SLAC-PUB-6812
LBL-37045
June 1995

PEP-II Injection Transport Construction Status and Commissioning Plans

Stanford Linear Accelerator Center,
Stanford University, Stanford, CA 94309

Presented at the 16th IEEE Particle Accelerator Conference (PAC 95) and International Confernce on High Energy Accelerators, Dallas, Texas, May 1-5, 1995

Work supported by Department of Energy contract DE–AC03–76SF00515.

SLAC–PUB–95–6812
LBL–37045
June 1995

TRANSPORT CONSTRUCTION STATUS AND COMMISSIONING PLANS*

T. Fieguth, E. Bloom, F. Bulos, T. Donaldson, B. Feerick, G. Godfrey, G. Leyh, D. Nelson, M. Ross, D. Schultz, J. Sheppard, P. Smith, C. Spencer, J. Weinberg, SLAC, Stanford CA
M. Ronan, Lawrence Berkeley Laboratory, Berkeley CA

Installation of the PEP-II electron and positron Injection beamlines in the SLAC linac housing is now underway. Utilization of the existing high power, low emittance beams available at SLAC required that a great portion of the systems for pulsed extraction and transport of 9.0 GeV electrons and 3.1 GeV positrons for injection into the PEP-II rings will reside in the existing linac housing. Approximately 4.7 kilometers of these beamlines will be completed during the summer of 1995. All components, including orbit correctors and diagnostic instruments, required for extraction and transport of the electron beam will be in place and ready for commissioning as soon as this fall. The positron transport line in the housing will also be complete except for the pulsed extraction system. These systems are described, along with the status of the construction and installation of the important subsystems such as magnets and power supplies, vacuum systems, instrumentation and controls. The plan for commissioning is discussed.

I. INTRODUCTION

The SLC linac, including its damping rings and positron source, is a powerful source of low emittance positron and electron beams for injection into the PEP-II rings[1]. This injection system[2] starts within the linac housing and consists of two beamlines having similar sections referred to by their function. These are the High Energy (HE) and Low Energy (LE) beamlines, each with Extraction, Bypass, Arc, and Match regions. As illustrated in Fig. 1, LE positrons (3.1 GeV) will be extracted from the linac at Sector 4 and HE electrons (9.0 GeV) at Sector 10. After extraction, each beam will traverse the length (>2 km) of a respective Bypass line connecting to its Arc and to a following Match section, optically matching the beam for injection into the proper ring. Now under construction (see shaded region of Fig. 1.) are the HE and LE Bypass lines along with the pulsed electron HE Extraction system and its related subsystems. The positron LE Extraction system at Sector 4 will be constructed later. This work represents about 1/3 of the total injection system construction effort. Installation began in March 1995, and is scheduled to be complete and ready for commissioning by mid-July 1995. All subsystem hardware is of new construction including: a stainless steel, ion-pumped vacuum system; a slow-pulsed extraction kicker; bending, focusing, and orbit-correcting magnets; power supplies; beam position monitors (BPM) (of a modified SLC type for higher sensitivity, using existing the SLC control system) two SLC-type wire scanners to measure energy spread and emittance of the extracted beam, and additional diagnostics. A program is planned to extract and study a 9 GeV electron beam under stringent control of energy, energy spread, emittance and timing.

The entire system (including the remaining 2/3) will be capable of filling 1658 bunches of 9 GeV electrons (0.99A stored) and 3.1 GeV positrons (2.14A stored) in two separate rings in a total of about 6 minutes from zero ring current (i.e., full-fill mode, 0 to 100%) or in about 3 minutes from 80% ring current (i.e., topping-off mode, 80 to 100%). The overall goals of the PEP-II Injection System are summarized in Table 1.

TABLE 1: Selected PEP-II Injection Parameters.

Beam energy	
High-energy ring (HER)	9 [range:8-10] [GeV]
Low-energy ring (LER)	3.1 [range::2.8-4] [GeV]
Beam Current	
High-energy ring (HER)	0.99/4518 [A/10^{10} e^-]
Low-energy ring (LER)	2.14/9799 [A/10^{10} e^+]
Particles per bunch	
High-energy ring (HER)	2.7 [10^{10} e^-]
Low-energy ring (LER)	5.9 [10^{10} e^+]
Linac repetition rate	60/120 [Hz]
Linac current range while filling	0.1-3 [10^{10} $e\pm$/pulse]
Invariant linac emittance	
ε_x	4×10^{-5} [m rad]
ε_y	0.5×10^{-5} [m rad]
Normal filling time	
Topping-off (80-100%)	3 [min]
Full fill (0-100%)	6 [min]

II. THE EXTRACTION & TWO BYPASSES

The electron beam Extraction system begins with an on-axis pulsed magnet which kicks the beam into the aperture of a Lambertson septum magnet. The focusing optics in this region is simply an extension of the 90° per cell linac lattice. Several dipole magnets complete the extraction bending, bringing the beam back to be parallel to

*Work supported by Department of Energy contracts DE-AC0-76SF00515 (SLAC) and DE-AC03-76SF00098 (LBL).

