Title
Bevatron Operation and Development. IVII - February, March, April, 1958

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Publication Date
1958-06-01

UCRL-8334

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

BEVATRON OPERATION AND DEVELOPMENT. XVII
February, March, April, 1958

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June 26, 1958

Printed for the U.S. Atomic Energy Commission

Printed in USA. Price 75 cents. Available from the
Office of Technical Services
U. S. Department of Commerce
Washington 25, D. C.

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ABSTRACT

Beam evaluation was completed preparatory to a K^+-p^+ scattering experiment. The K^+ meson beam was also used to expose sixteen emulsion stacks for eight outside groups. The study of K^- mesons continued, using the liquid hydrogen bubble chamber and emulsions. Antiproton interactions were observed by using counters, the propane bubble chamber, and nuclear emulsions; p-$\bar{p}$ interactions were also observed in the hydrogen bubble chamber.

Three target bombardments were made for the laboratory chemistry group and sixteen bombardments made for external groups.

The rapid beam ejector was successfully operated and has been used to produce short beam pulses, 20 microseconds in duration, for bubble chamber runs.

On April 23, 1958, Bevatron operation was suspended when a bolt was sheared off the armature of the east generator, resulting in abrasion and fire damage to one-third of the stator windings and in electrical arc damage to a bearing and journal. Operation is scheduled to resume on May 26, 1958, with one generator, after an inspection has been made of the east machine. The damaged generator is expected to be operable about the end of July.

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EXPERIMENTAL FACILITIES

Gap-Mounted Targets

The gap-mounted targets available during this period are listed in Table I.

Rapid Beam Ejector

Glen R. Lambertson

The rapid beam ejector has been completed and now provides a means of deflecting the internal beam onto a target in an interval which is short compared with bubble-growth time in existing bubble chambers.

The power supply is a capacitor bank discharged through ignitrons; the electrical system is described in a separate report.[1]

The pulsed air-core magnet[2] located in the south straight section (see Fig. 1) produces a field which distorts the equilibrium orbit into an eccentric path. Maximum radial displacements from the normal orbit are about 6 inches inward at the north, 3 inches inward at the east and the west, and 2-1/2 inches outward at the south. These displacements are for a 6-Bev beam circulating at a radius where the field exponent n has the nominal value of 0.63. At operation with a full capacitor bank of 120 microfarads, the magnet-current pulse and corresponding beam displacements rise to a maximum in 55 microseconds. At peak current, a resistor is inserted to critically damp the discharge; in this way, the disturbance is terminated rapidly and beam excursions are unidirectional, occupying minimum radial aperture.

*Preceding reports: UCRL-8261, UCRL-8114

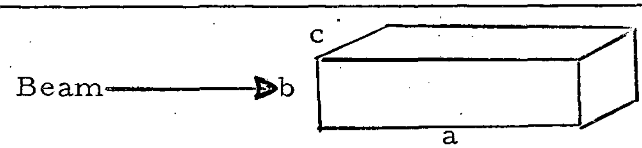
[1] Charles G. Dols, The Electrical System of the Bevatron Rapid Beam Ejector, UCRL-8346, June 1958.

