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Ernest O. Lawrence Radiation Laboratory

BEVATRON OPERATION AND DEVELOPMENT. NO. 36
October through December 1962

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BEVATRON OPERATION AND DEVELOPMENT. NO. 36

October through December 1962

Kenneth C. Crebbin and Rudin M. Johnson

December 16, 1963

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ABSTRACT

The shielding foundation was completed and some of the wall and roof blocks were placed in position. The travel-target track was extended to cover all of the normally used target area. A vacuum-to-air lock was installed in the west straight section to permit installation and removal of targets. The internal deflection magnets for the external beam were installed in the Bevatron along with their hydraulic plunging systems. A new three-sector stanchion and secondary-beam exit port were installed at the exit of quadrant II. A new thin window was installed in the outside west face plate for external and secondary beam.

The magnet sectors were repositioned to put the Bevatron magnet on a tilted plane. Graphite and aluminum beam stoppers were placed in the Bevatron gap to protect equipment and parts from the higher energy and intensity injected beam. The new linac injector system was moved into position and all the components adjusted and tested. The first beam (19.2 MeV) injected into the Bevatron tank gave 9 to 10 mA current at the exit of the inflector.

I. IMPROVEMENTS

There was no Bevatron operation this quarter. The shielding construction continued and some phases of the improvement program were completed. The vacuum shutdown ended on December 14 at 4:50 PM. The Bevatron had been at air for 182 days. There were a few details that had not been completed inside the vacuum tank–these were to be finished during a vacuum shutdown after the Christmas holidays. We wished to get as much pumping on the Bevatron vacuum tank as possible before looking for beam. This required that we start pumping a few days in advance of the start of the holidays in order to correct any vacuum leaks.

A. Shielding

The shielding foundations[1] were completed and some of the blocks for the outer shielding wall were placed in position. The wall was started in the east quadrant IV area and worked around the machine going toward the south and west. Part of this is shown in Figs. 1 and 2. The center-column igloo was poured in three pours. The finished igloo is shown in Fig. 3. The roof blocks started to arrive. Some of these were placed in position in the east and south (Figs. 4 and 5). A keyway at the inner edge of the blocks rides on a welded key on the supporting framework,[1] to provide a lateral restraint for earthquake motion.

Steel shadow blocks were installed under the west platform to shadow the west access tunnel (Fig. 6). The blocks are placed so as to shadow the radiation in the tunnel coming from the west target area. This increases the effective length of the access tunnel by moving the start of the irradiated area farther down the tunnel.

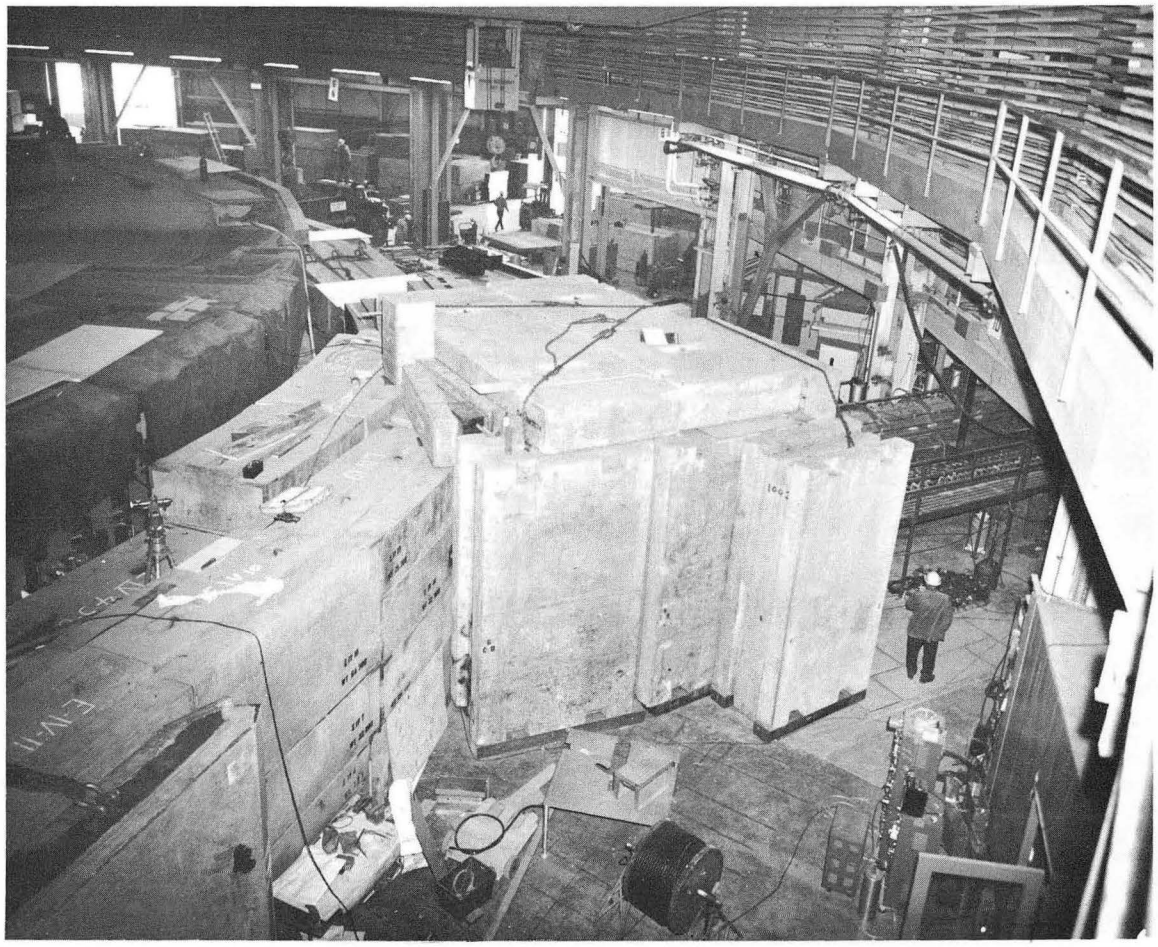
In the east wind tunnels, the floor above the wind tunnel was not thick enough to provide adequate shielding for neutrons coming up the tunnel. Additional shielding, in the form of 6 in. of steel, was installed in the roof of the wind tunnel.

