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BEVATRON OPERATION AND DEVELOPMENT. NO. 35 July through September 1962

Berkeley, California
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BEVATRON OPERATION AND DEVELOPMENT. NO. 35
July through September 1962
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December 16, 1963
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* Preceding Quarterly Reports: UCRL-10613, UCRL-10561.
ABSTRACT

There was no Bevatron operation this quarter. The long shutdown for shielding and injector changes continued. The foundations for the "igloo" and part of the outer shielding wall were completed. Part of the steel structure to support the inner edge of the roof blocks was installed.

The old pole-face windings were removed and new more trouble-free windings were installed. The rf house was modified to allow for the new roof-block shielding. A new rf accelerating electrode to eliminate harmonic resonances was installed. A magnet elevation survey was made on the bottom of the magnet and in the gap to provide data for future surveys on the bottom of the magnet only.

The new linac injector was tested at full energy (19.2 MeV) at currents up to 25 mA. The ion source was run at 460 kV with up to 100-mA currents available. The beam-transport-system magnets were completed and the beam was run through part of the system. This work was done in a building adjacent to the Bevatron building. The injector testing was then stopped and the equipment taken apart and moved to the Bevatron building where final installation was started.
SHUTDOWN

There was no Bevatron operation during this quarter. The following shutdown work was started.

Shielding Foundation

A pit 7 ft deep by 10 ft wide was dug around the center crane columns of the Bevatron for the igloo foundation (Fig. 1). Figure 2 shows the reinforcing steel in place prior to pouring the concrete. The pouring of 500 cubic yards of concrete was accomplished in one day by using both cranes to lift the buckets of concrete over and around the Bevatron. A concrete truck arrived every seven minutes during the pour. Figure 3 shows the foundation after the pour and before the start of the forming for the igloo.

Holes were cut in the floor on the inside radius of the machine for the inner roof-block support columns (Fig. 4). These columns are fastened to the foundation that was put in by tunneling around under the Bevatron last winter during normal Bevatron operation. Figure 5 shows the remaining steel structure for supporting the roof blocks, partially installed.

The increased thickness of the outer shield wall plus the addition of the roof load required new heavy-duty flooring around the outside of the machine in quadrants I and IV. The old floor was torn up and holes bored 50 ft deep for concrete pilings. Steel reinforcing for a pile is shown in Fig. 6. Figure 7 shows a section of the floor with the piles poured and ready for installation of the floor reinforcing steel.

Figure 8 shows the temporary covering of the Bevatron to minimize the amount of dust that might get into the magnet during the construction period. The magnet cooling fans are run at low speed to provide a positive air pressure under the canvas to further prevent dust and dirt from getting into the magnet structure. All of the equipment and materials used in the construction work in the center of the machine are lifted over the magnet by crane. To protect the magnet from falling objects, two access routes were established. The magnet is protected along these routes by 12- by 12-in. wooden beams placed on top of the magnet. All loads moved across the magnet must use one of these access routes.

Pole-Face Windings

The old pole-face windings were removed. New windings insulated with irradiated polyolefin were installed. These were laid along an epoxy-glass base strip on the pole tips. Physical protection and electrostatic shielding of the wire insulation is provided by a stainless steel channel. In the region of the travel target the channels act as the track for the target board.

The B windings on the lower pole tips were replaced by coax cable insulated with irradiated polyolefin. New sets of windings were installed on the upper pole tips to provide additional isolated B circuits.
Fig. 1. Igloo foundation pit.
Fig. 2. Igloo foundation reinforcing steel in place, ready for concrete pour.
Fig. 3. Igloo foundation after concrete pour, before starting the forming for the igloo.
Fig. 4. Roof support column.
Fig. 5. Support structure for inner end of roof-block shielding.
Fig. 6. Reinforcing steel for concrete pile.
Fig. 7. Section of heavy-duty floor showing top of piles after casting concrete.
Fig. 8. Canvas dust covers on Bevatron magnet.
New windings were installed to the inside of pole-face winding No. 2 and to the outside of No. 20, top and bottom. These are No. 2 A. W. G. wire, also insulated with irradiated polyolefin. These windings will be used for ripple correction of the Bevatron magnetic field. 3

**rf Changes**

The rf house on top of the north tangent tank had to be removed to make room for the new roof-block radiation shielding. A new rf house was built onto the inside radius of the north straight section (Fig. 9). The inside-radius tangent-tank face plate was made reentrant to provide a short lead distance for rf coupling of the final amplifier to a new accelerating electrode.

A new electrode was designed and tested in a scale model to eliminate harmonic resonances that existed in the original electrode. A new electrode was fabricated from this design study and installed in the Bevatron. A picture of the new electrode is shown in Fig. 10. Figure 11 shows the electrode in position in the north tangent tank.

