SPARK LOCATION IN RF CAVITIES

Q. Kerns, M. Popović and C. Kerns
Fermi National Accelerator Laboratory[*]
P.O. Box 500 Batavia, Illinois 60510, USA

Abstract

A spark detection system was constructed at the test station for the 400 MeV Linac Upgrade at Fermilab. To locate sparks in RF Cavities we placed five Ion Gauge Detectors along an accelerating module. The method used in detecting the spark location is based on the fact that sparks create pressure disturbances which travel throughout the cavity. Pressure signals from all five detectors are amplified using relatively fast amplifiers and then digitally recorded or monitored on the scope. The data recording is triggered by spark generation and data are recorded at a 15 Hz repetition rate. The system was also used to study different schemes for preferential spark generation at times that would be least detrimental to accelerator operations.

INTRODUCTION

The Fermilab Linac Upgrade has increased the energy of the H^- linac from 201 to 401.5 MeV[1]. This was achieved by replacing the last four 201.24 MHz drift-tube linac cavities with seven 804.96 MHz side-coupled cavity modules. Each module, is made of four sections of 16 accelerating cavities (Figure 1). They operate in a $\pi/2$ mode, and each accelerating cell is coupled to the next by a coupling cell. The end coupling cell is connected to a bridge coupler. The bridge coupler passes the RF power from one section to the next around the quadrupole magnet. The power is fed to the module through the center bridge coupler. Up to 12MW of RF power is pulsed at 15Hz for 60 - 120 microseconds.

Since the new side-coupled linac had to fit in the space vacated by the last four drift-tube tanks and provide more energy gain, the accelerating gradient had to be about 7.5 MV/m or about three times higher than in the DTL. This high gradient lead to concern early in the project that sparking could reduce the reliability of the linac to an unacceptable level. The purpose of the upgrade was to increase the beam intensity in the 8 GeV Booster and thus increase the luminosity of the collider. Too much sparking would reduce reliability and reduce the average beam intensities delivered[1]. Another concern was that too much sparking if localized at one spot could permanently damage an accelerating module. To resolve such questions, we constructed a spark detection system used during cavity testing in 1991 and 1992 which is described in next section.

METHOD

To locate sparks in Linac Upgrade side-coupled cavities we placed five ion gauge detectors as indicated in Figure 1. The method used in detecting the spark location is based on the fact that sparks are creating pressure disturbances which travel through the structure. The detector which is located the shortest distance from the spark will detect the largest and sharpest pressure burst. Due to the fact that cavity modules are very complicated internally (Figure 2), we were able to locate spark positions only approximately with our method. Pressure signals from the five detectors are amplified using relatively fast amplifiers and then digitally recorded or monitored on the scope. Input currents from the ion gauges range from 3 nA to 1 μa and the response time of the system is about 300 μsec.

Figure 3 shows signals from the five ion gauges during a 15 minute period. Sharp spikes (in arbitrary units) show when sparks were detected by these devices during this period. Continuous monitoring has lead us to the conclusion that the majority of sparks do not occur in the side-coupling cell. During steady state, the coupling cells do not dissipate much power. However, while the cavities are filling and emptying this may not be the case. In the structures such as these, with high fields, this power dissipation can produce high currents and voltages that may lead to sparking in areas other than the accelerating-cell nose cones. We were able to monitor the field in each accelerator section and did not see a large number of sparks generated during the filling or decay of the RF power. Based on this, we believe that most of the sparks are generated at accelerating-cell nose cones.

To locate the approximate location where a spark has occurred, we have used pressure data recorded for about 3 seconds after a spark occurrence. Each frame in Figure 4 represents signals from Ion Gauge Detectors as a function of time. The data recording is triggered by a large reflected RF power signal. The data are recorded for fifty 15 Hz intervals after the large reflected RF power is detected. The four frames are traces of pressure bursts created by four different sparks. In Frame 1, Ion Gauges 1 and 2 have recorded pressure bursts. From the relative sizes of the peaks we can conclude that spark has occurred in Section 1 in the region between Ion Gauge 1 and bridge coupler connecting Sections 1 and 2. From similar traces in Frame 4, we can conclude that a spark has occurred in the central bridge coupler on the end connected to Section 3. The vertical axis is in arbitrary units, and the vertical label is a time record denoting when the spark occurred. The 91100214543713 stands for 91/10/02 (Oct-02-91) at 14:54:37 and 13th of 15Hz pulses.