B. Travel Target

The track for the travel target[2] was extended to cover all of the region where targets are normally placed to produce secondary beams. The track now extends from 51 deg in quadrant II to the exit of quadrant III. A straight section of track and vacuum lock were installed in the west tangent tank (Fig. 7). This permits removed and replacement of targets without having to let the Bevatron vacuum system to air. In addition it is no longer required that people crawl down the gap to install and remove targets. This is a necessary change in view of the higher residual radiation level that is anticipated inside the Bevatron with the new higher-energy higher-current injector. The target control circuits have been expanded to provide control in short sectors of track. This allows the use of more than one target at a time in different sectors. At present there are four independent sections where targets can be operated for experimenters.

ZN-4096

Fig. 1. Shielding wall in place in quadrant II. The west outside thin window can be seen in the reentrant section of the tangent tank (lower left corner).



ZN-4097

Fig. 2. The shielding wall and linac vault at the east tangent tank.

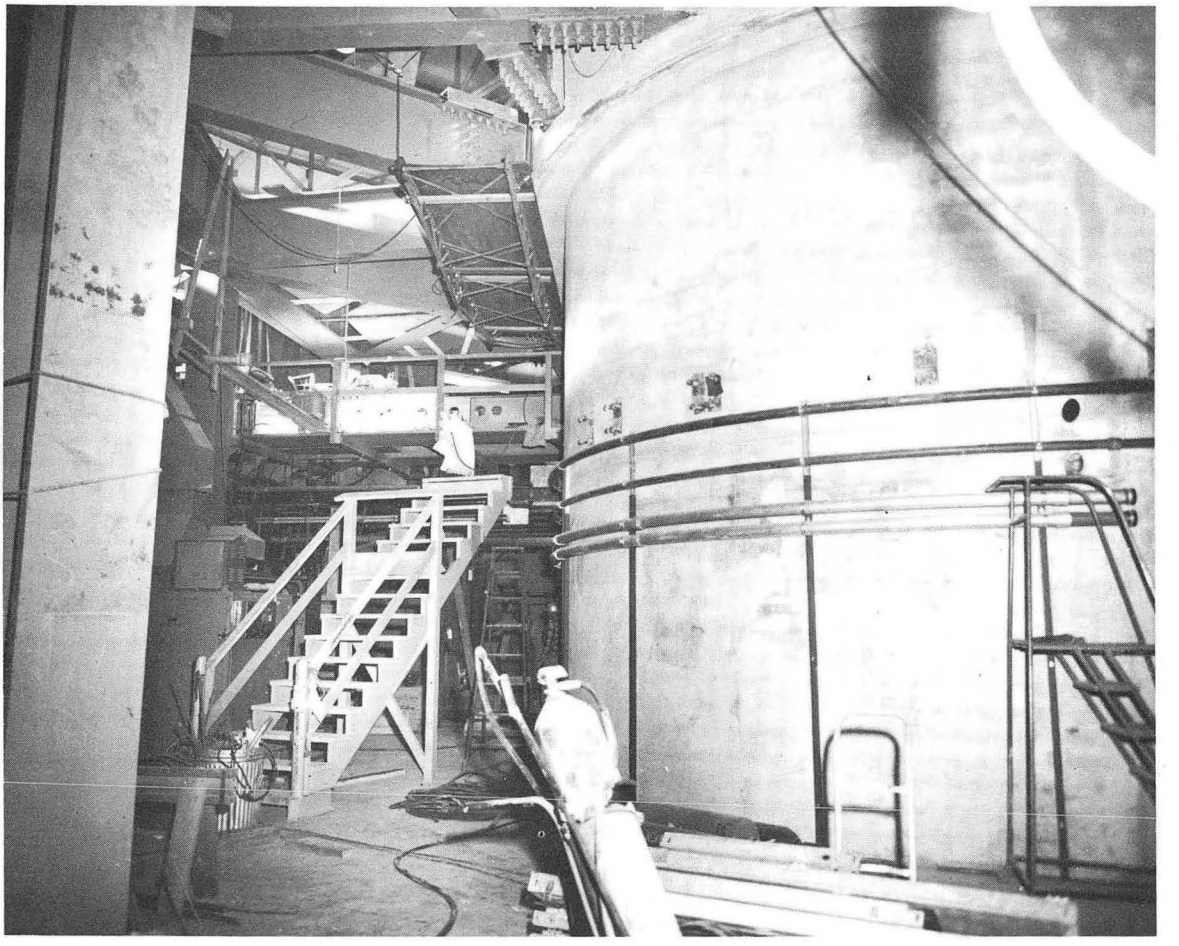


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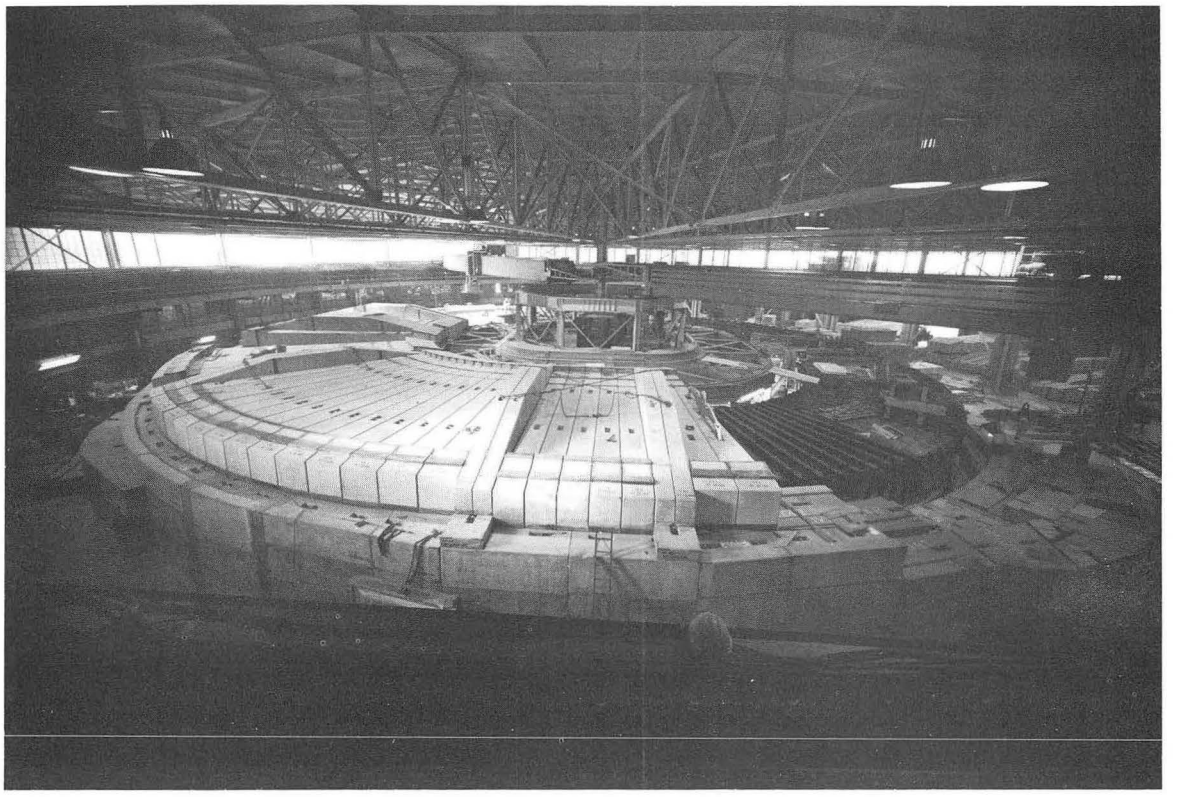
Fig. 3. The igloo shielding.

