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BEVATRON OPERATION AND DEVELOPMENT. XXI

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ABSTRACT

The principal research effort this quarter was the investigation of K-meson, antiproton, and θ_2^0-particle decay and interactions.

Nuclear emulsions were exposed for external groups to neutral particles, to antiproton and K^--meson beams, and to the primary proton beam.

Deflected-beam studies were continued.

The generator shafts were comprehensively surveyed; ultrasonic techniques were used to detect and record shaft discontinuities.

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INJECTOR

Cockcroft-Walton Power Supply

In March, the ion gun Cockcroft-Walton power supply was replaced by a new twelve-stage 480-kv Cockcroft-Walton power supply using selenium rectifiers. The new unit eliminates the previously used vacuum tube rectifiers, the cascaded filament transformers, and associated filament oscillator and power supplies which were the principal sources of the Cockcroft-Walton unreliability. The physical layout of the new unit is similar to that of the vacuum tube unit; however, the supply is fabricated of fire-retardant materials — polyvinyl chloride and vinyl chloride acetate (transparent). The power supply is rated at 480 kv, 1 ma.

Figures 1 and 2 show the new power supply.

EXPERIMENTAL FACILITIES

Quadrant-Mounted Targets

The quadrant-mounted targets available during the period February 17 to April 22 are listed in Table I; those available from April 22 to the end of the quarter are listed in Table II.

New-Model Gap-Mounted Flip-Target Mechanism (MK 8)

Recent beam-acceptance measurements have indicated that the useful Bevatron injection aperture might be increased if the flip-up target actuating mechanism were redesigned to reduce by about 2 in. their radial extent into the beam aperture. A redesign has been accomplished and the new mechanism tested. The actuating coil was reduced in its radial dimension but the new design maintained the operational requirements and desirable

