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## A 200-MHz DEBUNCHER FOR THE FERMILAB INJECTOR

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Because of the severe demands made on the rf accelerating system of the Fermilab booster by a very large frequency range and a 15-Hz sinusoidal accelerating cycle, it is necessary to keep the momentum spread of the beam injected into the booster to a minimum.

Although the momentum spread of the beam as it leaves the linac is comfortably within the design specifications, space charge effects in the 200-MeV transport line and in the booster increase the momentum spread of the debunched beam.1,2,3,4 The phase space density of the beam is further decreased during capture in the booster because the magnetic field is changing during capture and because the capture process is not completely adiabatic.5,6

The linac should be adjusted to provide a beam of minimum energy spread which is then allowed to drift until the phase spread of the beam covers the linear part of the rf waveform in the debuncher. The debuncher then rotates the beam in energy-phase phase space for a lower energy spread. This entire process is linear except for the effects of space charge forces. At Fermilab the drift distance from the linac to the debuncher is only about 42 meters, so the beam is spread over only 20 degrees in phase at the debuncher when the linac is adjusted for minimum energy spread. The space charge forces are large not only before the debuncher, but also after the debuncher because the beam is still relatively tightly bunched. Optimum conditions would require the operation of the linac with an initial momentum spread of ±0.25% in order to make the beam spread out more rapidly to cover  $\pm 30^{\circ}$  in the debuncher and to decrease the aberrations caused by the space charge forces. As soon as the permanent rf system for the debuncher is installed, the linac will be readjusted to provide the larger initial momentum spread that is desired.

Although the debuncher was installed primarily to reduce the effects of space charge forces, there is an additional very great advantage to its use. It automatically corrects small errors in mean momentum from the linac and, as a result, makes it possible to operate the linac at higher currents than would be allowed without the debuncher.

The Fermilab debuncher is a three-cell Alvarez structure very similar in design and construction to the Fermilab 200-MeV linac.<sup>7</sup> The cell geometry is nearly identical to that of a 200-MeV cell in the linac, proper. The major difference is the drift tube bore-hole diameter of 8 cm vs. 4 cm in the linac. Important parameters are listed in Table 1.

## Table l

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Frequency - 201.241 MHz
Number of Cells - 3, TM<sub>010</sub> Mode
Cell Length - 84.5 cm
Cell Diameter - 85 cm
Gap - 41.56 cm
Bore-Hole Aperture - 8 cm
Drift Tube Diameter - 16 cm
Transit Time Factor - 0.519
Q Factor - 4.1 \times 10^4
  for \Delta T_{max} = \pm 2 \text{ MeV}
Acceleration Gradient - 1.52 MV/m
Power - 190 kW
Energy Stored - 2.1 Joules
  for Momentum Errors, \left|\frac{\Delta p}{p}\right| \leq 10^{-4}
  \frac{\Delta E}{E} \simeq \pm 5\%
  \Delta \phi \simeq \pm 1^{\circ} (Phase Error Relative
  to Linac Cavity #9)
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As is evident from Table 1, the required gradient stability is easily achieved and the phase stability is not unreasonable.

The debuncher is provided with a temperature-controlled water system, a mechanical cavity-frequency-control system and a separate amplitude and phase-controlled 200-kW rf power amplifier system similar to the 200-kW driver power amplifiers used for the Fermilab linac.

The rf-power amplifier temporarily in use is part of the linac developmental system. It will be replaced soon by a permanent system located near the debuncher cavity.

The momentum distribution of the beam at the end of the linac and in the booster, with and without the debuncher, is shown for two different currents in Figure 1 and Figure 2. The distributions in the booster were obtained from frequency spectrum measurements (Schottky scans) made with coasting beam in the booster.<sup>8</sup> Further reductions in momentum spread can be expected when the initial linac momentum spread is increased as noted above. The momentum distributions at the end of the linac were measured with a 40° spectrometer system and do not include emittance corrections. The momentum distributions shown were measured with a pulse length of 2.8  $\mu \text{sec}$  (a single turn in the booster). For longer pulses, there is an additional shift in the mean momentum caused by a transient error in the linac-debuncher phase. That phase error will be corrected by improving the phasecontrol hardware.

<sup>\*</sup>Operated by Universities Research Association, Inc., Under Contract with the U. S. Energy Research and Development Administration



Fig. 1 Momentum distribution of 200 MeV 30 mA beam at the linac (solid line) and of coasting beam in the booster with and without debuncher operating.



Fig. 2 Momentum distribution of 200 MeV 80 mA beam at the linac (solid line) and of coasting beam in the booster with and without debuncher operating.

Currently, the use of the debuncher results in an increase in the booster acceleration efficiency of 20 to 30% at a fixed linac current. It also increases the useful current limit from the linac. The stability of the linac-booster system has been improved enormously by the installation of the debuncher.

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