ZN-4099

Fig. 4. A roof block ready for installation.

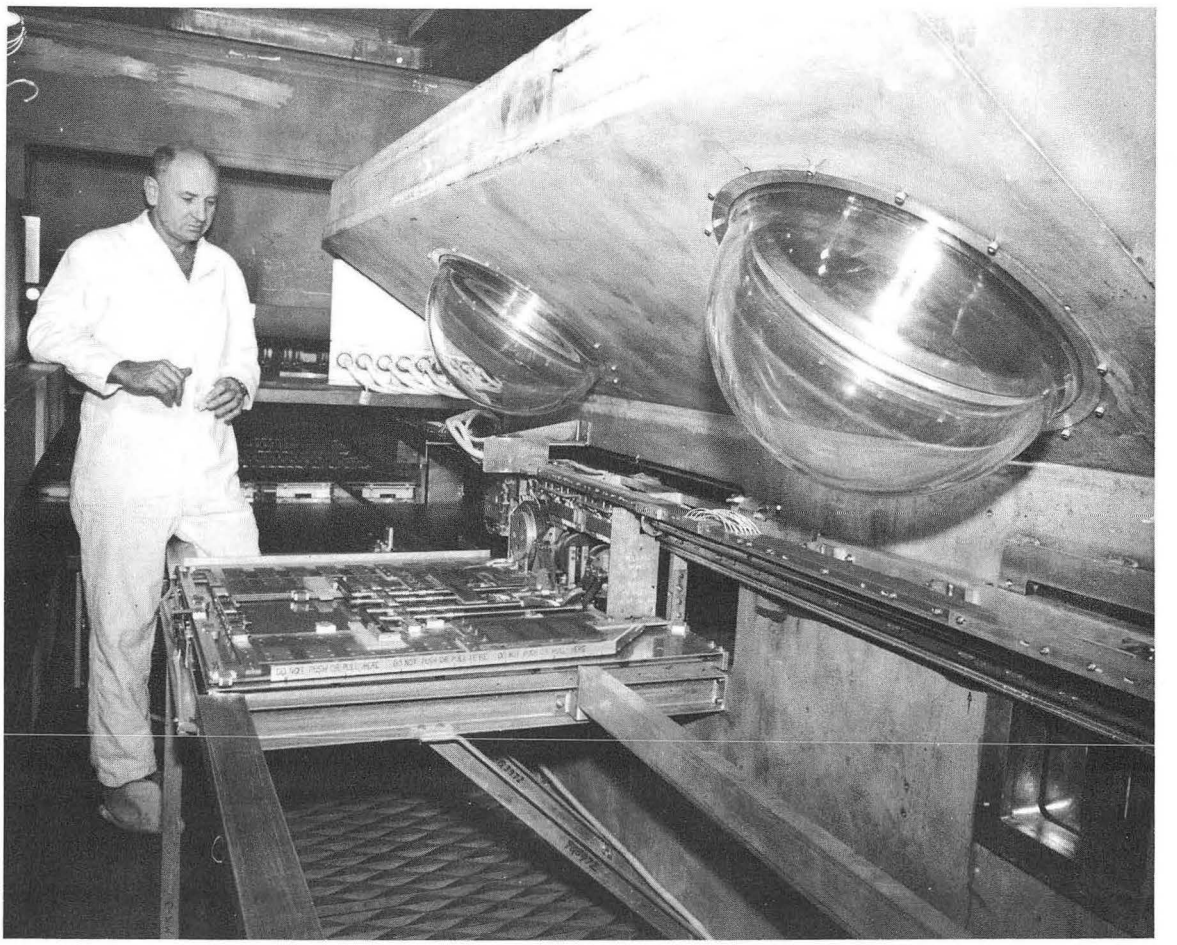


ZN-4100

Fig. 5. Roof blocks in position, viewed from the east.

ZN-4101

Fig. 6. Shadow block in west.



ZN-4102

Fig. 7. Travel target in west straight section in position to be withdrawn into air lock.

C. External-Beam Program

The magnets—M_1, Q_1, M_2, Q_2—that steer the external beam[3,4] out of the Bevatron were removed during the long shutdown to make some minor changes. When the igloo was finished they were reinstalled along with their hydraulic driving systems. These systems fasten to the side of the igloo (Fig. 8). It will now be possible, when the Bevatron goes back in operation early in 1963, to bring out an external beam using full beam intensity in the Bevatron. In the tests last spring[5,6] the runs were made at half Bevatron aperture and much reduced beam because the plunging mechanisms were still under test and were not installed on the Bevatron.

Modified leg slabs for the entrance sectors of quadrant III were made with a beam pipe for the external beam. They are completed and ready to install on the Bevatron.