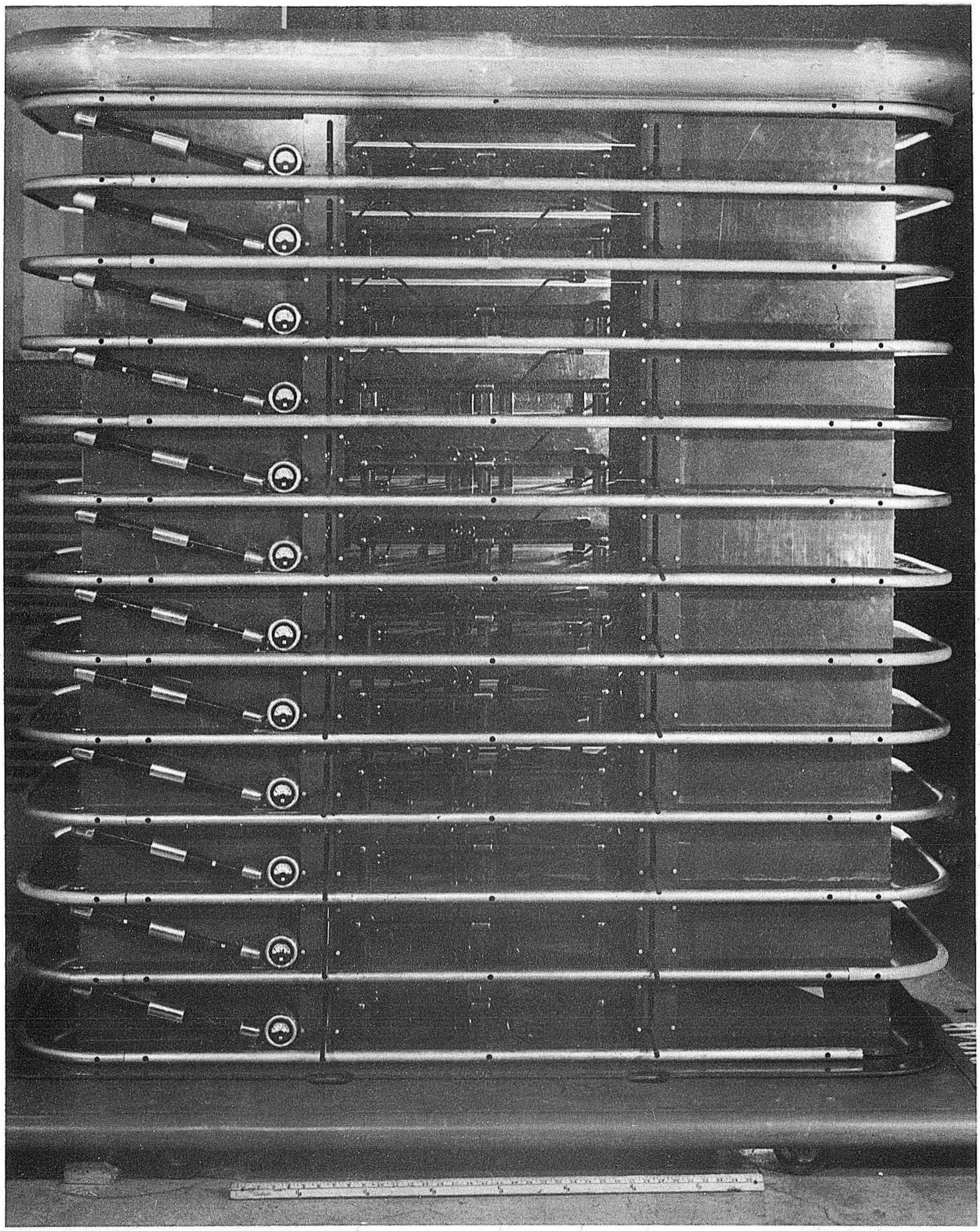

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Fig. 1. New 480-kv ion gun Cockcroft-Walton power supply.