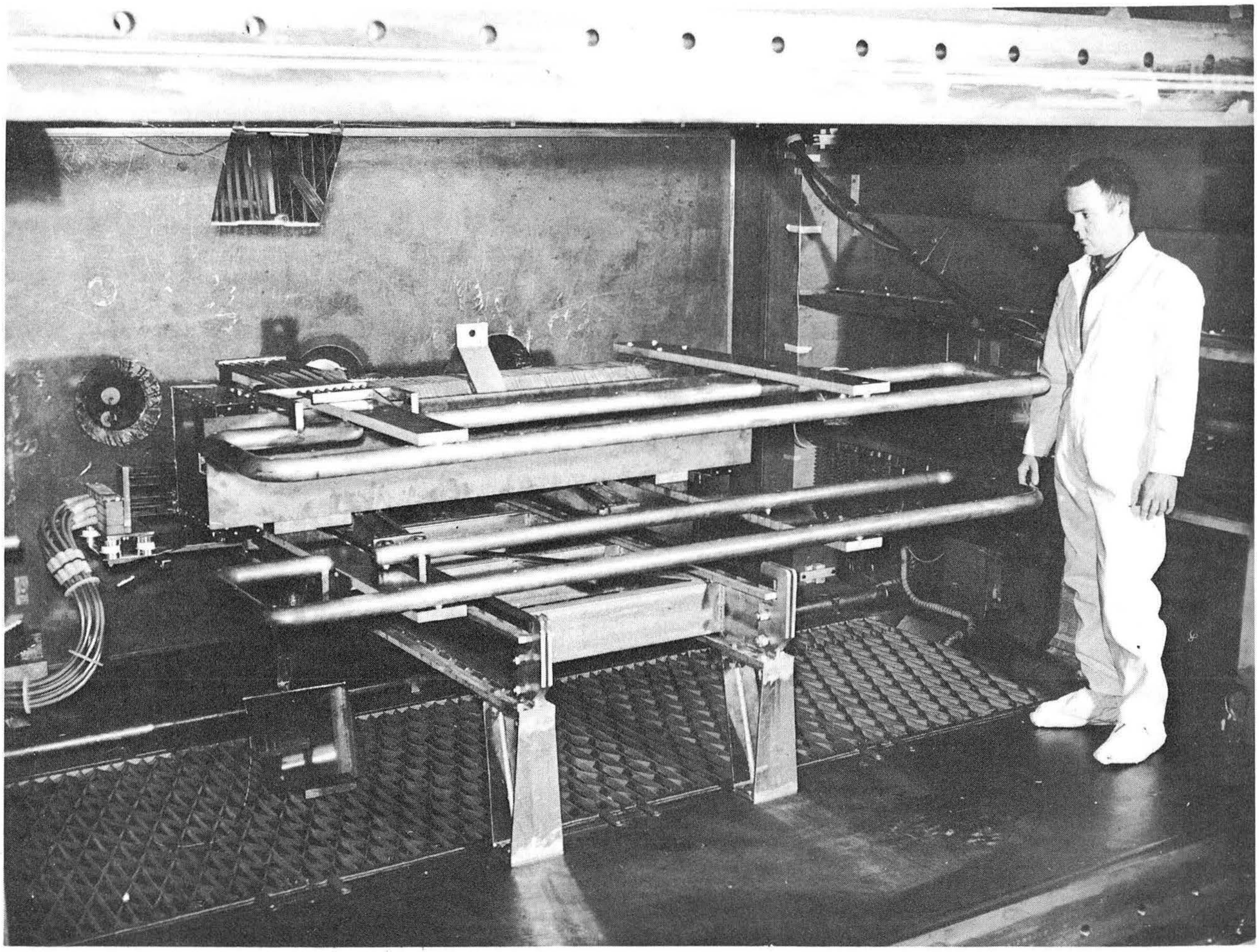
[2] Walter D. Hartsough, Bevatron Operation and Development, XV, UCRL-8114, Jan. 1958.

Table I

Quadrant-mounted targets
February 24, 1958 to end of quarter

Quadrant	Azimuthal location (Ref: entrance end of quadrant)	Radial location: Outer-radius edge of target (in.)	Radial location: Outer-radius edge of lip (in.)	Target material	Target size a x b x c (in.)
II	70°02'	601-1/8	601-5/16	Polyethylene	1 x 1/2 x 1
II	73°41'	605 1/16 to inner radius edge (outer radius target)	. . .	Copper	7/8 x 1 x 3/4
II	76°00'	601-1/2	601-3/4	Beryllium	6 x 1/2 x 1/2
II	82°58'	599-1/8	. . .	Scintillator	
III	35°33'	600-1/2	600-3/4	Graphite	3 15/16 x 1 x 4
III	71°42'	599-5/8	600	Aluminum	4 x 1/2 x 1/2
III	72°29'	597-3/4	598-1/8	Copper	3-1/2 x 1/2 x 1/2
III	79°05'	598-7/8	599-3/8	Lead	4 x 1/2 x 3/4
III	81°50'	602-7/16	602-5/8	Beryllium	6 x 1/2 x 1/2
III	82°32'	602-5/16	602-1/2	Beryllium	6 x 1/2 x 1/2
III	83°28'	599-3/4	599-15/16	Beryllium	6 x 1/2 x 1/2
III	84°16'	602-3/8	602-9/16	Beryllium	6 x 1/2 x 1/2
III	85°15'	596-3/16	596-3/8	Tantalum	1/4 x 3 x 1/4
IV	15°30'	599-1/2	599-3/4	Graphite	2-35/64 x 1 x 4





ZN-2013

Fig. 1. Rapid beam ejector.

The duration of a beam pulse depends upon the radial distribution of the circulating beam and upon operating conditions in the beam ejector system. A typical beam pulse is about 20 microseconds wide at half maximum and has the rf modulation of the circulating beam.

While the air-core deflecting magnet is energized, the circulating beam has a frequency of rotation which is less than the normal value. This frequency deviation reaches a maximum of about 0.3%. If it is desired to eject only a fraction of the beam and to continue to accelerate the remainder for another experiment, it is necessary to modulate the frequency of the accelerating voltage. A voltage-sensitive pn-junction capacitor has been inserted in the master oscillator and connected to receive a modulating signal proportional to the magnet current of the rapid beam ejector. With this frequency compensation and a full beam-ejector pulse, 85 to 90% of the beam which does not strike a target during the 55-microsecond rise time remains phase stable and can be directed to other targets by the normal methods. Improvements in the system are planned which may eliminate the residual beam loss. At present, the loss may be reduced by using less than maximum current in the deflecting coil. For applications in which all the circulating beam is directed upon the target by the rapid beam ejector, no frequency compensation is needed.