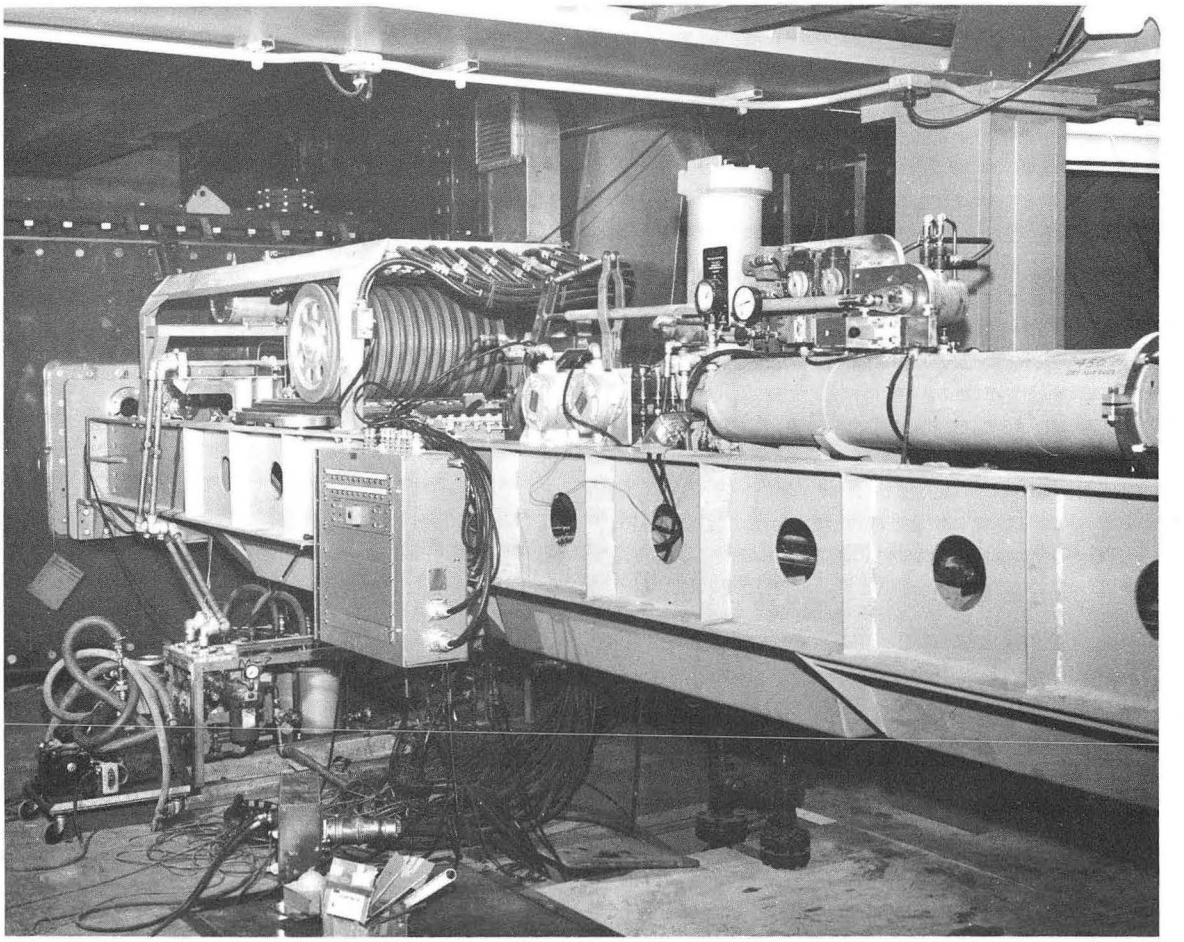
External-beam monitoring on the west platform will be improved. A television camera and scintillation crystal will be used for preliminary adjustments. The beam intensity will be monitored by an integrating current transformer, which is under design, and a secondary-emission chamber, which is undergoing preliminary tests.

Shielding studies for the external-beam channel are underway. The major interest at present is where the beam channel passes through the main shielding wall of the Bevatron. In this section the concrete blocks on the beam median plane will be replaced with iron blocks.

An order has been placed for the quadrupole magnets to be used in the first section of the beam transport system. The design for the bending magnets has been completed.

D. Quadrant II Deg Area Exit Port

A new three-sector stanchion was installed at the exit of quadrant II. A vacuum extension tank and head gate were attached to the Bevatron vacuum system at this point to provide a vacuum-coupled secondary-beam vacuum channel for experiments in the west area. The head gate is a sliding unit that closes at the Bevatron vacuum skin to provide access to the extension tank area. This will permit collimator or exit-port direction changes in this region without having to let the Bevatron vacuum system go to air. The details of this region are shown in Fig. 9.



ZN-4103

Fig. 8. External-beam-magnet plunging system ("mighty mouse").

