test area consists of a shielded enclosure, cryogenic system, LLRF, and traveling wave Tube amplifier capable of providing up to 150 watts CW. A basic controls system allows for Labview™ applications, electronic logbook, and file archival.

## Vertical Tests

More than fifty cold vertical tests have been conducted to date. Figure 2 shows the Q vs E slope for all such tests. Recently, cavities have been operated at the default operating temperature of 1.8K as well as the operating FLASH temperature, 2K. One can note that with few exceptions, cavities are able to achieve gradients well in excess of the goal of 14 MV/m. Several factors limit ultimate cavity performance in this stage. In best cases the limit is the available RF power. Excessive x-ray emission suggesting a need to re-rinse or, in isolated cases, repeat a BCP is not uncommon. Performance of cavities fitted with HOM feedthroughs tend to be limited by heating or quenching of one or both HOM's.

The number of tests per cavity have ranged from as few as 3 (for #7) to 14 (for #6) in the case of poor-performing cavities. All cavities destined for the next step in processing must achieve the cavity performance parameters and gradients at least 20% better than the goal of 14 MV/m. Figure 1 shows the Q vs E result for the four cavities passing the vertical test and welded into helium vessels.

Table 2: Summary of Best Performance in Vertical Tests

| Cavity | # of tests | E <sub>max</sub> (MV/m)                    | Status  |
|--------|------------|--|---|
| #1     | n/a        | n/a  | Prototype; used as test bed   |
| #2     | 6          | 12   | Fractured HOM formteils; to be repaired   |
| #3     | 10         | 24.5 @ 1.8K<br>20.27 @ 2K                  | Welded into helium vessel; dressed; being prepared for horizontal testing         |
| #4     | 10         | 24.27 @ 1.8K                               | Final vertical testing in progress  |
| #5     | 4          | 24 @ 1.8K<br>Horizontal test:<br>22.5 @ 2K | Welded into helium vessel; Horizontal testing completed; awaiting string assembly |
| #6     | 14         | 22.5 @ 1.8K                                | Weld repair, plasma processing attempted to improve vertical test performance     |
| #7     | 3          | 24.5 @ 1.8K<br>19.17 @ 2K                  | Welded into helium vessel; awaiting dressing & horizontal testing                 |
| #8     | 5          | 24.5 @ 1.8K                                | Welded into helium vessel; awaiting dressing & horizontal testing                 |

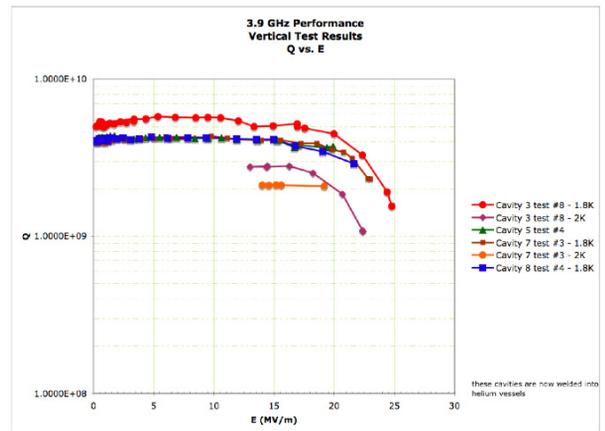


Figure 1: Q vs. E slope for 3.9 GHz cavities welded into Helium Vessels.

Recently, one cavity, #3, has undergone a final vertical test after being welded into a helium vessel, but prior to dressing. As the schedule permits, additional cavities may be subjected to this intermediate step.

Two production cavities, #4 and #6, remain to complete vertical testing owing to recent problems with vacuum system contamination and High Pressure Rinse system failures.

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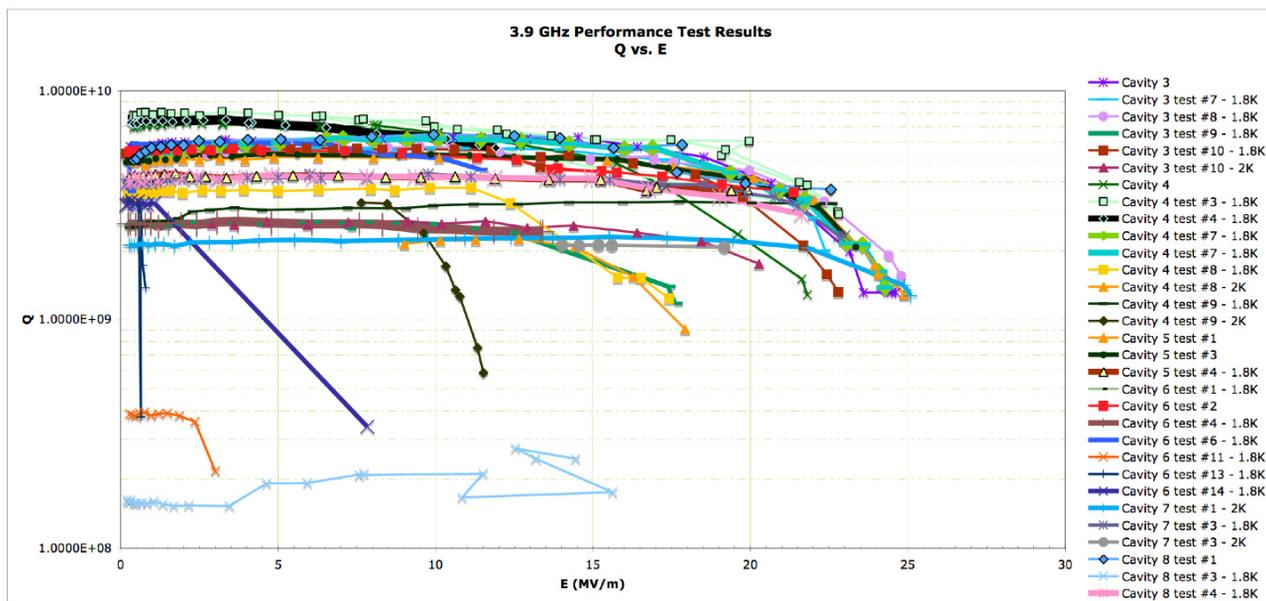