New 9-by-12-Inch Auxiliary Bending Magnets

Two new bending magnets of identical design (C-type construction) have been made available to research groups for use in experiments at the Bevatron. On each the pole tip size is 9 x 12 inches; the normal gap is 4 inches (Fig. 2). At the rated operating point--200 amperes in the magnet--the magnetic field at the center of the pole tip, in the median plane, is 12.2 kilogauss for a 4-inch gap; 9.5 kilogauss for a 6-inch gap.

TRACKING BEAM DURING INVERSION

A new analog computer is in use in the beam-steering circuitry which allows the beam to be tracked during rectification, from injection to 6.2 Bev, and during inversion back down in energy to 300 Mev (Fig. 3). The beam loss during deceleration from 6.2 Bev to 1 Bev is less than 50%. This work is reported separately.[3]

DEFLECTING THE HIGH-ENERGY PRIMARY BEAM THROUGH THE INNER-RADIUS n = 1/2 POINT USING THE RAPID BEAM EJECTOR

Beam has been deflected through the inside radius $n = 1/2$ resonance point with negligible beam loss. The beam was tracked at an orbit of 597-3/4 inches by use of an analog beam-tracking device. The radial position of the beam was verified by erecting a target at the above radius and observing that the beam was lost before reaching full energy. Then, with the target out of the aperture, the rapid beam ejector was pulsed to a voltage corresponding to a beam deflection of 4 inches and the beam was observed to survive with

[3] Harry G. Heard, Analog Tracking of the Bevatron Beam During Acceleration and Deceleration, UCRL-8296, June, 1958.

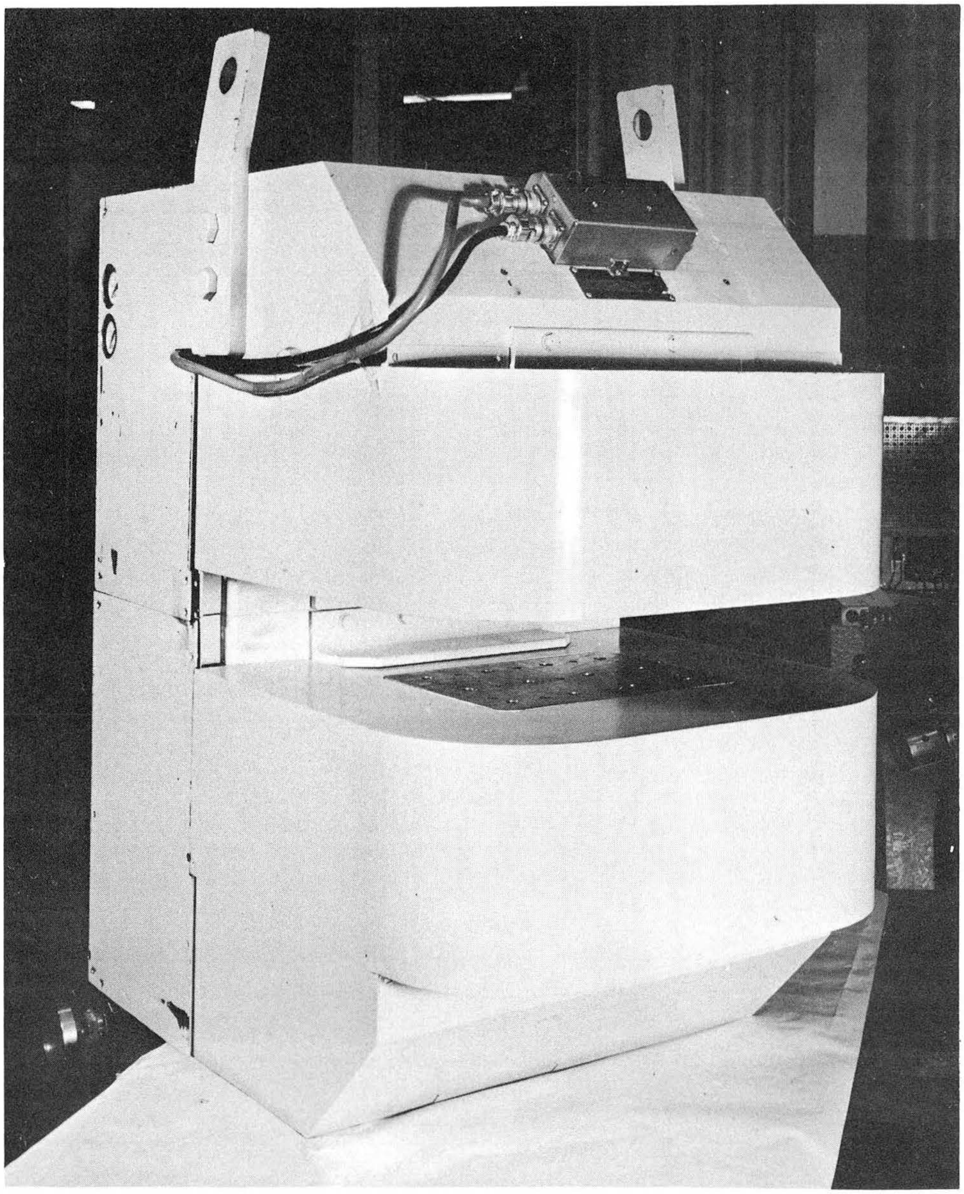


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Fig. 2. New 9-by-12-inch bending magnet.