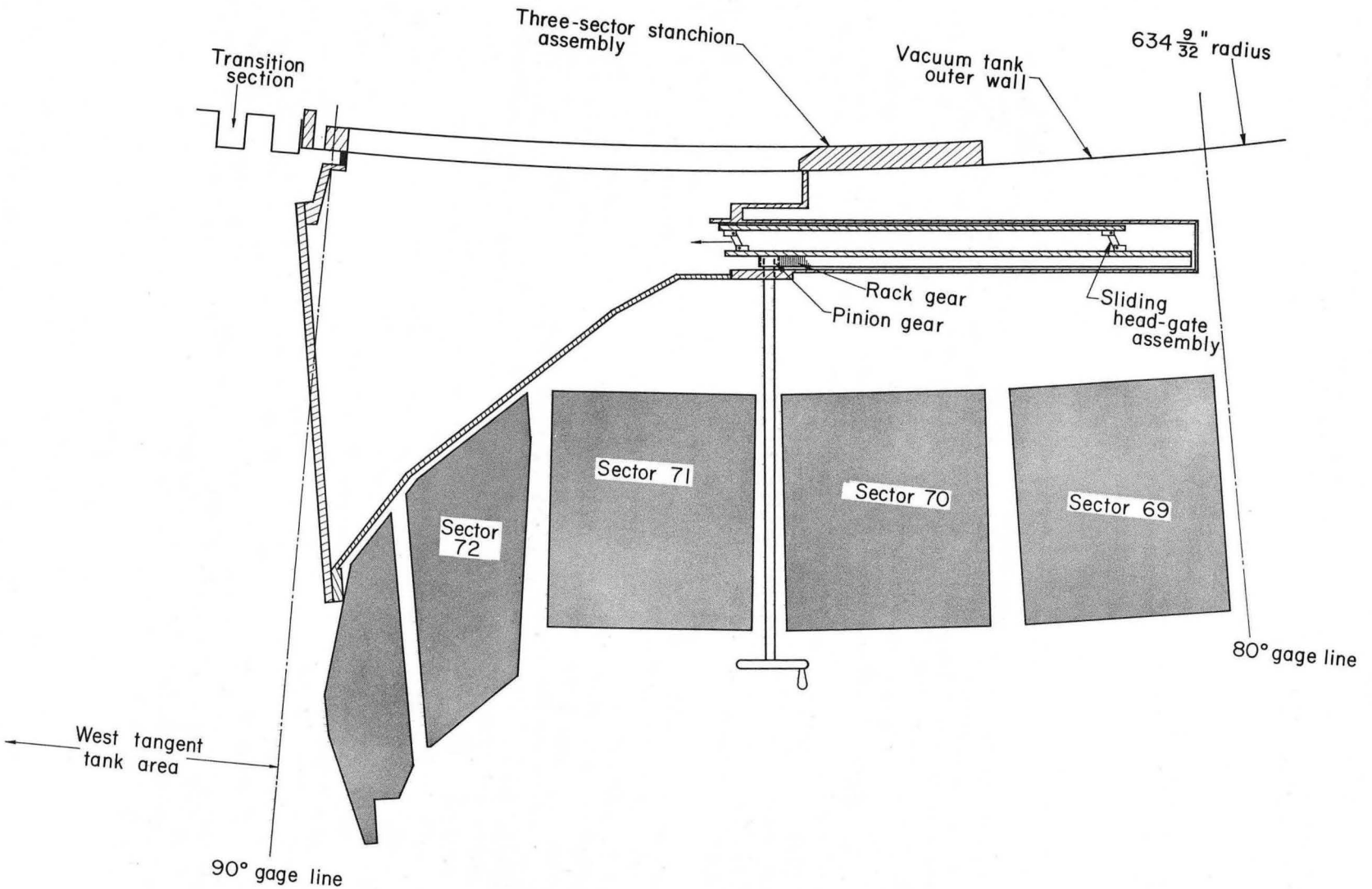


Fig. 9. Layout of quadrant II 89 deg area.

E. West Outside Thin Window

We needed a thin window in the west to bring out the external beam, but as the same time we wished to retain as much flexibility as possible for bringing out secondary beams in this area. A single curved window was designed to satisfy both of these requirements. The general plan is shown in Fig. 10. The window has a 6-in. vertical aperture and is made from 0.020-in. aluminum. The window is not usable for simultaneous external beam and secondary beams, because of location of the external-beam magnets.

F. Internal-Beam Stoppers

The increased energy and beam intensity of the injected beam creates some new problems. The beam power is sufficient to cause thermal damage where the focused beam strikes the surface of a material. This was dramatically shown when the focused beam struck the ground plane of the electrostatic inflector because of misadjustment of the beam transport system (Fig. 11). The higher injection energy will produce a much higher activity level in materials it strikes. Also, the higher intensity can create some charge-buildup on insulated surfaces. This could be particularly troublesome on the beam induction electrode where it could give wrong beam-level readings. Some materials, such as plastics, suffer radiation damage and require protection to gain a reasonable life.

About 89% of the beam injected into the Bevatron is lost because it: (a) is outside the acceptance time, (b) is outside phase acceptance, (c) strikes the inflector, (d) has increased radial oscillation from phase oscillations superimposed on betatron oscillations, and (e) loses phase stability because of gas scattering and phase noise. Beam stoppers were placed around the Bevatron aperture on the inner and outer radii to stop as much of this beam as possible from striking particularly vulnerable parts of the Bevatron. All plastics were shielded. The induction electrode and accelerating electrode were protected. The area near the output of the inflector was protected for injection with magnet off. With the magnet on, two injector pulses, 1/2 sec and 1 sec after normal injection, would strike the inner stanchions near the entrances of quadrant I. They might possibly go through the spaces in the stanchion and impinge on the vacuum skin. The inner stanchions were protected in this region. Where possible the shielding material was graphite because of its low neutron yield and low induced activity. Aluminum was used where the higher strength and workability were needed to form or mount the part. Aluminum was also used on moving equipment such as the external-beam plunging magnets and the travel target. With the exception of those mounted on the beam induction electrodes, these beam stoppers did not become aperture-limiting devices. Complete details of the beam-stopper installation are given in a separate report.[7]

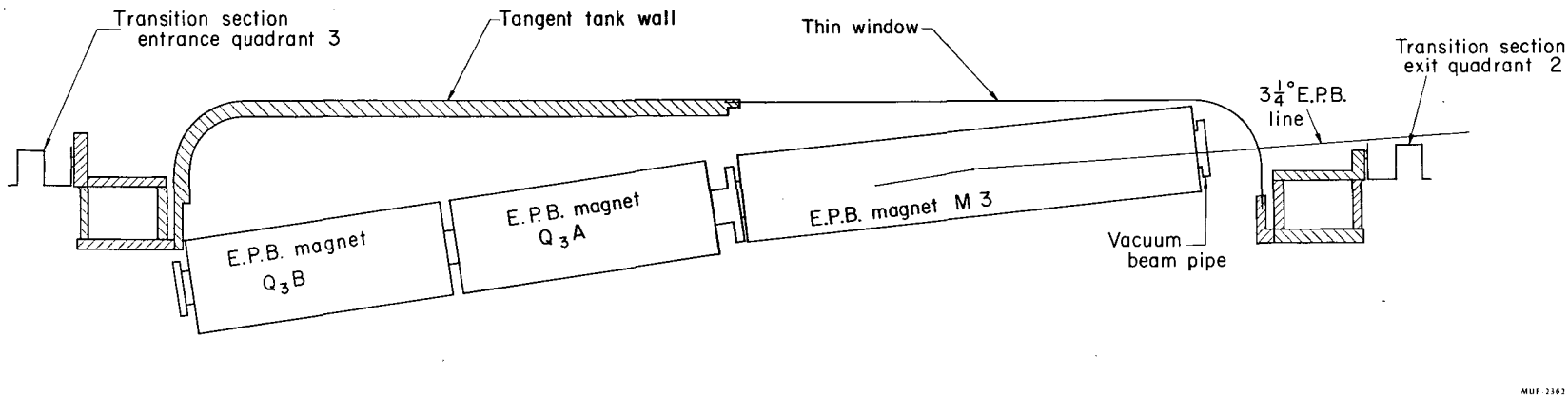
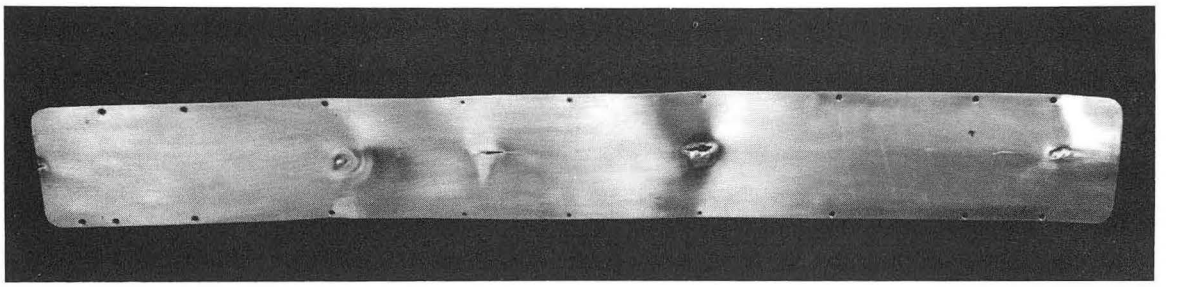


