

# OVERVIEW OF THE BUMP-MAGNET SYSTEM AT THE LANSCE PROTON STORAGE RING

C. R. Rose, D. B. Barlow, B. Blind, F. Neri, J. F. Power, and P. L. Walstrom  
 Los Alamos National Laboratory, Los Alamos, NM 87545

## Abstract

An upgrade program for increasing the stored beam current in the Proton Storage is presently under way. A part of the upgrade is the design and installation of a four-magnet beam-bumping system used for phase-space painting and minimizing interaction of the stored beam with the injection stripper foil. This paper describes the bump-magnet system including the relevant beam requirements, magnet specifications, power-cable specifications, pulsed-modulator requirements, and beam-tube eddy-current effects. The magnets are ferrite window-frame magnets with saddle windings. The series-pass pulsed modulators are programmable both in rise and fall time as well as amplitude. The peak current can be varied between 50 and 300 A. The pulsed-current rise-time is fixed at 1 ms, and the linear fall-time during which beam is injected into the ring can be varied between 0.5 and 1.5 ms.

## 1 SYSTEM OVERVIEW

The purpose of the bump-magnet modulator system is to "paint" the injected beam into the storage ring. To do this, four bump magnets are used that have precisely controlled, linear-decaying magnetic fields that move the injected beam into the ring synchronously with the ring-orbit cycle. The beam is bumped in the vertical plane. The maximum field strength in any one magnet is on the order of 500 gauss, and each of the four magnets is pulsed at different field levels with respect to the others. The magnetic field strength of 500 gauss translates roughly to 300 A peak current in the magnets. A simplified view of one modulator/cable/magnet system is shown below in Fig. 1.

The required current waveshape is depicted next to the waveform generator. It has a linear risetime, a flat-top, and a linear decay time. The decay time is variable from 0.5 to 1.5 ms. The amplitude can be varied from 50 to 300 A.

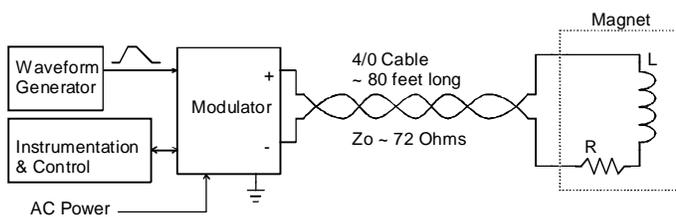


Fig. 1 Block diagram of one bump-magnet system.

## 2 BUMP MAGNETS

The four bump magnets are fast-slewing small-deflection dipole magnets. In order to minimize design and prototype development costs, a single magnet design is used for all four magnets. This standardized design produces a field strength of 488 gauss (at 300 A) which is sufficient to produce a deflection of 3 mrad for 800 MeV protons. Important magnet parameters are: 30-cm length, 12 cm by 12 cm clear aperture, 16 turns, and 140- $\mu$ H inductance. A drawing of the magnet is shown in Fig. 2.

Ferrite-yoke magnets were chosen on the basis of

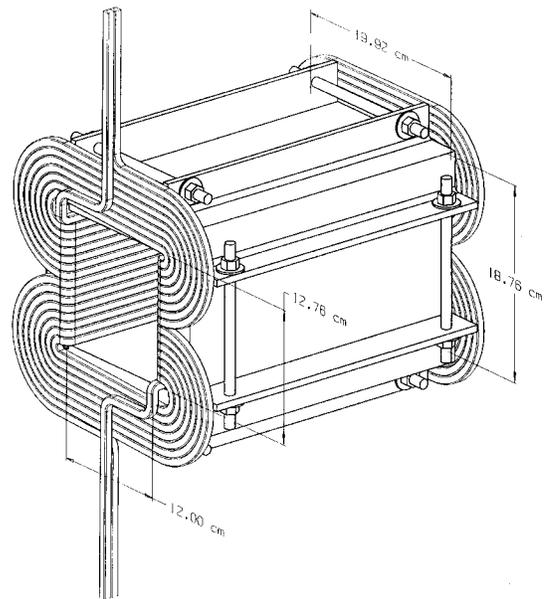


Fig. 2 Diagram of the bump magnet with dimensions.

their lighter weight, smaller size, and lower overall cost compared to tape-wound-core magnets. A Ceramic Magnetics Inc. MN60 magnetically-soft manganese-zinc ferrite with an initial relative permeability of 6500, a maximum flux density of 0.45 T, and a coercive force of 0.08 oersteds was chosen for the magnet. At this frequency and flux density, the continuous power loss is less than 1 mW/cm<sup>3</sup>. When the duty-cycle (about 3% for a typical magnet power cycle) is factored in, the average ferrite power loss is negligible. The magnet yoke is made from four ferrite pieces with steps in two of the pieces to lock the pieces together when pressed by an external

clamping structure. The magnet windings are single-layer epoxy-potted saddle coils of insulated square copper conductor with a circular internal cooling channel. Resistive power losses in the windings are small enough to be easily removed by air or water cooling.