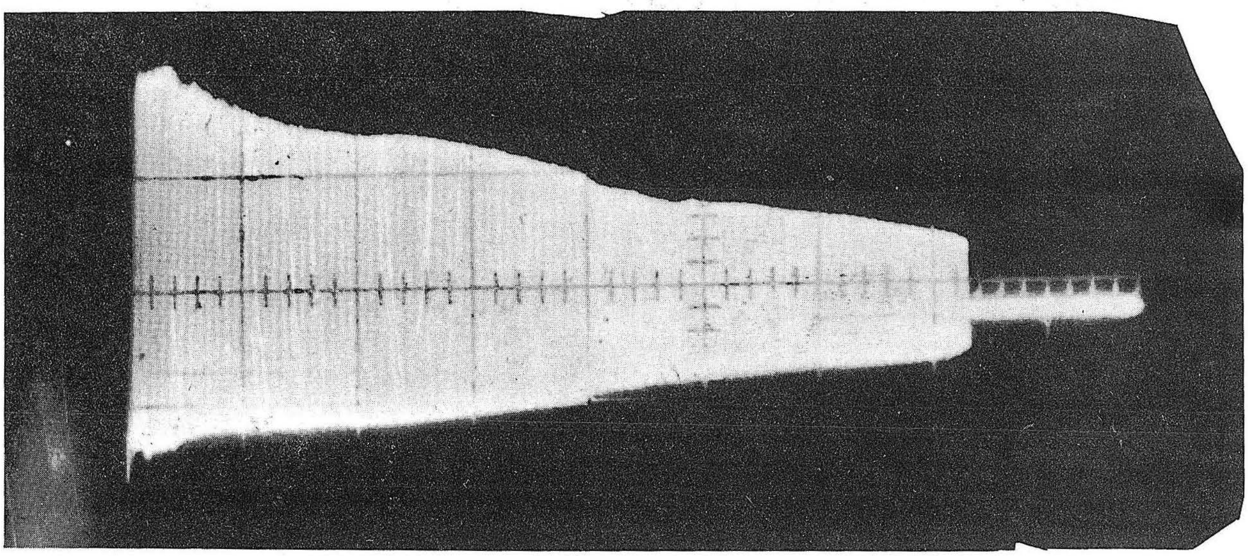


Fig. 3. Sweep trigger--end of rectification. Sweep speed 200 msec/cm. Sum induction-electrode signal of circulating proton beam tracked during the inversion period from 6.2 Bev down to 300 Mev.

less than 5% beam loss. As n = 1/2 occurs at 596 inches, the beam was therefore deflected through the n = 1/2 resonance point and returned to the original equilibrium orbit.

It has been subsequently observed that for low rates of rise of magnetic field, the lower limit of n for high-energy beam is n = 0.2.

MAGNET POWER SUPPLY

Failure of the West Generator

On April 23, 1958, before magnet pulsing commenced, a bolt on the armature of the west generator was shedred off and became entrapped between the armature and the field pole tips, resulting in abrasion damage to about one-third of the field windings. When an attempt was made to build up field voltage, a smoldering fire ignited in the damaged field windings. Figure 4 shows the subsequent damage to the stator. In addition, an arc occurred between the bearing and journal in the shaft bearing between the generator and flywheel, resulting in severe pitting on both the bearing and journal surfaces (Fig. 5).