Fig. 10. Layout of west thin window.



ZN-4104

Fig. 11. Damage to inflector ground plate when struck by the injected beam.

G. Magnet Alignment

When the full load of the new concrete shielding is in place, the Bevatron is expected to sink from 3/4 in. to 2 in. during the first year. We expect that this settlement under the foundation will be somewhat uniform azimuthally around the Bevatron magnet. At worst, it should at least be a smooth curve with no sudden discontinuities.

We assume that we will have to make at least several magnet-sector elevation adjustments during this time. This is to keep the closed orbit of the beam in a reasonable position in the gap. In the past we have had problems making the internal beam strike the targets properly[6] when the closed orbit became distorted too badly from a plane. The external beam will be more sensitive to this type of beam orbit perturbation. If the magnet sectors are not in a plane, the beam orbit calculations to determine the necessary correction are quite involved.[8] For these reasons, we felt it was desirable to put the magnet sectors on a plane. This was done during the long shutdown. In the past the magnet adjustments, necessary to return the beam orbit to an operating position, had always been minimum-motion adjustments to minimize any physical stress in the vacuum skin. As a result some of the magnet sectors had been tilted from the approximate plane formed by the entire magnet. In some sections the sectors actually sloped the wrong way.

The plane determined by the entrance and exit magnet sectors at the north, east, and south tangent tanks was chosen for the first adjustment. This plane was chosen to minimize the physical movement of the magnet in the region of the tangent tanks. Only the west tangent had to be moved. This tank was raised about 1/4 inch. Where the jacking schedule showed a sharp change between adjacent sectors, a check survey was made in the gap. In this manner we were reasonably certain that we were relieving rather than increasing strains in the vacuum skin in these regions.

H. Linac Injector Mark II

Rudin M. Johnson

1. General

During this period the linac was reassembled and connected to the Bevatron. The ion source, linac, various beam transport magnets and vacuum pipes were aligned optically and, where possible, by magnetic measurement techniques. Most component parts were tested and run. The ion source and 460-kV beam optics were optimized for maximum current in phase space. The shielding was built up around the injection area to allow us to run a proton beam briefly into the Bevatron east straight section. The linac was run successfully and a current of 9 mA of 19.2-MeV protons measured in the Faraday cup at the end of the east straight section.

2. 460-kV Ion Source and Beam Transport

The reassembly of the ion source and the optical bench was completed in October. All the wiring and power supplies were tested. The 400-cycle generator shaft was aligned. The accelerating column was installed.

On November 5 the ion source was run at 460 kV and a current of 70 mA.

At 3% rhenium-tungsten filament was tried in the ion source in place of the tantalum filaments we normally use. This 3% rhenium alloy behaved much like ordinary tungsten. We returned to the use of tantalum filaments because they are easier to make and require less heater power.

The steering magnet S1 was used to analyze the H_2^+/H^+ ratio. The buncher aperture was too small for good measurements so we drifted the beam through the linac and used the IM 1, 50 deg spectrometer to make the measurements. These measurements indicate there may be 20% H_2^+ in the beam.

The ion-source geometry was changed in an effort to decrease the H_2^+ content in the beam. The exit-button apertures were made smaller and longer but operation became erratic. The aperture became plugged after a few sparks so we returned to the original geometry, which was 0.020 in. diameter by 0.040 in. deep.

The ion source ran satisfactorily on the ion pumps alone when the mercury diffusion pump failed once.

3. Linac Tank and rf System

The drift-tube optical alignment was completed October 24. The move from building 64 did not disturb the original alignment very much. Following the move a few drift tubes were off as much as 0.010 to 0.020 in. transversely and 0.040 in. axially. Drift tube No. 2 was displaced transversely nearly 0.1 inch. A realignment was made. We now believe the drift-tube alignment is within 0.003 in. transversely and 0.015 in. axially.

We began tank flattening as soon as the drift-tube alignment was completed. We borrowed some of Argonne Laboratory's linac tank-flattening equipment in order to save ourselves from developing similar equipment. Joseph Abraham and William Meyer from the Argonne group spent a week helping us flatten the linac E-field. Most of this work was done from 8 PM to 4 AM in order to avoid noise and vibration during these measurements. The tank rf field was measured by detecting the frequency shift caused by an aluminum ball as it traversed each gap between drift tubes. Several sizes of ball were pulled through on a nylon fish line. There was some difficulty in interpreting the effect (frequency shift), of the perturbing aluminum ball size as a function of the drift-tube gap and bore sizes. The final adjustment of field is probably within ±5% of the calculated theoretical E-field.

After flattening the E-field we cleaned all the tank inside surfaces and pumped it down with the mercury diffusion pump and the two 1000-liter/sec vacion pumps. The vacuum is typically 2.5×10^{-6} mm Hg.

We began running the preexciters and oscillators in mid-November.

There was no particular problem getting the rf voltage on the tank up to operating level.

The buncher cavity originally had 3/4-in.-diameter grids. These were replaced with 1-1/2-in. grids and the cavity frequency returned to 200 Mc/sec.