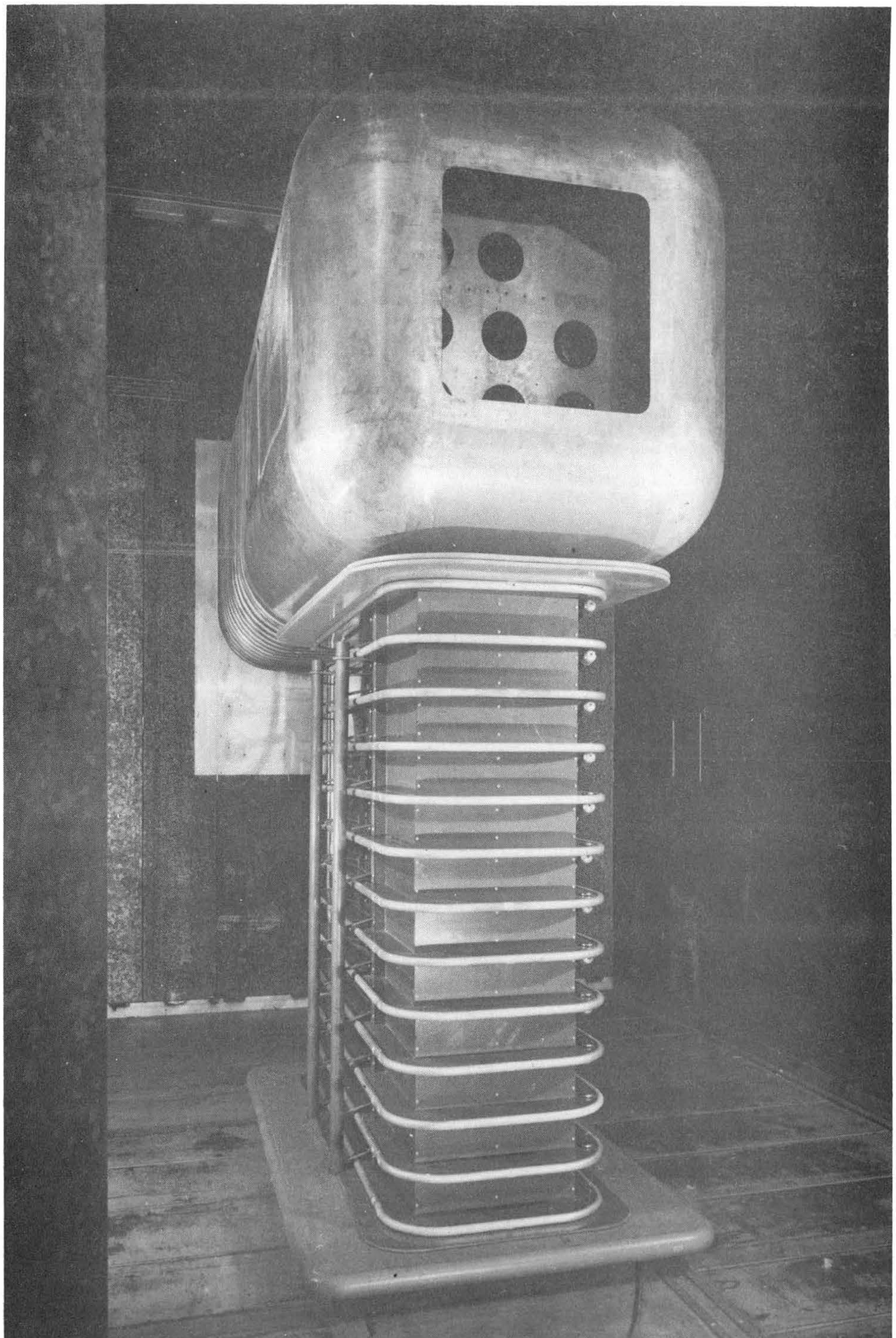

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Fig. 2. Ion gun with the new 480-kv selenium rectifier Cockcroft-Walton power supply.

Table I

Quadrant-mounted targets February 17, 1959 to April 22, 1959					
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	84° 08'	598-1/4	-	Carbon	3-19/32×51/64×2
II	84° 08'	598-1/4	-	Polyethylene	4-23/64×51/64×2
II	85° 58'	596-3/16	-	Carbon	4-5/16×51/64×2
II	85° 59'	596-3/16	-	Polyethylene	4-5/16×51/64×2
II	87° 47'	598-1/4	-	Carbon	3-19/32×51/64×2
II	87° 47'	598-1/4	-	Polyethylene	4-9/32×51×64×2
II	90° 03'	601-9/16	601-15/16	Copper	7/8×51/64×1/2
III	17° 16'	597-5/8	597-7/8	Beryllium	4×1/2×1/2
III	72° 28'	597-11/16	598-1/16	Copper	3-1/2×1/2×1/2
III	72° 35'	597-11/16	598-1/16	Copper	3-1/2×1/2×1/2
III	75° 30'	599-1/2	599-3/4	Graphite	2-35/64×1×4
IV		599-1/2	599-3/4	Graphite	2-35/64×1×4

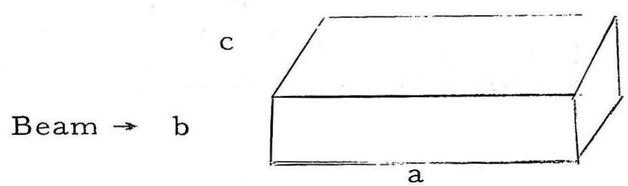
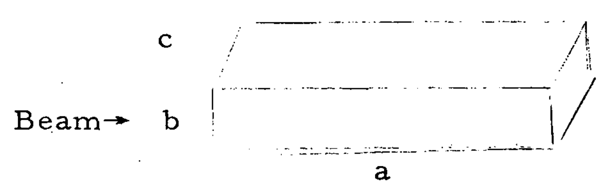


Table II

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.)
Quadrant-mounted targets April 23, 1959 to end of quarter					
II	81° 29'	599-7/16	599-5/8	Copper	5×5/8×1
II	81° 29'	599-7/16	599-5/8	Copper	5×5/8×1
III	17° 16'	597-5/8	597-7/8	Beryllium	4×1/2×1/2
III	72° 28'	597-3/4	598-1/8	Copper	3-1/2×1/2×1/2
III	72° 35'	597-3/4	598-1/8	Copper	3-1/2 ×1/2×1/2
III	75° 30'	599-1/2	599-3/4	Graphite	2-35/64×1×4
IV	17° 11'	599-1/2	599-3/4	Graphite	2-35/64×1×4



features of the MK 7 mechanism[1] (the mechanism must be capable of raising a 1-lb target to the plane of the beam in 100 msec and lowering the target in equal time, and must be dependable to 1,000,000 cycles). The actuating mechanism now becomes a radial interference at 576 in. rather than at 578 in. as with the MK 7 mechanisms.

Figures 3 and 4 show the new MK 8 flip-up target mechanism.

EXTENDED ACCEPTANCE PERIOD

(Fred H. G. Lothrop)

During the first quarter of 1959 tests were made to explore the feasibility of an increase in beam yield by extending the acceptance time of the Bevatron at injection. One method of extension requires a reduction in rate of change of magnet field during the injection period. The required $\dot{B}$ reduction was accomplished through the use of pole face windings Nos. 1, 2, 20, and 21, which were pulsed from a capacitor energy-storage bank through a thyratron. A $\dot{B}$ reduction of 1/2 was obtained, and a corresponding increase in accepted charge was observed. About twice the previous charge was circulated and was observed as it spiraled into a Faraday cup on the south inside radius. The results indicated that this method of extending the acceptance time was feasible and that the next step was to build a programmed pulser for the pole-face windings so that the shape of $\dot{B}$ could be controlled. During these tests no serious attempts were made to accelerate the beam. Equipment required for such acceleration had not yet been fabricated, since the feasibility of the system had been open to question.