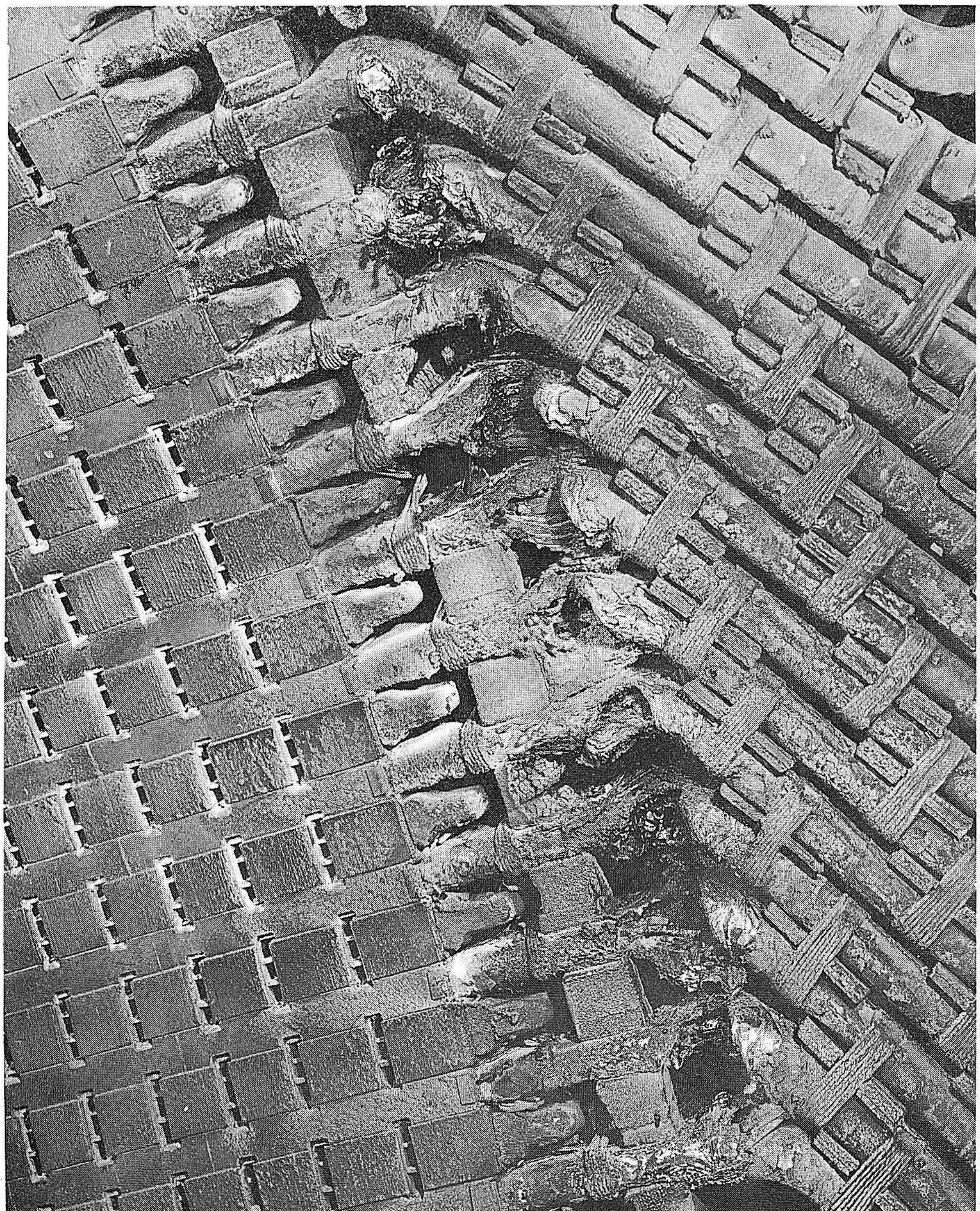
It is estimated that three months will be required to rebuild the stator, grind the journal, and reassemble the machine. In the interim, the east generator will be disassembled and inspected for fatigue failures before it is again pulsed. It is expected to be ready for operation about June 24, at which time, after a reasonable period of ignitron bake-in, Bevatron operation will resume at reduced energy and pulse rate.

Fault Report

The ignitron fault report appears in Table II.

