#2

CONF-9208109--77

Fermi National Accelerator Laboratory

FNAL/C--92/388

DE93 008880

Fermilab Linac Upgrade – Module Conditioning Results

T. Kroc, A. Moretti and M. Popovic

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

December 1992

Presented at the *16th International Linac Conference*,
Ottawa Ontario, Canada, August 1992

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CHO3000 with the United States Department of Energy

Disclaimer

FERMILAB LINAC UPGRADE – MODULE CONDITIONING RESULTS

T. Kroc, A. Moretti, M. Popovic
Fermi National Accelerator Laboratory *
Batavia, Illinois 60510

Abstract

The 805 MHz Side-coupled cavity modules for the Fermilab 400 MeV linac upgrade have been conditioned to accept full power. The sparking rate in the cavities and in the side-cells has been reduced to acceptable levels. It required approximately 40×10^6 pulses for each module to achieve an adequately low sparking rate. This contribution outlines the commissioning procedure, presents the sparking rate improvements and the radiation level improvements through the commissioning process and discusses the near-on-line commissioning plans for this accelerator.

Introduction

The Fermilab Linac Upgrade involves the replacement of four of the present linac's drift-tube cavities with seven side-coupled structures. These seven structures, called modules, are each made of four sections of 16 accelerating cells each. They operate in the $\pi/2$ mode so each accelerating cell is coupled to the next by a coupling cell. At the end of each section within a module, the end coupling cell couples to a bridge coupler of length $3\beta\lambda/2$. This bridge coupler passes the RF power from one section to the next. The power is fed to the module through the center bridge coupler. It then passes through the two center sections, through the two outboard bridge couplers, and into the outer two sections. The operating frequency is 805 MHz which is pulsed at 15 Hz for 60 - 120 microseconds.

In a previous paper [1] we reported on observations we made on the conditioning of prototype cavities. These structures were composed of combinations of two, three, and six cells with two different nose-cone profiles. The six-cell cavities were powered singly and coupled to either the two- or three-cell cavities. Also, two sixteen-cell sections with the production nose-cone profile were individually powered. These tests were done with a Litton L-5120 klystron producing 1.5 to 3 MW.

This paper reports on observations made on the conditioning of full modules and compares these observations to the results from operating the prototypes. The modules were powered with a Litton L-5859 Klystron producing up to 12 MW.

Motivation

Since the side-coupled cavities for the linac upgrade have to fit in the space vacated by the drift-tube cavities and yet must double the output energy of the present linac, the accelerating gradient is much higher than one would choose for a completely new machine. This high gradient leads to concerns that sparking will reduce the reliability of the linac to an unacceptable level. The purpose of the linac upgrade is to increase the luminosity of the collider; too much sparking would negate this. Another consideration is that high sparking levels would lead to high beam losses and high activation. The goal that was chosen was that sparks should occur in less than .1% of the RF pulses. Finally, there was concern about the level of x rays produced by the cavities and their effect on organic materials in the area.

Based on the results of conditioning the prototype cavities, we felt that the sparking rate was a continuously decreasing value as a function of the total number of RF pulses. The decrease was exponential but would attain our goal within 10 to 20 million pulses. X-ray production was acceptable and could be reduced by applying high power to the cavities. This presumably burned off field emission sites.

The results of the conditioning of the full production modules were not as straight forward. While the behaviour of the x-ray production was very similar to that of the prototypes, the behaviour of the sparking has been quite different.

Results from Production Modules

The results presented here are based on the conditioning of six modules which have accumulated between 10 and 50 million RF pulses each. The behavior of the x-ray production was the same as was observed with the prototype cavities. The behaviour of the sparking has been quite different. Some cavities have been reopened for visual inspection of the structure. Based on this and other clues, new types of sparking are suspected that seem to have altered the conditioning rate. These new categories seem to interfere with one of the trends used in analysing the prototypes. Therefore, this trend could not be verified with the production cavities.

Figure 1 is a plot of the spark rate as a function of the number of RF pulses accumulated by that cavity. The data from the first 20 million pulses for each cavity, prototype and production (12 cavities in all), are plotted. The

---

*Operated by the Universities Research Association, Inc. under contract No. DE-AC02-76H03000 with the U.S. Department of Energy.