The ground-plane copper liner in the north tangent tank was removed and reworked to install the reentrant section. While it was out of the tangent tank, the two end sections of the liner were cut off and reinstalled with screws and tapped holes. This provided a removable access to the pole-face-winding "waterfalls" at the exit of quadrant III and entrances of quadrant IV. Previously, access could only be had by removing the top face plate, electrode, and liner.

**Magnet Survey**

The general problem of Bevatron magnet elevation alignment has been increased this year by the foundation tunneling work last winter 4 and the changing heavy loads near the foundation. The concrete shielding was all removed at the start of the shutdown. When the new shielding is installed this winter a much larger load will be placed around the Bevatron foundation. This will cause additional subsidence. The amount of rebound was not as much as expected when the shielding was removed. This leaves some uncertainty as to what will happen when the load is restored and additional load added.

An elevation survey was made under the magnet, simultaneously with a gap survey. The gap survey was made by using the pole tip leveling gauge. This gave a direct reading of the pole tip slope and vertical gap aperture. From this the gap elevation at center line and the slope of the gap were determined. This compared very well with the previous survey from the top of the magnet. Some adjustment of the magnet elevation is planned for later in the shutdown.
Fig. 9. New rf feed-through on side of tangent tank.
Fig. 10. New rf electrode showing support rods and slotted electrodes.
Fig. 11. New rf electrode installed in north tangent tank.
Linac Injector Mark II
Rudin M. Johnson

General

During this period the testing and measuring program of the last quarter was continued and completed. The proton beam was run at full energy (19.2 MeV) and currents ranged from 0 to 25 mA. The efficiency of the capture of the beam injected into the linear accelerator was measured under various conditions. As a result we have decided to replace the quadrupole triplet lens between the ion source and the linac tank with a solenoid lens. All other components are operating satisfactorily.

Operation of the linac in its temporary installation in building 64 stopped on September 10. All major components of the linac were moved to the prepared permanent site in the Bevatron building by the end of September.

We intend to finish the installation of the linac in the Bevatron in October and begin to run beam. The beam energy and optical properties will be measured, and preparations made to inject into the Bevatron in December. We then plan to measure the beam inside the Bevatron, thus testing the linac as a whole from ion source to inflector.

460-keV Ion Source and Beam Transport

The ion source and Cockroft-Walton ran at beam currents of 40 to 60 mA at 460 keV during this period. Currents of 100 mA were possible but not needed for a major part of the measurements and tests.

During the rf buncher tests we discovered the beam to be off axis at the exit end of the accelerating column by approximately 3/4 inch. A large part of this was due to misalignment of a few thousands of an inch of the ion source electrodes. A method of better alignment was developed by using the alignment telescope mounted on the lens box together with alignment jigs and targets. The magnetic axis of the solenoid lens at the bottom of the column was not parallel and collinear with the mechanical axis of the column. It was replaced with the spare solenoid whose magnetic and mechanical axes were more nearly collinear.

The four-jaw measuring apertures continue to work well and are used for measuring the beam size, direction, and emittance.

The solenoid lens $S_2$, which focuses the beam into the first drift tubes of the linac, was replaced by a quadrupole triplet lens, IQ 0, in August. This was done so we could have more freedom in matching the beam emittance to linac acceptance. An extensive series of matching tests and measurements were made with the IQ 0 triplet before the linac was moved to the Bevatron.

Linac Tank and rf System

We continued to operate with eight oscillators and one preexciter during this period. We tried various methods of exciting the tank by using two
preexciters. When the two preexciters were driven from the same plate supply (pulse line), two troubles appeared: (a) they tended to share the load unequally because they are not exactly alike electrically, and (b) they did not necessarily begin oscillating at the same frequency and tended to fight one another before locking on the proper tank frequency. If the preexciters are driven from separate adjustable power supplies they can be made to share the load. This solved the first trouble. A solution to the second problem is to let one preexciter be self-excited by the tank and drive the second preexciter as an amplifier with coax coupled to the tank. This was temporarily hooked-up and tried with fair success. More effort will be made on this method as time allows.

Meanwhile, one preexciter is used at position No. 6 on the tank. An extra 6 in. of transmission line between the preexciter and the tank helps match the preexciter to the tank. This is particularly helpful during periods of gas loading. As the tank cleans up and the vacuum gets better this gas-loading effect is reducing.

The 25-kV, 1-μF capacitors in the pulse line have been breaking down because of overvoltage. We replaced them with 50-kV, 0.5-μF capacitors. The pulse line was adjusted and Gibb's suppressors added to give a good pulse shape.