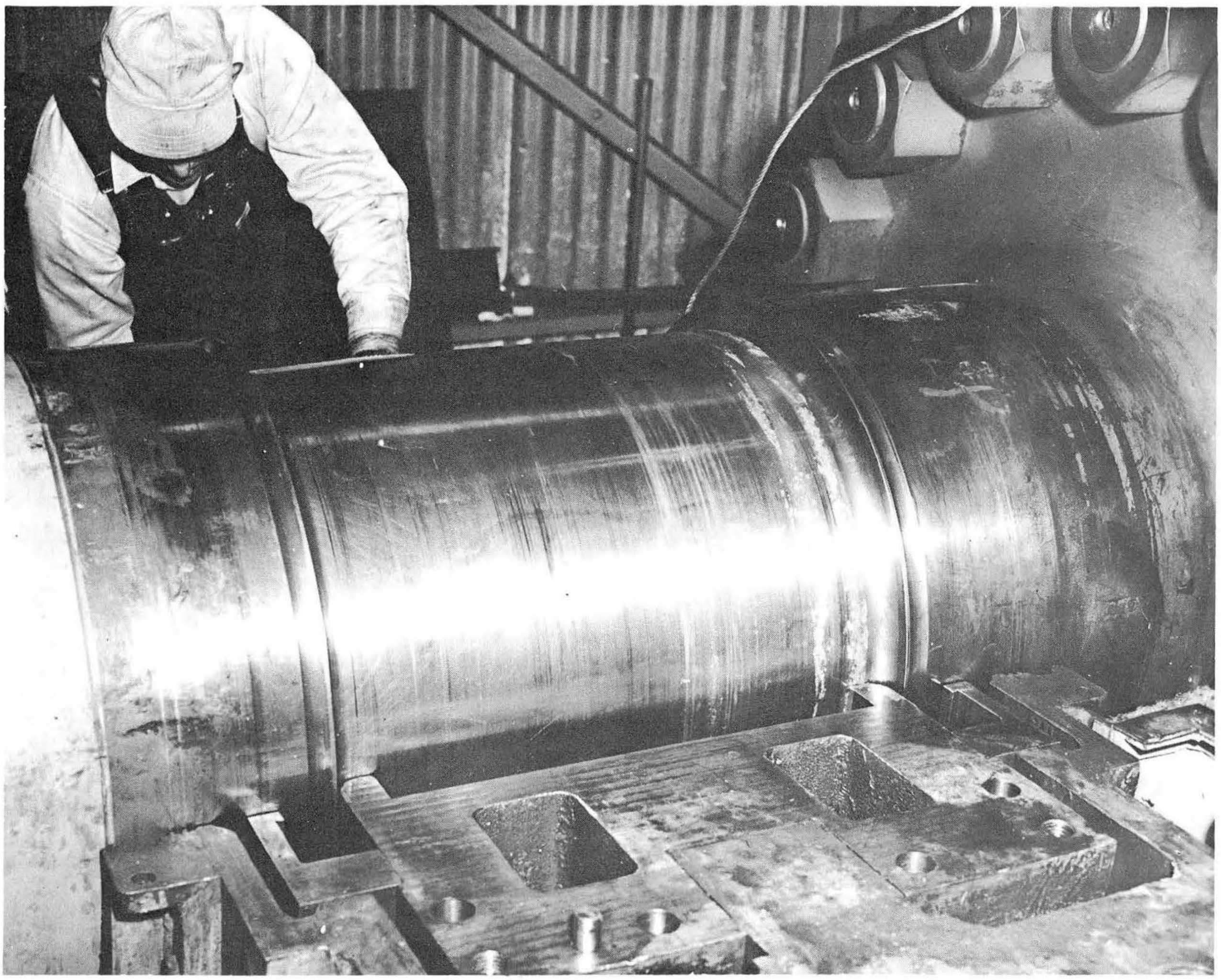
SHUTDOWNS

A scheduled shutdown occurred on February 24, 1958 for maintenance and for installation of experimental facilities. One inflector insulator (steatite) was found cracked and was badly burned owing to arcing. Ten of the steatite insulators were replaced with zircon insulators. On April 2, 1958 the clogging of storm-drain facilities by an earth slide caused storm water and silt to be diverted into the transformer-pad area and wire-ways adjacent to the generator control room, and subsequently resulted in the flooding of the motor generator control room and the generator pits. Operation resumed on April 4. A short shutdown occurred on April 7 when it became necessary to repair an air lock. On April 23 a bolt was sheared off the armature of the west generator and the ensuing damage resulted in an extended shutdown for rebuilding of the generator. The failure is reported in a preceding section of this report.



ZN-1994

Fig. 4. Abrasion and fire damage to the stator of the west generator.



ZN-1993

Fig. 5. Pitting on the west generator journal.

Table II

Ignitron fault rate

Month	5 to 6 Pulses Per Minute						7 to 9 Pulses Per Minute						10 to 17 Pulses Per Minute					
	1500 to 6000 amp			6100 to 9000 amp			1500 to 6000 amp			6100 to 9000 amp			1500 to 6000 amp			6100 to 9000 amp		
1957	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F	PULSES	FAULTS	P/F
June	1144		144	12799	23	550	1744	1	1744	36648	80	458	17929	9	1992	106896	124	878
July	72		72	5012	11	456	1372	2	686	48854	70	6979	33027	35	945	89439	53	1686
August	2711	5	542	7463	14	533	536	1	536	81217	89	912	20918	5	4183	98469	97	1015
September	959	2	479	5674	10	567	1053	3	351	22926	40	573	11644	18	647	22967	25	918
October				1335	5	267	1124			129138	114	3133	14070	4	3515	56409	50	1128
November							2419	4	605	117513	124	948	23379	4	5695	167868	175	1530
December				359						4082	3	1360	11855					
1958																		
January	1842	0	1842	2423	2	1212	305	0	305	14974	12	1248	16435	4	4109	170844	106	1612
February	3189	4	172	2146	2	1071	736	0	736	83637	85	984	6937	10	694	77452	82	944
March	1408	2	704	638	3	233	1215	0		75304	72	1061	13101	3	4367	165124	94	1754
April	751	0	751	888	0	888	188	0	188	600	0	600	14006	4	3501	153052	43	3559

Totals

MONTH	Number of Pulses	Number of faults		P/F
		Arc-Backs	Arc-Through	
1957				
June	70,264	6	117	562
July	195,233	29	247	707
August	202,284	29	138	1211
September	140,725	47	123	828
October	168,634	80	68	1139
November	199,720	67	115	1097
December	184,164	41	137	1055
1958				
January	206,823	31	93	1668
February	174,093	74	107	951
March	265,790	22	152	1476
April	187,155	13	34	3982