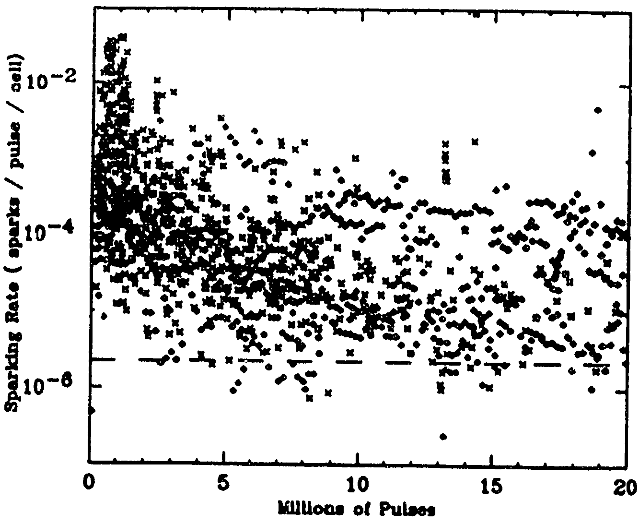

Fig. 1. Plot of the spark rate during the first 20 million pulses for all cavities tested. Points are actual rates; no scaling power level has been used.

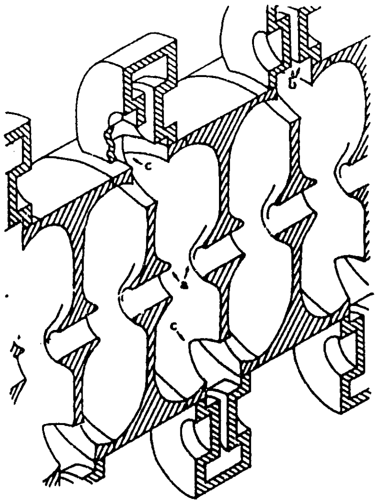

Fig. 2. Spark locations: a) accelerating-cell nose cones, b) coupling-cell nose cones, c) coupling slots.

points representing the individual conditioning histories for each cavity are not connected as the figure would be too confusing. Rather, the data are presented as a sort of scatter plot that illustrates the range of values for the sparking rate. The dashed line shows the target rate that corresponds to .1% for the full linac. In our previous paper we used a scaling to normalise all the various power levels to the nominal level that produced the desired accelerating gradient. This produced nice smooth curves that showed steady progress towards the target rate. We now feel that this scaling is only valid for sparking that occurs between the nose cones in the accelerating cells (Fig. 2a, other types of sparking will be described later). Therefore, we were not able to use this scaling for the data from the production cavities. The data in Figure 1 is for all power levels. Although no definitive distinction can be made, the data from the prototype cavities tend to populate the darker band in the lower left of the distribution. The production cavities tend to populate the more diffuse upper right.

When the conditioning of the production cavities did not progress as hoped, a number of things were investigated and tried. Module 1 was opened and the interior was examined. Evidence was found for sparking in places other than the nose cones of the accelerating cavities. Figure 2 shows these locations.

During the 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 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. There are three places where we felt this occurred. One was the gaskets between the cavity structures and the bridge couplers. When the first module was opened, we found evidence of sparking in this area. The original design of the gaskets had the mating faces close together but not quite touching. The gaskets were redesigned to open up this area and the sparking there disappeared. The second area is the coupling-cell nose cones (Fig. 2b). The third area is in the coupling slot between the side cell and the accelerating cell (Fig. 2c). This slot is in the shape of an American football due to the intersection of the toroidal accelerating cell and the disk shaped cavity of the side cell. Again it is felt that high voltages and currents form on the edges of this opening, especially at the point.

The sparking rate of the last two new areas does not seem to follow the scaling law discovered with the prototypes. A number of things were tried but were unsuccessful. We were able to monitor the field in each section and to count the number of sparks that originated in each section. No consistent correlations were found that would assist in either predicting the sparking rate nor suggest solutions. Still it is hoped that the problem is that the fields in this area during the transients are high enough to induce sparking but do not last long enough to quickly clean the area. If this is true, with time they too will condition.

The only successful method of coping with the present sparking rate has been to adjust the length of the RF pulse. We originally planned to use a 120 μsec pulse to match that of the present linac. However as figure 3 shows, the sparking rate is strongly dependent on the pulse length (the curve is a fourth order fit). This was not noticed with the prototypes. A 65 μsec pulse is sufficient for the linac's needs. Using this pulse length has brought us to within a factor of 2 of our sparking rate goal.