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[1] Bevatron Operation and Development. XIV, May, June, July 1957, UCRL-8022, Walter D. Hartsough

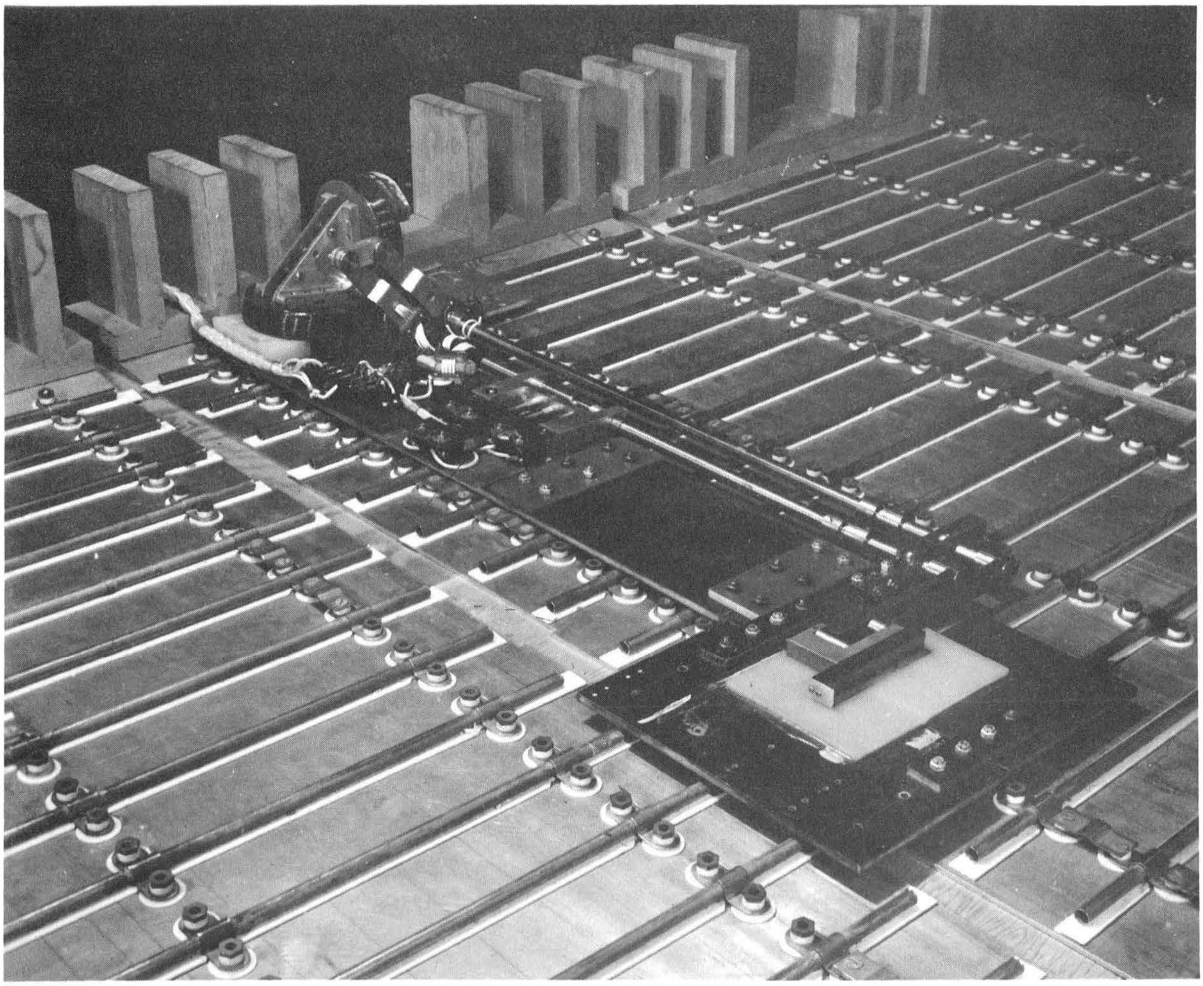

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Fig. 3. New MK 8 flip-up target mechanism (target in the "down" position).