Figure 2: Vertical Test Performance of 3.9 GHz cavities. A handful, roughly 15%, indicate significantly poor performance.

*Horizontal Testing*

After vertical testing is completed and a cavity dressed, it is subjected to additional RF testing in a horizontal configuration. As of this writing only one cavity, #5, has been completed this sequence. A description of the Horizontal Test Stand (HTS) and the test of #5 has been reported elsewhere [2].

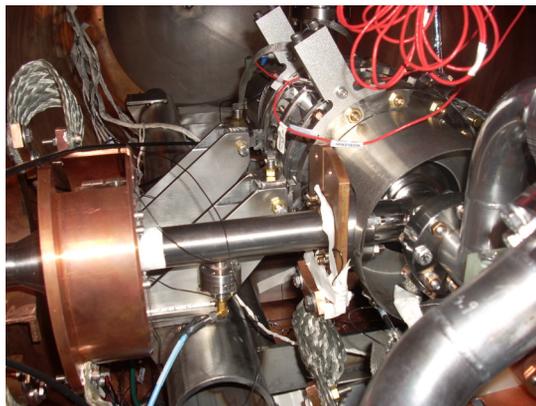


Figure 3: Cavity #5 mounted in the HTS.

This horizontal test with RF power was carried out over the period from early April through August 2008. Early on it was observed that 5 Hz operation led to unacceptable heating of the HOM coupler feed throughs. Various heat intercept schemes were attempted and each such iteration required a complete warm-up and cool down cycle. Future horizontal tests will benefit from this exercise.

Cavity #5 is now deemed ready for string assembly. Recently Cavity #3 was pressure tested and is being readied for horizontal testing.

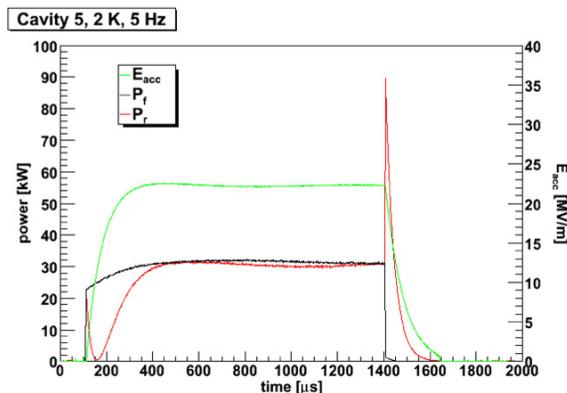


Figure 4: Cavity 5 performance in HTS just below its quench limit.

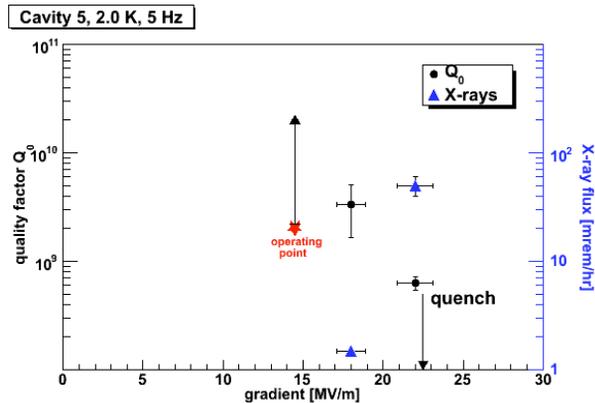


Figure 5:  $Q_0$  vs.  $E_{acc}$  and X-rays vs.  $E_{acc}$  curves for Cavity #5.

## THERMAL ANALYSIS

The cavity performance data as shown here is quite reproducible and indicates a limit of about 24-25 MV/m for these cavities. It becomes interesting to try to perform a simple thermal analysis to compare with the measurements. Such an analysis might give an indication as to how close the global thermal breakdown limitation is being approached and is reported previously [4].

## SUMMARY

Fermilab is in the process of providing a 4-cavity 3.9 GHz cryomodule to DESY for installation in the FLASH facility. Most cavities perform well in excess of the design gradient of 14 MV/m. A sufficient number of cavities have now passed vertical testing and have helium vessels welded onto them. Horizontal testing of dressed cavities is in progress and string assembly will shortly commence.

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## REFERENCES

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