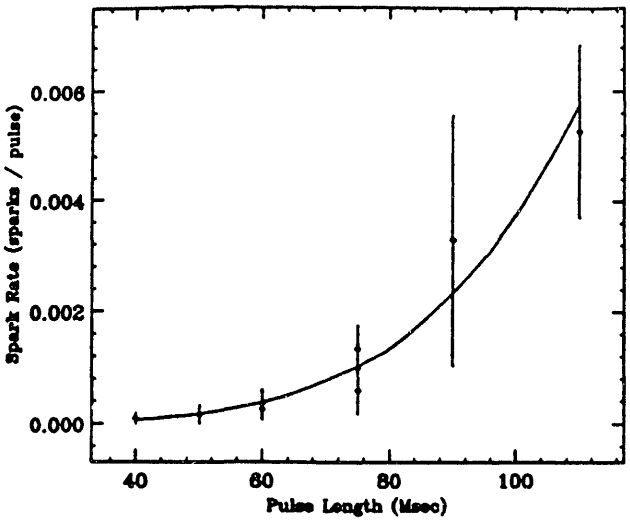

Fig. 3. Sparking rate as a function of the RF pulse length. The curve is a fourth order fit.

A final attempt to manage the present spark rate has been to adjust the power output of the klystrons to induce sparks. Figure 4 is a histogram of the interval between successive sparks. It shows that the probability of a spark occurring is approximately inversely proportional to the time since the previous spark. The spikes that start at about 1000 are the result of an attempt to manipulate the timing of the sparks. At Fermilab, the linac does not produce beam continuously. By raising the power level above nominal at the proper time it is hoped to be able induce the sparks to occur when we don't care about them and that the induced sparks will clean things up for when we want beam. While this would raise the overall sparking rate, it would result in a decrease in the spark rate during beam time. If the probability of sparking is purely an inverse relationship, this will not work. However, initial trials of this procedure (resulting in the spikes in figure 4) have given encouraging results. If this procedure works then the sparking probability leading to figure 4 also has other components buried in it.

X rays

In comparing the behavior of the full modules to the prototype cavities, no significant changes have been observed in the behavior of the x-ray production. The dependence of the x-ray dose on the electric field in the cavities is still rises as the 10th power of the field. Projections of the dose that will be absorbed by organic materials near or on the modules gives a life of at least 20 years.

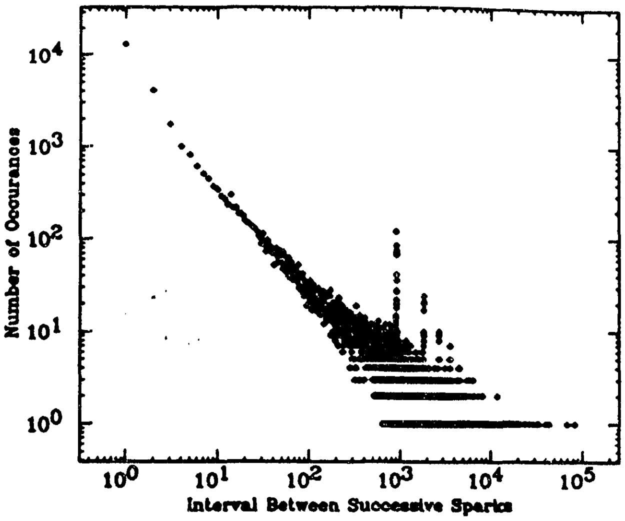

Fig. 4. Histogram of the interval between successive sparks.

Future Plans

All cavities have now been placed in the linac tunnel along side the present linac. They are currently being connected to the klystrons and will be powered in this location for a few months. During that time, the conditioning of all the cavities can be completed and the features discussed above will be investigated more thoroughly. Remedial actions will continue to be tried to ensure the reliable production of beam.

Conclusion

Initial conditioning of full modules for the Fermilab Linac Upgrade has been completed. While the x-ray production is understood, the progress in the conditioning of the sparking has not progressed as predicted from the behaviour of prototype cavities. New sparking sites have been discovered. Various observations are being made and remedial actions evaluated.

References

[1.] T. Kroc and A. Moretti, Proc. 1990 Linear Accelerator Conf.,(LA-12004-C, Los Alamos, 1991), pp. 102-104.

END

DATE
FILMED

5/03/93