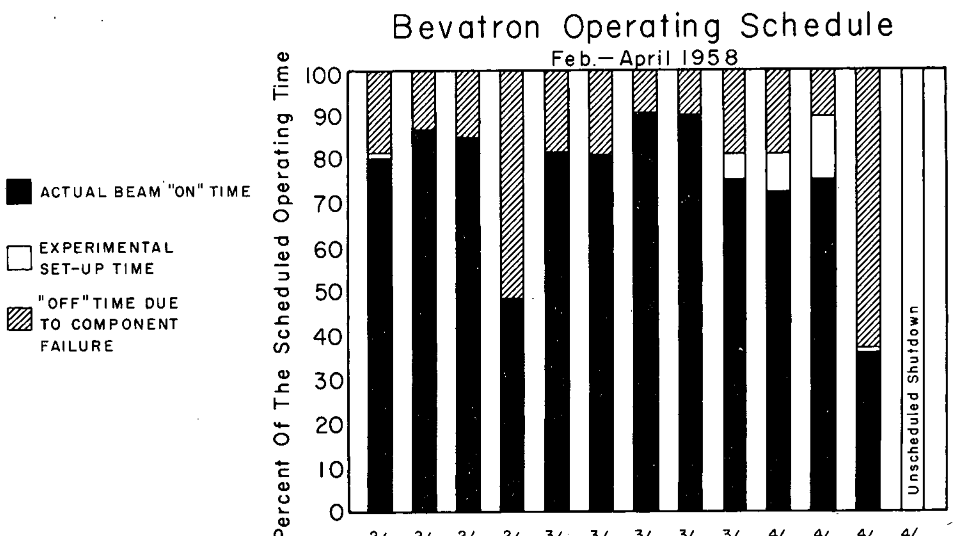
OPERATION

Bevatron operation during this period is summarized in Fig. 6. The maximum recorded beam amplitude at high energy was 8×10^{10} protons per pulse; the maximum injected beam was 310 microamperes.

The failure of the west generator forced a suspension of Bevatron operation on April 23. The nature of the failure suggested that a thorough inspection be made of the east machine before operation was resumed. It is expected that pulsing will resume using one generator, about May 26. Maximum beam energy will be limited to 5.7 Bev at a pulse rate of seven pulses per minute. Normal operation with both generators is expected in the latter half of July.

RESEARCH

The research activity this quarter is summarized in Table III.



WEEK OF	2/2	2/9	2/16	2/23	3/2	3/9	3/16	3/23	3/30	4/6	4/13	4/20	4/27
CREW HOURS	$126\frac{1}{2}$	$126\frac{1}{2}$	$126\frac{1}{2}$	122	$126\frac{1}{2}$	$126\frac{1}{2}$	$126\frac{1}{2}$	$126\frac{1}{2}$	125	$126\frac{1}{2}$	$126\frac{1}{2}$	$106\frac{1}{2}$	85
TURN-ON & MAINTENANCE TIME (HR)	$18\frac{1}{2}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$3\frac{1}{2}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$11\frac{3}{4}$	$18\frac{1}{2}$	$18\frac{1}{2}$	$9\frac{1}{2}$	
SCHEDULED OPERATING TIME (HR)	108	108	108	$33\frac{1}{2}$	$97\frac{1}{2}$	108	108	108	$79\frac{1}{4}$	108	108	108	
SCHEDULED BEVATRON TEST TIME (HR)	0	0	0	0	$10\frac{1}{2}$	0	0	0	0	0	0	0	
SCHEDULED SHUTDOWN TIME (HR)	0	0	0	85	0	0	0	0	34*	0	-0	0	
HOLIDAY	0	0	0	0'	0	0	0	0	0	0	0	0	0

* THIS TIME WAS ABSORBED IN AN UNSCHEDULED SHUTDOWN

MU-15932

Fig. 6. Bevatron operating schedule

Table III

Bevatron experimental research program
February, March, April, 1958

INTERNAL GROUPS

Group	Experimenters	Experiments
ALVAREZ	Gow, Horwitz, Murray	Interactions of K^- mesons in hydrogen, using the 15-inch liquid hydrogen bubble chamber (450 Mev/c).
		p-$\bar{p}$ interactions and annihilations, using the 15-inch liquid hydrogen bubble chamber.
		A study of K^--meson interactions in deuterium and abandoned temporarily because of contamination of the deuterium.
BARKAS		Emulsion exposure to separated and focused 420-Mev/c K^--meson beam ($1.4 \times 10^{14} p^+$).
BIRGE	Kerth	K^+-p^+ scattering, using counters and a liquid hydrogen target. (350 Mev/c). This work was interrupted by the unscheduled shutdown.
LOFGREN	Cork, Galbraith, Lambertson, Wenzel	Antiproton total cross sections, angular distributions, and annihilation cross sections in hydrogen, using counters and a liquid hydrogen target (500 Mev/c to 900 Mev/c).
MOYER-HELMHOLZ	Atkinson, Hess, Perez-Mendez, Wallace	Measurement of the attenuation mean free path of 5-Bev neutrons in various materials, using counters. Good-geometry cross-section measurements.
SEABORG	Baltzinger	U, Al foil bombardments: 6.2 Bev, 3.6×10^{13} p^+ 6.2 Bev, 3×10^{13} p^+ 1.1×10^{14} p^+