4. High-Energy Beam Transport

The beam transport system—consisting of magnets IQ 1, IQ 2, IM 1, IM 2, and IM 3 plus the electrostatic inflector—was all installed and tested during this period (Fig. 12). The three bending magnets IM 1, IM 2, and IM 3 were run together in place and a single wire orbit test was made on all three. We were thereby able to adjust the currents of these three magnets with respect to each other and compare them with the design values.

All the beam vacuum piping, the four-jaw measuring apertures, and the debuncher cavity were installed. The Bevatron shielding wall is nearly complete in the area of injection. The 2-ft-thick-wall concrete blockhouse at the end of the linac was built with some temporary shielding blocks. This blockhouse allows us to run the 19.2-MeV proton beam into a carbon stopper inside the blockhouse and be shielded from the neutrons that are produced.

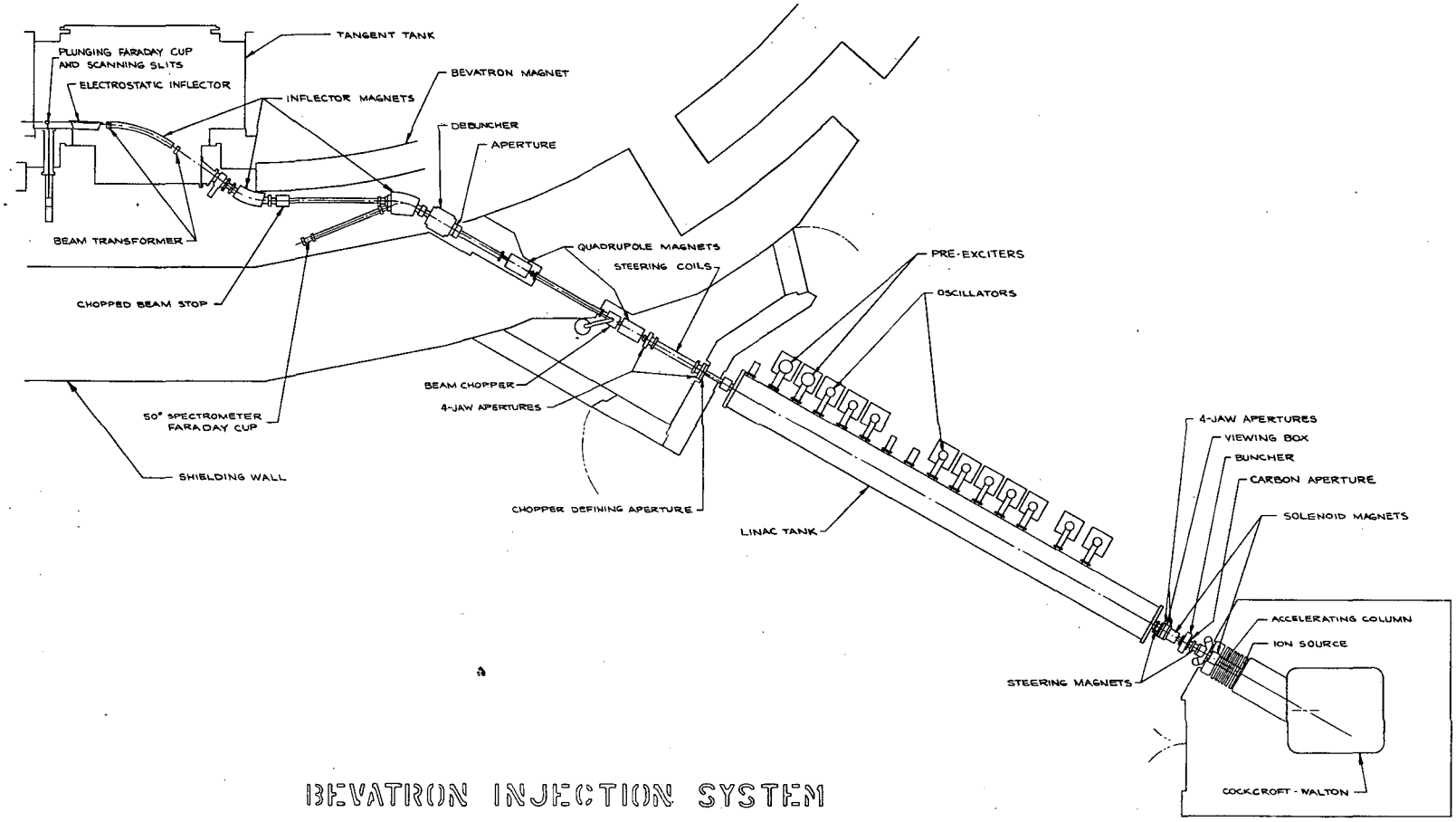
5. Mechanical, Electrical, and Plant Engineering Jobs

During this period the alignment of the drift tubes and beam transport system into the Bevatron was completed by the mechanical engineers together with the Bevatron crew. The general building-construction work and other installation work during the day shift caused vibration and temperature changes that made optical alignment difficult. The drift-tube alignment, therefore, was done on swing and owl shifts in order to work in a stable environment.

The IM 3 bending magnet was installed inside the Bevatron east straight section. The water cooling connections were brazed in place and the joints x-rayed to make sure that there would be no water leaks in the vacuum.

The electrostatic inflector was installed in the east straight section.

The plunging Faraday cup and scanning-slit mechanism for study of the inflected beam is designed and in the shops. This cup will be mounted at the east outside south straight section. It will intercept all the beam leaving the inflector the pulse that is to be accelerated by the Bevatron. This job plus a number of others necessary for beam testing in January are being pushed through the shops on high priority.



MUB-1946

Fig. 12. Bevatron injection system.

The electrical wiring of the pulse lines, power supplies, magnets, control console, etc. was nearly all completed and tested. The rf shunt regulator required adjustments by the engineers because it tended to oscillate. This trouble was probably due to gas loading when we first came on.

The amplifier system for the beam transformer signals at four-jaw apertures Nos. 2 and 4 was reworked so that the noise level was below 1 μA. This was accomplished by placing the amplifier tube as close as possible to the transformer terminals, and using both magnetic and electrostatic shielding.

The 2-ft-thick concrete blocks for the shield house at the end of the linac are not all finished. Two blocks are now installed together with temporary shielding. The three remaining blocks and the two doors should be ready in January.

Two overhead hoists were built over the linac. One, the optical bench crane and crane rail system, will lift 1 000 lb. and the other, a monorail over the oscillators, will lift 300 lb.

