FERMILAB LINAC 1997-98 OPERATIONS, STUDIES AND IMPROVEMENTS

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Abstract

The Fermilab Linac operated as an injector for the Tevatron Fixed Target Program, booster studies and as a neutron source for cancer treatment during 1997 and 1998. Operational reliability was 98% of the scheduled operating time. Beam currents were generally in the 45 to 48 mA range with a high of 52 mA during studies. After completion of the Fixed Target Program, the Linac embarked on a series of studies. The studies were intended to verify visual survey data indicating a misalignment of the low energy linac, correct the misalignment, and install and use new wires for determining emittance. Operations data and studies results will be presented.

1 OVERVIEW

The Fermilab Linac operates at 400 MeV for linac studies and injection into the 8-GeV Booster for further studies and high energy physics (HEP). It also operates at 66 MeV as a neutron source for treating cancer in the Neutron Therapy Facility (NTF). There are two ion sources, feeding DC accelerating columns powered by Cockcroft-Walton generators at 745 kV. The Linac RF pulse repetition rate is 15 Hz, useable RF pulse length is 120 µsec and the maximum source beam pulse length is ~80µsec. The operating beam pulse length is dependent upon on its ultimate use and determined by choppers in the 750-keV line. Pulse lengths for HEP beam are determined by the Booster requirements, typically 15-25 µsec. NTF uses the unused 15-Hz pulses with a 57-µsec length. Linac studies use typically a 20 µsec pulse generally at 3 Hz.

2 FIXED TARGET RUN

In 1996 and 1997 Fermilab operated a Fixed Target Run providing 800-GeV beams to experimenters in the external beam-lines and 8 GeV antiproton beams to experimenters in the Accumulator Ring. The Linac provided 12 pulse bursts of beam for HEP and single pulses at 2.5 second repetition rates for antiproton production along with NTF. In September 1997 the Fixed Target program ended and the Linac embarked on a one year program of maintenance and studies with the Booster. Aside from the usual preventive maintenance a drift tube was replaced in tank two, a resurvey was done and scanning profile wires were added at the 400-MeV output of the Linac. Studies included the sampling of drift tube quadrupole placement to investigate a suggested vertical misalignment between tank 5 and the high-energy linac.

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Beam intensity, during the Fixed Target Run, averaged 45 to 48 mA as shown in Figure 1. Problems with the 2400 l/sec ion pumps used to maintain column vacuum on the preaccelerators, forced the use less efficient roughing turbo pumps. The resulting increase in pressure reduced the intensity slightly until they could be rebuilt. After the run was over and beam level safety permits were readjusted the Linac achieved 52 mA.

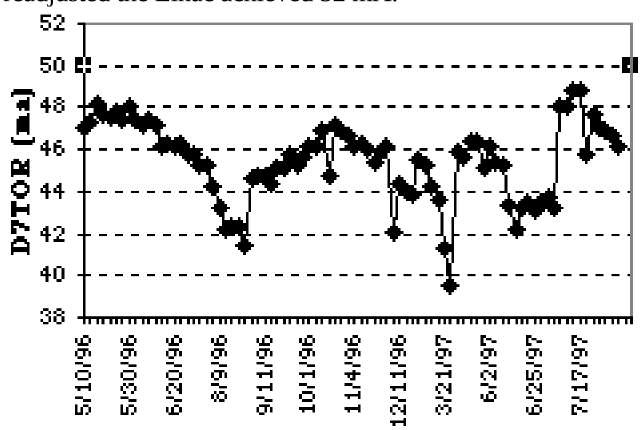

Figure 1. Linac intensity during fixed target run.

There are 35 loss monitors in the high-energy linac. They are of the Tevatron type [1] with Main Ring style amplifiers. They are not calibrated, but used as tuning aids and for comparison with previous data. The maximum value of the relative computer signal is 100 equivalent to 10V from the amplifier. By saving and averaging these values the tuning quality and level of losses in the Linac can be monitored. Reviewing this average since the high-energy linac was installed, Table 1, shows that the losses have decreased especially in the RF accelerating structures. Typical beam loss through the Linac from tank 2, after the beam has been captured, to the 400-MeV output is ~1% or less. Of the 65-70 mA of the preaccelerator beam 70% or more is captured in tank 1.