The largest magnet-related power losses are expected to be in the beam pipe running through the bore of the magnet. Eddy currents in the tube not only cause a power loss but also affect the field within the tube. It is important that the field perturbations be minimized. In the pipe, a characteristic decay time of dipole eddy currents of 15 microseconds or less is allowable. In order to provide a thin-enough wall to minimize the eddy currents and to simultaneously withstand external pressure when the pipe is evacuated, we have chosen to use a 0.2 mm (0.008 in.)-wall 316 stainless-steel formed bellows for the beam pipe within the magnet. The duty-cycle averaged eddy-current power for this pipe is estimated to be about 50 watts at 60 Hz repetition frequency. This amount of power can be removed by natural air convection.

The first of the five magnets (four for installation and one backup) has been fabricated by Everson Electric Company and delivered to Los Alamos.

### 3 MODULATORS

To date, Los Alamos National Laboratory has received one of the five modulators from the vendor, Dynapower Corporation, to be used in the complete bump system. It has been connected to the magnet as shown in Fig. 1 and data taken. In the final system, the peak current of each magnet is independently adjusted while maintaining the same functional shape. In addition, when or if needed (or desired) the waveform of each magnet's current can be slightly adjusted or shaped because each modulator will be controlled by a separate programmable-waveform generator. However, in all cases, the timing of all four modulators will be synchronized. An actual current waveform from the first modulator and magnet pair is shown in Fig. 3. The top waveform is the magnet current, and the bottom waveform is the voltage across the magnet. The leading-edge risetime will be fixed at about 1 ms. The ring injection takes place during the down-trending portion of the waveform. It is this portion that must be accurately and repeatedly controlled to ensure accurate and repeatable beam bumping. Each of the four magnets requires different magnetic-field strengths, and different electric-current values. During the leading edge and flat-top, the magnet is energized and brought

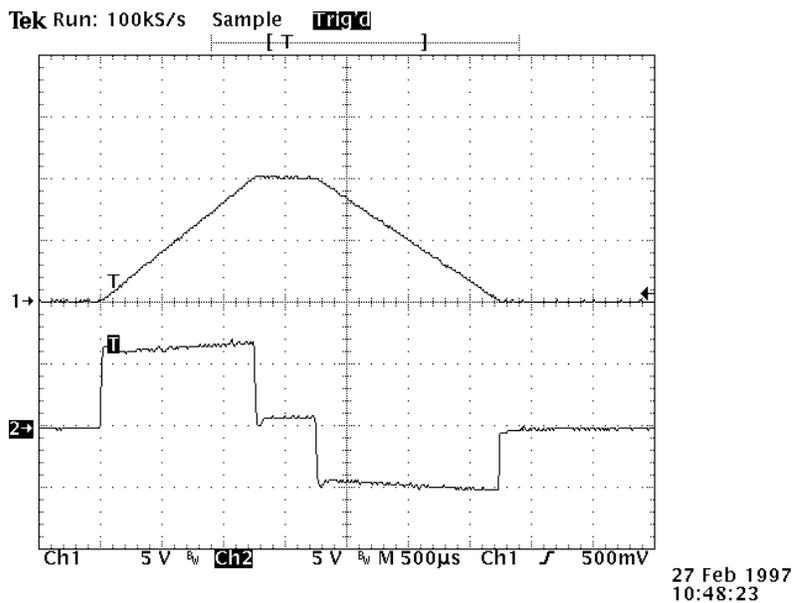


Fig. 3 Actual waveforms of magnet current and voltage across the magnet. Top scale: 30 A/V. Bottom: 10 V/V.

to the desired current and field level. The flat-top is a holding period used to synchronize the bump system to the ring injection system from which it receives a timing pulse and begins the down ramp.

### 4 CONCLUSIONS

At present, there is one operating bump system at Los Alamos from which data has been taken. The first magnet and modulator have been connected together and operated at full current and full repetition rate of 60 Hz. Test data show that the error between the programmed current and actual current is less than one percent at the corners which is twice as good as the specified accuracy, and less than 0.2 percent during the smooth parts of the function. The first bump magnet has been field mapped, and the integral field varied less than one percent across the bore of the aperture. The remaining magnets and modulators are presently on order from the respective vendors and are scheduled for installation during the Fall of 1997.