Presented at the 16th IEEE Particle Accelerator Conference (PAC 95) and International Conference on High-Energy Accelerators, Dallas, Texas, May 1--5, 1995

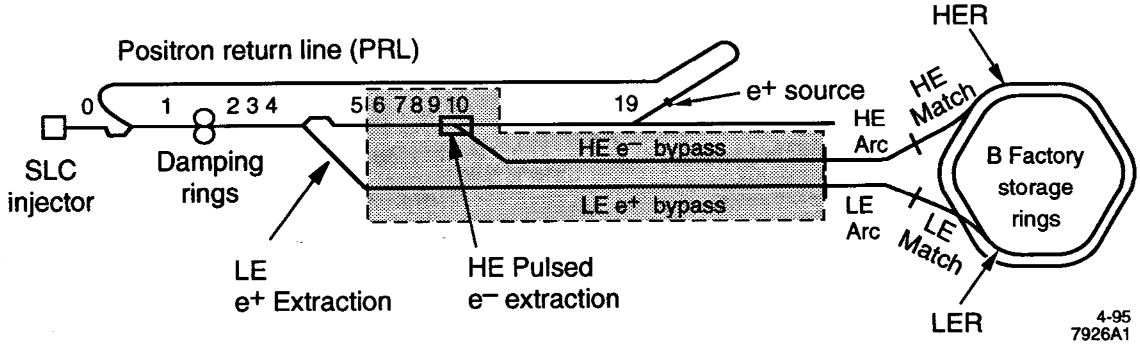

Figure 1. Schematic of the SLAC Linac showing the PEP-II Injection Transport System and the Rings.

the linac. Four independently powered quadrupoles are then used to match the beam parameters to the Bypass lattice, also a 90° per cell lattice but with the quadrupoles 101.6 m apart occuring only once per linac sector.

MAGNETS

Savings of engineering and design costs for the dipole and quadrupole magnets were obtained by modifying existing SLAC designs. This technique improved reliability by using field tested components and also allowed the use of a large number of existing quadrupole laminations at no cost to the PEP-II project.

There are two similar types of quadrupoles now constructed; a 4" long air cooled Bypass line quadrupole, and a 10" long water cooled Extraction line quadrupole. The quadrupole quarter sections were made from fine blanked laminations welded into magnet quarter sections. Four sections were assembled into a quadrupole core. The cores were blanchard ground to length and fiducials, bolt holes, etc. were machined. While assembled as a core, all four pole tip profiles were machined using a wire Electric Discharge Machine. This method resulted in magnet length errors being held to ±.002" and errors in magnet pole profiles to ±.001" at no extra cost. Improvements to the design included improved coil terminations, larger coil pockets with greater coil to core axial clearance, elimination of internal conductor brazes and the exclusive use of G-10 for insulator blocks.

Similarly, the dipole magnets are based on earlier designs. The Lambertson septum magnet is a larger version of the SLC positron source extraction Lambertson. The dipole bend magnets are standard H-bend type constructed either from single pieces of iron or from slabs bolted together. The small corrector magnets are a low cost (≈$300) sheet metal design

MAGNETIC MEASUREMENTS

After a standardization procedure, the integrated gradient and harmonics of each quadrupole was measured at 12 different excitation currents using a long rotating coil of 1.89 cm radius. The variance of the integrated strengths at the typical operating current of all the Bypass quadrupoles are within 0.25%. The sextupole component at a radius of 1 cm is less than 0.1 % of the quadrupole strength and the sum of all the higher multipoles is less than 0.5%. The dipole magnets are now being measured.

POWER SUPPLIES

The High Energy Extraction Stub and transport lines utilize one pulsed power system[3], and 20 DC power systems. The pulsed power system consists of a solid state pulse generator capable of delivering high current trapezoidal shaped pulses into an inductive load. The capacitor bank is switched into the load through a pair of IGBT devices. A combination of diodes with these IGBT modules is used to shape the current pulses and recover the inductive energy back into the capacitor bank without reversing capacitor voltage. A DC power supply to the capacitor bank compensates for pulse to pulse power losses. The rack mounted pulse generator unit contains a storage capacitor bank of up to 660 uF, and can deliver 600 amps at 1000 volts into inductive loads of up to 3 mH. The current amplitude and discharge time are controlled to 0.02% accuracy by a specially developed precision controller via the SLAC central computer system.

The dipole magnets are powered by a 48 kW supply and a 20 kW unit. Both of these supplies employ SCR primary regulators, and an external feedback amplifier for current regulation. The external amplifier sums the CAMAC generated reference and the magnet current feedback signal, which is provided by a precision DC transductor (0.001%), to stabilize the power supply current to 0.01%.