A spark detection system was also used for monitoring the randomness of spark generation. A concern was that too much sparking at one spot could permanently damage an accelerating module. Figure 5 shows a number history of spark accumulation as recorded by five ion gauges. During a period of 14 hours (7.56×10^5 RF pulses), there were 418 sparks. As can be seen from Frame 1, Section 1 was initially very active, but a majority of the sparks occurred in Section 4. Close examination of

[*]Operated by the Universities Research Association under contract with the U. S. Department of Energy

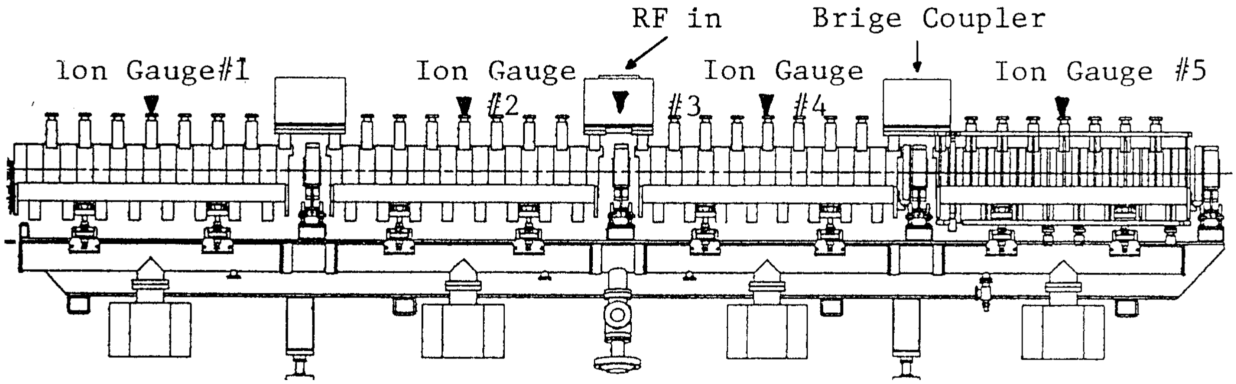

Figure 1. Side-Coupled Cavity Module

individual traces did not show any accumulation at a particular spot. During the conditioning period no consistent pattern was found in the distribution of sparks. A section may be active for a couple of hours and after that remain quiet for a day or two. The bridge coupler was generally a place with minimal sparking.

CONCLUSION

Although initial voltage conditioning of the high-gradient 805 MHz side-coupled modules did not progress as quickly as hoped, the method presented here gave us confidence to proceed with high power RF conditioning even at high sparking rates. Today the sparking rate in the operating 400 MeV linac is bellow 0.01%, and sparking does not have any noticeable effect on operations.

References

[1] T. Kroc et al, "Fermilab Linac Upgrade - Module Conditioning Results", Proceedings of the 1992 Linac Conf., pp. 187 - 190.

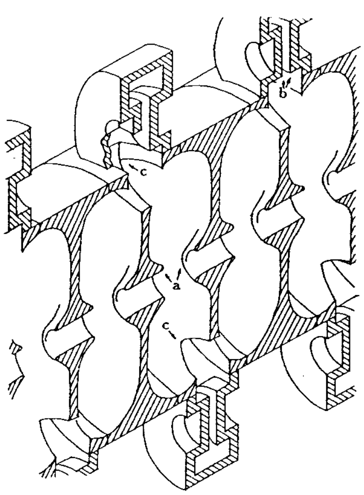

Figure 2. Possible spark locations: a) accelerating-cell nose cones, b) coupling-cell nose cones, c) coupling slots