The buncher position was adjusted for maximum bunching and the coupling rf coax cable was fitted with a spark gap to protect it from overvoltage when the buncher cavity sparks. The buncher beam aperture was changed from 2 to 3/4 in. diameter to test the effect of aperture size on bunching efficiency. No appreciable increase in bunching efficiency was detected with the smaller aperture.

**High-Energy Beam Transport System**

The focusing magnets IQ 1 and IQ 2, and the bending magnets IM 1, IM 2, and IM 3 were completed in the shops during this period, and the magnetic measurements were completed except on IM 3. These magnets were installed in line with the linac in building 64. The 19.2-MeV proton beam was run through the system up to IM 2. We used IM 1 in its spectrometer mode to measure the energy of the linac beam. The four-jaw measuring apertures 4J3 and 4J4 were installed and used to measure the size of the 19.2-MeV proton beam and its optical emittance properties. Some of the stainless steel bellows and vacuum piping is not yet complete but will soon be ready for installation on the Bevatron.

All of the high-energy beam transport system (from the end of linac tank onward) was shielded with concrete shielding blocks in order to protect personnel from neutrons and x rays.

The debuncher cavity was completed and some high-power rf measurements made under vacuum but not in place on the beam transport system. Time did not permit the debuncher to be tested with proton beam before we started moving the linac to the Bevatron. The debuncher is phase-locked to the main tank by a transmission line an integral number of half-wavelengths long.
Mechanical, Electrical, and Plant Engineering Jobs

During this period the engineering groups prepared for and began the final installation of the linac in the Bevatron building. The concrete floor and foundation work being done by the contractors was scheduled so that the linac area would be completed by September 1. The ion-house construction was completed, including the computer-type flooring installation. The sheet-metal workers began to apply the 1/8-in. lead shielding to the outside of the ion house.

The beam line position of the linac was first carefully surveyed and a series of monuments were grouted in the floor to mark this line for future reference.

The entire linac was then moved to its place in the Bevatron; the Cockroft-Walton, optical bench, tank, rf platform, pulse lines, power supplies, control racks, and vacuum pumps are all in place. Plumbing and wiring is started. The high-energy beam transport system has not been moved yet, and is being preassembled and tested in building 64 so as not to interfere with the drift-tube alignment operation. A temporary enclosure has been built around the tank and rf platform so that the tank environment could be stabilized for the drift-tube alignment operation. The linac tank has been vacuum leak-tested after the move in order to fix all vacuum leaks before the drift-tube alignment begins. The tank temperature-regulated water system is in operation. The 2-ft-thick concrete shielding for the blockhouse at the end of the linac is designed and the pouring of these concrete blocks should begin soon.

A system of Faraday cups, slits, and probes is being designed and built for measuring the injected linac beam inside the Bevatron.

Two overhead hoists are being designed. A 1000-lb hoist will service the optical bench and a 300-lb hoist and monorail will service the oscillators on the tank.

Theoretical Work and Beam Measurements

A careful study of the low-energy beam transport system was made. The theoretical emittances and acceptances of the ion source and linac were calculated with help from Lloyd Smith and the Theoretical Group. Victor Cook, William Layson, and Robert Allison of the Bevatron Group worked on calculating the best match that could be made with 10 0 triplet quadrupole. A small analog computer was used to help speed these calculations and was quite useful as a check of calculated solutions. This theoretical work went on in conjunction with the actual beam studies and measurements that were made on the linac. Measurements were made at 30- to 60-mA input beam levels with the intent of maximizing the accelerated (19.2-MeV) beam current.

Emittance measurements

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<tr>
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<th>Beam into linac</th>
<th>Beam out of linac</th>
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<tbody>
<tr>
<td>Horizontal</td>
<td>127 mm-mradians</td>
<td>15 mm-mradians</td>
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<tr>
<td>Vertical</td>
<td>175 mm-mradians</td>
<td>17 mm-mradians</td>
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As a result of these matching measurements we found that the IQ 0 triplet could not easily match both the horizontal and vertical linac acceptance simultaneously. It was decided that the solenoid lens that was used earlier would do the job better and would be less critical to adjust.

The energy of the accelerated beam was measured to be 19.2 MeV with an energy spread of ±3/4 %.

A series of measurements was made with collimated beam injection into the linear accelerator. The four-jaw apertures were used to produce the collimating apertures for the 460-keV beam. We found that by forming horizontal or vertical slits we could accelerate different fractions of beam. If we tuned the IQ 0 triplet to maximize beam in one plane we would get less beam in the other plane, and vice versa. A collimated beam formed by two 0.050-in. square holes 7-1/8 in. apart on the beam center line gave 50% transmission and a buncher gain of 2.5 times, which is about what we expect from theory.
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 Olson 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 Praff, Robert Richter, Joseph Smith, William Wenzel, Glenn White, Emery Zajec, and Theordore 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.
REFERENCES


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