Table 1. Relative beam loss levels for each period for the total Linac structures and along the RF accelerating cavities.

Time	Whole Linac	RF Cav. Only
March, 1994	3.06	2.18
Beginning of run	2.82	1.43
End of run	2.61	0.95

Linac operated for 98% of the 10442 scheduled operating hours. As has historically been the case the vast majority of downtimes are very short. There were 1166 downtime entries, of which 80% are less than six minutes and while 4% are one hour or longer they account for 66% of the 212 hours of downtime. Downtime by major system is shown in Fig. 2. The three major causes of downtime during the run were; the failure and replacement of klystron 3, replacing the power amplifier for low energy RF station 4 with an unconditioned spare and multiple failures of the SCR switches in klystron charging supplies and PFN's.

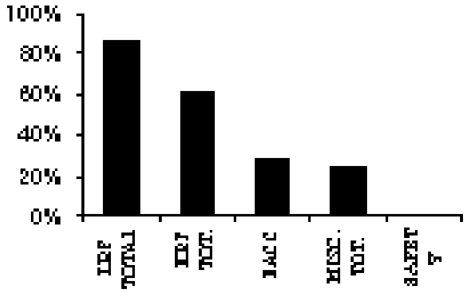

Figure 2. Linac downtime for fixed target run by major system

Klystron 3 was the first failure of a klystron and caused 7.8% of linac downtime. Being the first klystron to fail in use from aging, it had ~35,000 hours of operating time, the problem was at first unclear. Diagnosing the klystron emission failure, assembling the people and replacing the klystron assembly required a total of 16.5 hours over two days.

The power amplifier for RF station 4 was the last in an series of 7835 failures during a time when the test stand was unavailable for conditioning spares due to moving the test stand and an error by the manufacturer for a new dummy load. Total downtime for this failure was 7.4% of the linac downtime.

There have been repetitive problems with SCR switches and other components in the charging supplies and PFN's for the klystrons. This has caused 10.3% of the linac downtime. Solutions have been implemented and the failure rate has decreased dramatically.

3 STUDIES

In an effort to confirm survey data which showed a vertical misalignment between tank 5, the last tank of the low-energy linac, and the beginning of the high-energy linac, studies were done of the beam centering for each of the drift tube quadrupoles. This procedure was first used about ten years ago and now repeated where the current of each drift tube quadrupole pair (in the Fermilab Linac the DT quads are connected in FD pairs except for the two at the beginning and end of each tank) is individually changed by 10% up and/or down. The resulting beam motion at a downstream position detector (BPM or wire scanner) gives an indication of the beam centering at the changed DT quadrupole. If the beam center coincides with the magnetic center of the quadrupole, no motion of the beam center at the detector is observed. However, if the beam is off center relative to the quadrupole, when the current is changed a kick is given to the beam. This kick would then start an oscillation which continues down the Linac to be observed at an appropriate position detector. Usually two detectors, ~90^{O} apart in phase and at the farthest downstream position of the Linac are used so all DT quad positions could be observed relative to the same detectors. This is analogous to observing beam motion due to quadrupole misalignment in a transport line.

This procedure was used on the Linac in the late 1980's and predicted a large quadrupole misalignment in tank 2 by showing a cusp in the data. The drift tube was subsequently found to be off center by 1 mm. After correction the cusp was gone and the downstream beam oscillations reduced. It also indicated tank misalignments by showing increased errors from one tank to the next. Figure 3 shows a typical set of measurements for the old Fermilab Linac before tanks 6 through 9 were removed and replaced by the side-coupled cavities. The low errors in tanks 7, 8 and 9 are a result of steering magnets at the entrance and exit of tank 6 (~90% separated in phase) to remove beam errors and have the beam leave the Linac on axis of the 200-MeV beam line.

