

## INJECTION INTO THE 8 GeV BOOSTER SYNCHROTRON

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### Summary

With the single turn injection system now in use, it would be necessary to inject over 240 mA with the 200 MeV linac to reach the goal of  $4 \times 10^{12}$  protons/pulse in the 8 GeV booster synchrotron. ( $5 \times 10^{13}$  protons/pulse in the main NAL accelerator.) Multiturn injection is planned to reduce the required linac intensity. The 200 MHz linac beam is allowed to debunch. It is then rebunched and captured adiabatically by turning on the 30 MHz booster rf system in steps. The present momentum spread  $\Delta p/p$  of  $\pm 0.8 \times 10^{-3}$  is within the design acceptance. Space is available for a debuncher if it is needed at higher intensity.

### Transport From The Linac<sup>1</sup>

A short portion of the linac beam pulse is sent to the booster, and the remainder is stopped near the linac. The last part of the transport system from the linac and the injection area is shown in Figure I. To provide drift space for a debuncher without the expense of a transport tunnel, the beam proceeds along the outer wall of the booster tunnel for 18 m before being bent across the tunnel to the inflector. The  $24.6^\circ$  bending magnet, the  $9.0^\circ$  inflection bend, and three quadrupoles between them match the dispersion of the transport system to the momentum compaction function of the booster synchrotron. Because of the asymmetry, tuning is critical and achromatic operation reduces the acceptance. The beam is matched to the transverse acceptance of the booster with quadrupoles in the drift space ahead of the  $24.6^\circ$  bend.

During the booster start-up, 70% of the linac beam is transported to the inflector. Achieving a higher transmission will require careful matching of the linac emittance to the acceptance of the transport system and careful trimming of the bending magnets. So far, it has not been found necessary to devote tune-up time to this.

### Inflection

The inflector is an  $0.7^\circ$ , 85kV, dc electrostatic deflector with an 0.002 inch wire septum similar to the one developed for the main synchrotron extraction system.<sup>2</sup> The septum is located 1 1/8 inch outside the closed orbit in a 6 m long straight section. Here the half width of the circulating beam is 0.93 inch. The inflector provides clearance for the 0.20 inch septum in the  $8.3^\circ$ , 3 kG, dc septum magnet. The septum is made of a single layer of eight turns of 1/8" square copper conductor with a 1/16"

square hole for water cooling. At the nominal current of 800 A, the current density in the conductor is 68,000 A/in<sup>2</sup>. The septum coil is insulated with glass cloth impregnated with epoxy resin.

### Multiturn Injection

For multiturn injection, the closed orbit will be displaced outward by a pair of bump magnets located at each end of the injection straight section. As injection proceeds, the orbit displacement decays linearly from the initial value of 1 1/8 inch, and the radial position of the injected beam with respect to the closed orbit increases. In principle, if  $v_x$  were shifted to exactly 6.50 during injection, it would be possible to focus a linac beam, with the nominal emittance of  $8\pi$  mm-mrad<sup>2</sup>, so four turns fit into the  $90\pi$  mm-mrad acceptance of the booster without any losses from beam hitting the inflector septum. The elimination of this beam loss would reduce undesirable residual radioactivity. However, adjustment of  $v_x$  to the required tolerance of .01 is difficult in practice, and the orbit may not be sufficiently stable near the half integral stop band for satisfactory injection. Calculations and experience at other laboratories indicate that less than half the beam is lost on the inflector for other values of  $v_x$ , and that the loss is not a sensitive function of  $v_x$ . Therefore, during early operation of the booster no attempt will be made to shift  $v_x$  from the nominal value of 6.7.

The bump magnets are built in pairs with a single one turn coil exciting both magnets of a pair. By feeding the coil in the center, equal and opposite fields are produced in the two magnets. Injection starts at 3 kG, half way down the decay of a 25,000 A, half-sine-wave current pulse applied to the magnets. Much weaker bump magnets could be used if they were placed  $\frac{1}{4}$  betatron wave length from the inflector, but space is not readily available.

### Single Turn Injection

The closed orbit bump is not used for single turn injection. The incoming beam enters the first period of the booster magnet displaced 3.6 cm outward from the closed orbit and parallel to it. It crosses the central orbit a quarter of a betatron wave length downstream in the next 6 m long straight section. Here the beam is bent 7 mrad by a fast kicker magnet to point it along the closed orbit. After the booster ring has been filled, the kicker magnet is turned off in 50 nsec. This magnet consists of two 80 gauss,

44 inch long, delay-line type magnet sections identical to those developed for extracting the beam from the booster.<sup>3</sup> Later this magnet may be used for producing a gap in the circulating beam to avoid losses during extraction.

Initially, the inflector has been set 5/8 inch outside the central orbit. To date, the largest beam to make a complete turn around the booster is about 3 mA, which corresponds to  $2 \times 10^{10}$  protons in the ring. This was achieved with a beam of 12 mA from the linac and 8 mA at the inflector. So far, the emphasis has been on accelerating a small beam in the booster for transfer to the main ring rather than tuning parts of the system carefully.

### References

1. E. L. Hubbard, W. C. Martin, G. Michelassi, R. E. Peters, and M. F. Shea, Proc. of the 1970 Proton Linear Accelerator Conference, National Accelerator Laboratory, Batavia, Illinois.
2. C. H. Rode, R. A. Andrews, A. W. Maschke, and R. M. Mobley, Proc. of the 1971 Particle Accelerator Conference, Chicago, Illinois.
3. J. D. McCarthy, R. E. Daniels, R. F. Nissen, and E. B. Tillis, Proc. of the 1971 Particle Accelerator Conference, Chicago, Illinois.

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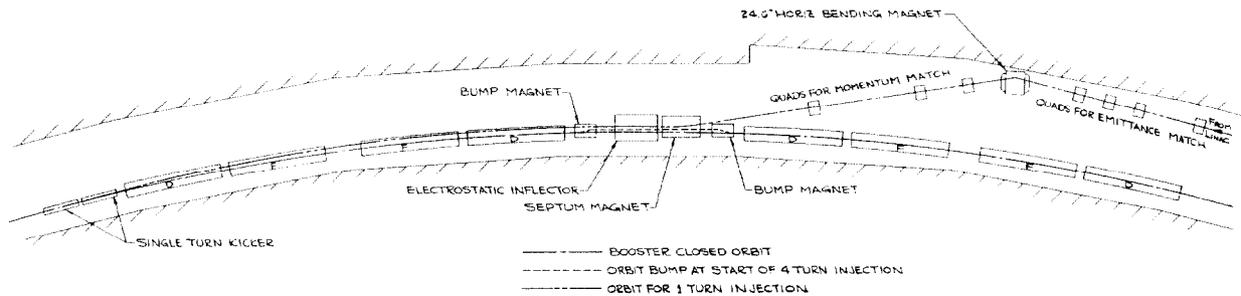


Figure I: Layout of Booster Injection System