6. Beam Measurements

We made a study of beam current through a 1-in. square at four-jaw aperture No. 1 as a function of ion-source lens voltage (Fig. 13). The E_1 voltage was the most sensitive; it was set four different values and beam emittance measurements were made at each value. The optimum lens voltages were: probe, 70 kV; focus, 100 kV; E_1, 22 kV; and E_2, 50 kV – for 36-mA beam (89 mm-mrad).

The ion-source emittance was very carefully measured by scanning the beam cross section every 0.2 in. with 0.1-in. square apertures with the four-jaw scanning slits Nos. 1 and 2. The results of these scans, when added together, gave results that were consistent with our previous measurements. We learned that there was no cross-coupling of beam from horizontal to vertical planes. We also determined that the emittance areas were no larger then previously measured, and may have been smaller.

On December 6, the first linac beam was run. We measured the energy to be 19.2 MeV ± 1/2%.

The beam was run through the entire beam transport system into the Bevatron's east straight section on December 16. The Bevatron was pumped down but there was no magnetic field. The beam was collected in a Faraday cup at the east-outside-south port. We measured 9 to 10 mA in the cup, with 16 mA at four-jaw No. 3 (IQ 2 was off).

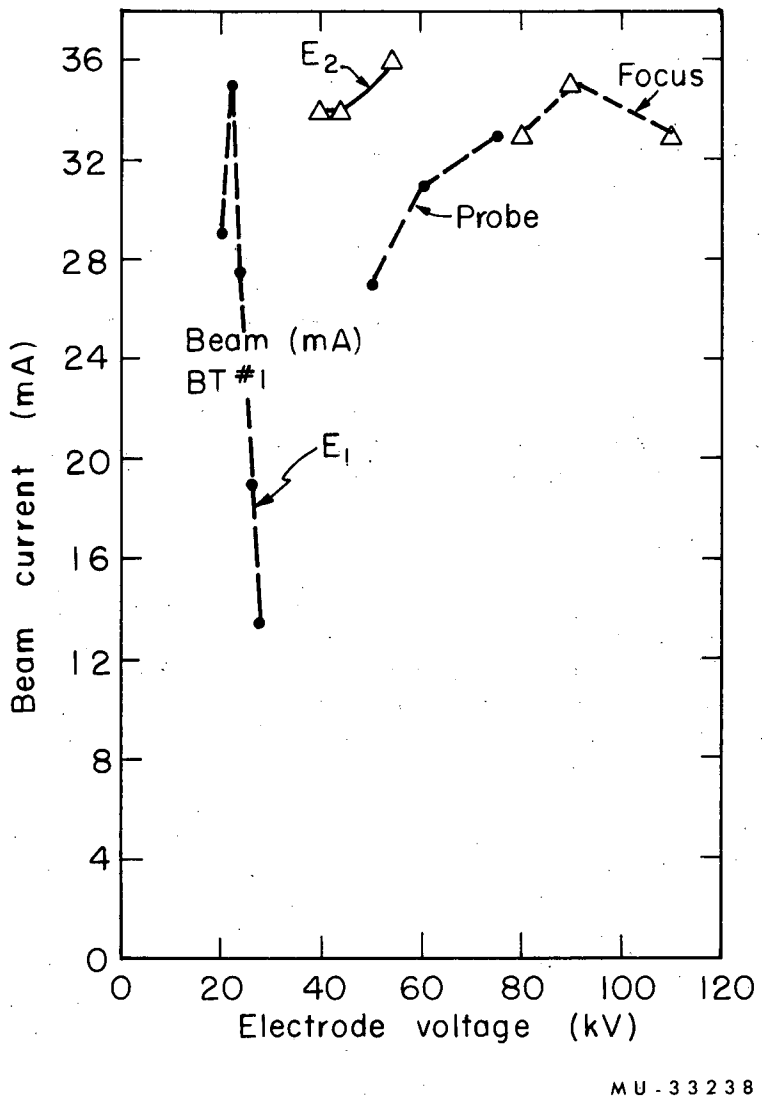


Fig. 13. Ion-source beam current through a 1-in. square at 4J 1 as a function of source-lens voltages.

II. EXPERIMENTAL EQUIPMENT

Twenty new quadrupole magnets of Brookhaven type have been ordered. These are for use in the secondary-beam channels of the experimenters and along the external proton beam; they are scheduled for delivery during the summer of 1963.

Quantity	Size (in.)
6	8 × 16
4	8 × 32
6	12 × 24
4	12 × 48

III. MAGNET POWER SUPPLY

The main-magnet pulser was rebuilt to clean up some of the maintenance problems of the past. The grounding system for flat-top operation was modified to permit remote switching of the grounding when changing from normal to flat-top operation.

The main motor-generator sets plus all the auxiliary sets were completely overhauled. Eighteen of the ignitron tubes were taken apart, the graphite electrodes vacuum-baked, and the tubes cleaned, repaired, and reassembled.

ACKNOWLEDGMENTS

Edward J. Lofgren is the Bevatron Group Leader; William A. Wenzel is the Alternate Group Leader. Walter D. Hartsough, with Glen R. Lambertson and Wendell Olsen assisting, is in charge of Bevatron Operation. Members of the Operating Crew are: Robert W. Allison, G. Stanley Boyle, Robert W. Brokloff, Ashton H. Brown, Duward Cagle, Norris D. Cash, Frank W. Correll, Ferdinand Dagenais, John R. Ellisen, Robert Gisser, William Kendall, William Lee, Kenneth Morgan, Martin E. Scolnick. The following members of the Operation Group are carrying out support and development projects: Robert Anderson, Trancuilo Canton, Warren Chupp, Charles Coad, Bruce Cork, Kenneth Crebbin, Walter Hartsough, Rudin Johnson, Leroy Kerth, Glen Lambertson, Fred Lothrop, Ross Nemetz, Douglas Pounds, Robert Pratt, Robert Richter, Joseph Smith, William Wenzel, Glenn White, Emery Zajeck, and Theodore Zipf. Engineering groups were headed by Edward Hartwig, Electrical Engineering; Clarence Harris, Electrical Coordination; Harold Vogel and Gordon Harding, the Motor Generator Group; and William Salsig, Mechanical Engineering. Donald Milberger was in charge of the Electrical Maintenance Group.

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