SEGRÈ - POWELL	Segre Group, Powell Group	Interactions of antiprotons in the 30-inch propane bubble chamber, using a focused and separated 720-Mev/c antiprotons beam.
SEGRÈ	G. Goldhaber	Emulsion exposure to the separated and focused-740 Mev/c antiproton beam (3 x 10^{14} p^+)

EXTERNAL GROUPS

Experimenter	Institution	Experiment
Block	Duke University	Test of a liquid helium bubble chamber in a 1-Bev/c π^- beam.
Cool, Yuan	Brookhaven National Laboratory	Proton polarization from Λ^0 decay using counters--preliminary study.
Friedlander, Yaffe	Brookhaven National Laboratory	U, Al foil bombardments, 3.0 Bev, 4.4 x 10^{13} p^+
Pate, Poskanzer	Brookhaven National Laboratory	Thirteen target bombardments by 1.8-Bev p^+ (U, Al, Au). One target bambardment by 3.0-Bev p^+(U, Al)
Schaeffer	Brookhaven National Laboratory	Pb, Ag, Fe foil bombardment, 6.2 Bev, 3 x 10^{13} p^+
Taft	Yale University	Emulsion exposure to focused and separated K^--meson beam (420 Mev/c).

EMULSION EXPOSURES TO SEPARATED AND FOCUSED 740-Mev/c ANTI-PROTON BEAM WERE MADE BY THE FOLLOWING GROUPS:

Amaldi	University of Rome, Italy	3 x 10^{14} p^+
Berthelot	Saclay, France	2 x 10^{14} p^+
Blau	University of Miami	3 x 10^{14} p^+
Ekspong	Uppsala, Sweden	2 x 10^{14} p^+

EMULSION STACKS WERE EXPOSED TO SEPARATED AND FOCUSED K^+ MESONS BY THE FOLLOWING GROUPS:

Boggild, Hansen	Universitetets Institut for Teoretisk Fysik, Copenhagen	350-Mev/c K^+	1.4 x 10^{14} p^+
Camerini, Fry	University of Wisconsin	340-Mev/c K^+	1.7 x 10^{13} p^+
		350-Mev/c K^+	6.9 x 10^{14} p^+
		350-Mev/c K^+	6.9 x 10^{14} p^+
		350-Mev/c K^+	5 x 10^{14} p^+
		750-Mev/c K^+	1 x 10^{12} p^+
		1.3 -Bev/c K^+	1 x 10^{12} p^+
		1.3 -Bev/c K^+	2.5 x 10^{12} p^+
		1.3 -Bev/c K^+	2.5 x 10^{12} p^+

O'Ceallaigh	Dublin Institute of Advanced Studies	350-Mev/c K^+ 750-Mev/c K^+ 750-Mev/c K^+	2×10^{14} p^+ 1×10^{11} p^+ 1×10^{11} p^+
Pevsner	Johns Hopkins University	350-Mev/c K^+	1.8×10^{14} p^+
Ritson	M. I. T.	350-Mev/c K^+	1.4×10^{14} p^+
Shapiro	Office of Naval Research	350-Mev/c K^+	1.4×10^{14} p^+
Winzeler	University of Bern, Switzerland	350-Mev/c K^+	3.1×10^{14} p^+
Prowse	Istituto di Fisica, Bologna, Italy	350-Mev/c K^+	2.3×10^{14} p^+

ACKNOWLEDGMENTS

The Bevatron operating crew supervisors are Robert Anderson, Duward Cagle, Ross Nemetz, and Robert Richter. The operators are Robert Allison, G. Stanley Boyle, Gary Burg, Norris Cash, Charles Coombes, Frank Correll, Robert Gisser, William Kendall, Otho Kinsley, Raymond Lutzker, Roy Olson, Edwin Rosenblum, Seth Shepard, and Glenn White. Edward J. Lofgren is the Bevatron group leader, and under him Harry Heard, with Walter Hartsough and Wendell Olson assisting, is in charge of operations. Trancuilo Canton, Bruce Cork, Harry Heard, and Glen Lambertson carried out special development and support projects. William Salsig headed the mechanical engineering group, Clarence Harris and Marion Jones the electrical engineering group, and Ivan Lutz the electronic development group. Lorenzo Eggertz was in charge of the electrical maintenance group.

This work was done under the auspices of the U.S. Atomic Energy Commission.