One dipole and 11 quadrupole magnets are powered by 5kW commercial switching power supplies controlled by the same type of external feedback amplifier described above. Similarly regulated are the four switching power supplies, two for the focusing strings (8 quads each) and two for the defocusing string (8 quads each) for the HE Bypass line(5 kW) and the LE Bypass line (15 kW).

VACUUM

The Vacuum System is an all metal, unbaked, ion pumped system, comprised mostly of long drift tubes (18 to 46 m long) of 50.8 mm diameter 304 welded stainless steel tubing. The required average pressure for H_2 is 7×10^{-6} Torr. At 101.6 meters intervals a tee chamber connects the two Bypass lines and both are pumped by a 55 liter per second ion pump. Six meter lengths of tubing are butt welded together, by an orbital welder, in the accelerator tunnel. The remainder of chambers consist of bellows, tees, crosses, magnet vacuum chambers, vacuum isolation valves and assorted diagnostic components connected by Conflat® flanges.

ORBIT CORRECTION

Approximately 150 individual X-Y corrector magnets will be installed on the HE and LE Extraction and Bypass lines. The corrector strengths are 10 G-m and 20 G-m for the LE and HE Bypass respectively. Each corrector will require a bi-polar current of up to 6 A, with a 24 hour stability[4] of better than 0.1%.

The low corrector strengths require that the average remnant field inside the 50.8 mm beam pipe be reduced to <50 mG so the correctors compensate for alignment errors only. The earth's field is attenuated by μ-metal shielding over 96% of the length of beam pipe. The material used is 150 μm thick, rolled into tubes 40 cm long, before annealing at high temperature. Studies showed that a field attenuation of better than 50:1 was easily achievable and that normal handling during installation does not affect the shielding properties.

INSTRUMENTATION & COMMISSIONING

An X-Y Beam Position Monitor (BPM) followed by an X corrector and Y corrector is placed downstream of each quadrupole. Each BPM plate is 61 cm long and covers 20% of the circumference at an inner radius of 29 mm. The BPM signals are time multiplexed into existing Linac BPM ADCs through 11 dB loss directional couplers. The expected single pass position resolution (rms) in x or y is ± 50 microns for >2 x 10^9 electrons in the bunch, increasing to ± 200 microns for .5 x 10^9. The BPM centers will be surveyed into better than ± 1 mm (rms) in the transverse dimensions. A very cost effective method (<$900 ea) of construction resulted in a ± .28 mm rms distribution of electrical centers for the 100 BPMs now built and tested. The extracted beams as they enter the extraction lines will be stabilized in energy, x, x', y, and y' by a feedback system (~1 sec time constant) using eight Linac BPMs an the first four injection line BPMs. The BPM system allows measurement of a single bunch as it travels down the injection line and around the ring.

A wire scanner in the dispersive region of the Extraction line will measure the beam energy spread and a second wire scanner placed in the Bypass line will measure the beam emittance by varying an upstream quadrupole. An insertable fluorescent screen profile monitor accompanies each wire scanner. In the dispersive region of the extraction there is a horizontal set of jaws for limiting the momentum acceptance of the line. The electron Bypass line terminates in a temporary 10 kW dump in Sector 28 for a 1995-96 beam test. Toroids will be placed at the beginning of the Extraction line, the beginning of the Bypass line, and just upstream of the dump. The LSB will be 4×10^7 charges. Full scale will be 4×10^{10} charges and the noise should be < 1 LSB.

Commissioning begins with the Personnel Protection and certification of the Beam Containment System. Ion chamber thresholds will be set to limit the repetition rate of a mis-steered beam for Machine Protection. The beam will be iteratively steered through BPM centers using model generated algorithms. The energy feedback loop will be energized, tuned and its stability measured. Phase advance of betatron oscillations will be measured and corrected. The wire scanners will be used to measure the energy distribution, beta match and the emittance of the beam.

SCHEDULE

The PEP-II Injector schedule is affected not only by the overall PEP-II commissioning schedule but also the SLC running schedule. Targeted for PEP-II is the commissioning of the High Energy Ring on 1/1/97 and the Low Energy Ring on 10/1/97. The Low Energy Extraction(sans chicane) and both Arcs will be installed during the 1996 downtime. The High Energy Match (which can be installed with the accelerator running) to HER will be done from 10/1/96 until 1/1/97 followed by commissioning of HER. During the 1997 downtime the Low Energy Extraction Chicane and the Match to the LER will be installed.

III. REFERENCES

[1] LBL-PUB-5379, SLAC-418, CALT-68-1869, UCRL-ID-114055, UC-IIRPA-93-01 (1993).

[2] T. Fieguth et al., "Injection System for the PEP-II Asymmetric B Factory at SLAC," proceedings EPAC92, Berlin, Germany, March 1992.

[3] V. NESTEROV, AND A. R. DONALDSON, "A High Current, High Accuracy IGBT Pulse Generator", contributed to this conference.

[4] G. E. LEYH, A. R. DONALDSON, AND L. T. JACKSON, "A Multi-Channel Corrector Magnet Controller", contributed to this conference.