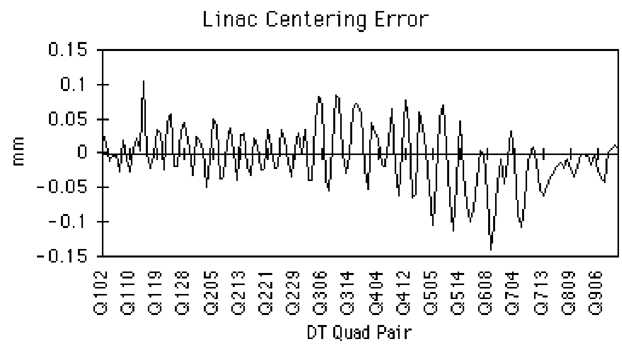

Figure 3. Detected beam motion for a 10% decrease in each Linac DT quad pair.

Recently similar measurements were made for the current Linac, figure 4, and consentrating on tank 5, figure 5. The mismatch in tank 5 is a result of beam leaving the tank off axis and at an angle for lowest losses in the high-energy linac. The steering magnets at the beginning of the high-energy linac were on hard to correct the angle. Moving the downstream end of tank 5 down 0.75 mm as indicated by the survey and beam, reduced the mismatch, allowed steering changes to reduce the errors in tank 5 (see figure 6), decreased the steering at the beginning of the high-energy linac, and reduced the losses significantly throughout the high-energy linac.

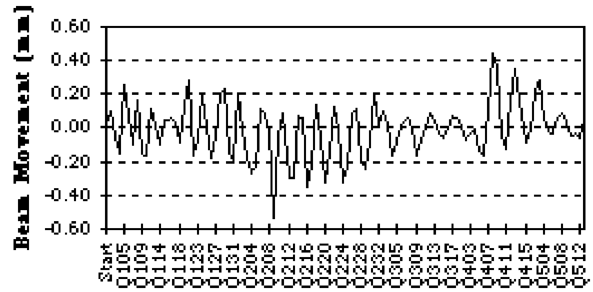

Figure 4. Recent detected beam motion for a 10% decrease in each Linac DT quad pair.

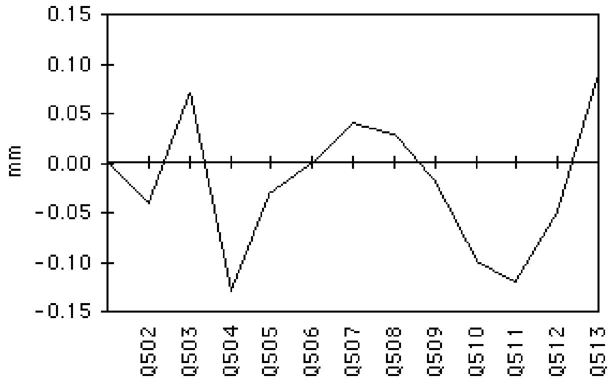

Figure 5. Error measurements before tank 5 change.

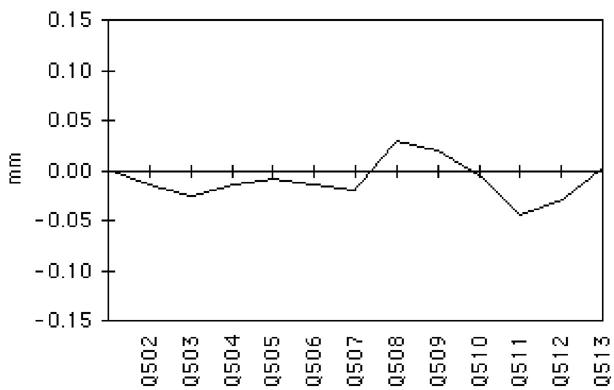

Figure 6. Repeat of figure 5 after lowering the downstream end of tank 5.

The condition of tank 5, indeed the complete Linac, depends on the tuning of earlier components. Tank 5 does not remain this good at all times, never-the-less the losses in the high-energy linac have remained very low. Table 2 shows current loss averages. Some loss monitors were moved to places where they are more sensitive to beam loss.

Table 2. Losses after moving tank 5.

Time	Whole Linac	RF Cav. Only
After studies	2.17	1.20

4 IMPROVEMENTS

During the recent shutdown, three wire scanners were installed in a drift space just beyond the 400-MeV output on the Linac. These wires will give better monitoring of the beam size, position and emittance leaving the Linac.

REFERENCES

[1] M. Johnson, "Loss Monitors". AIP Conference Proceedings 212 Accelerator Instrumentation, 1989, pg. 156.