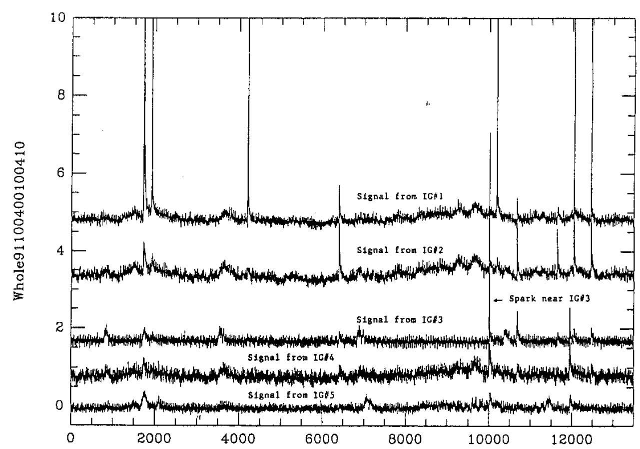

Figure 3. Continues recording for 15 minutes (13500 RF pulses)

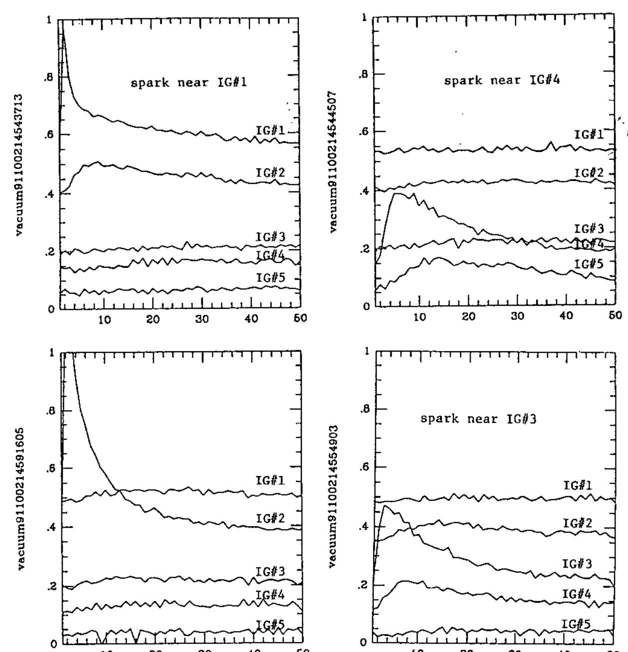

Figure 4. Ion Gauge signals created by four different sparks

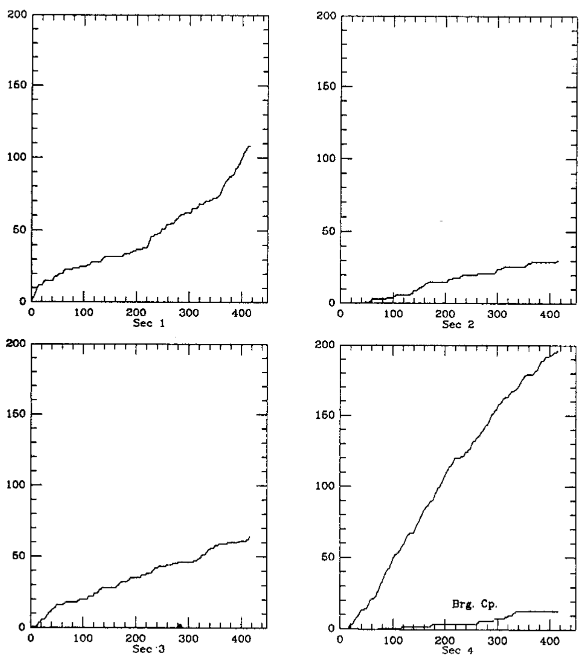

Figure 5. Ion Gauge signals created by four different sparks