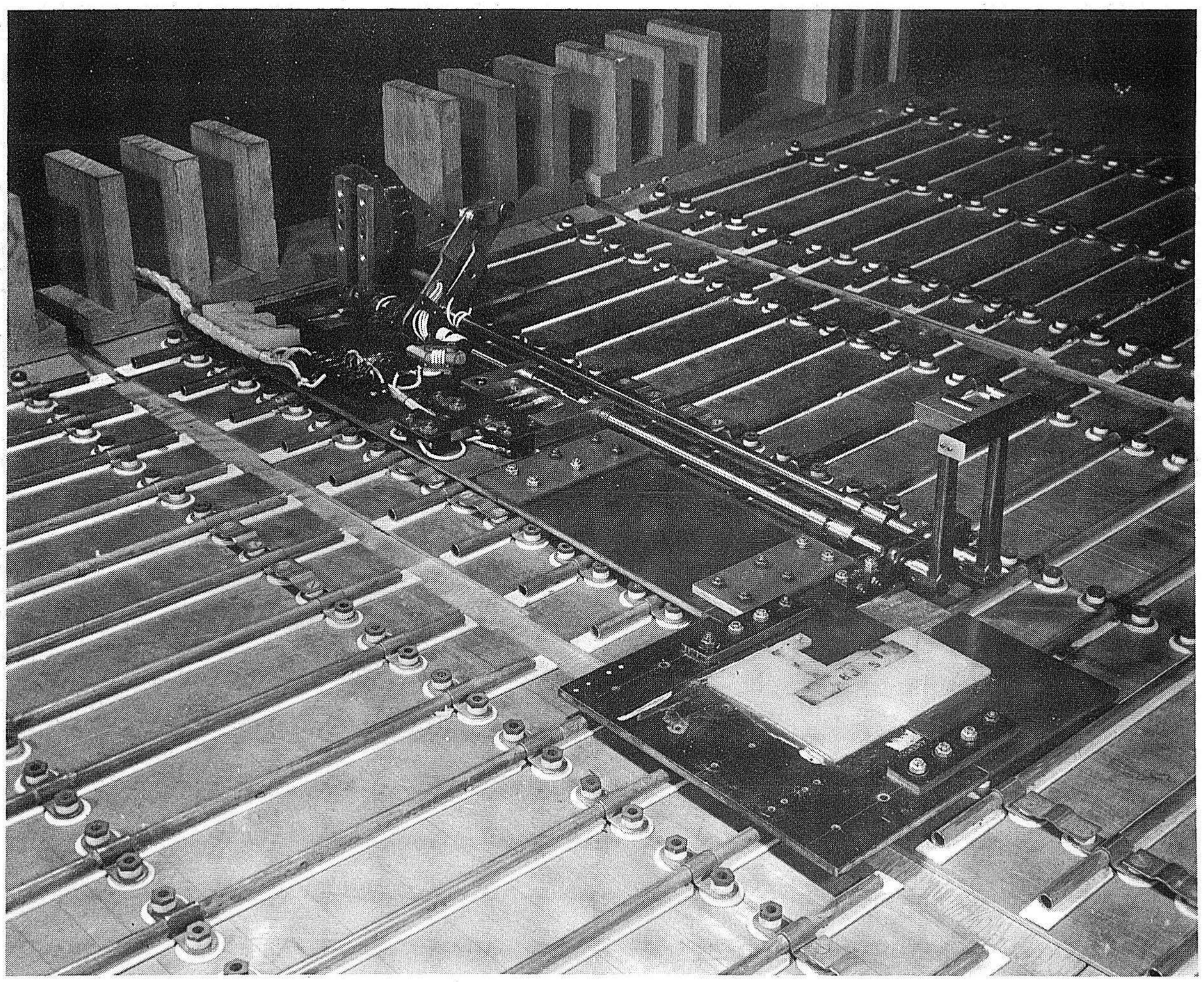

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Fig. 4. New MK 8 flip-up target mechanism (target in the "up" position).

PERSONNEL SHIELDING

In recent months the background radiation level in the occupied control and experimental areas has become a problem of increasing concern. These areas are at present shielded by a concrete wall 4 to 10 ft thick surrounding the Bevatron. The problem has resulted from an increase in the peak and average beam intensities and in the operating hours of the machine. Last fall, the Health Physics Group measured the neutron flux and found it to be about one-half the tolerance level in the main control room and counting area with the machine running at a level of 5×10^{10} protons per pulse and 10 pulses per minute (tolerance is considered to be 2.5 m rem/hr). It is evident that the neutron level in the control and shop areas during periods of 1×10^{11} protons per pulse average beam operation is at the maximum permissible level considered safe for contiuous occupancy on a long-term basis. The shielding must be improved. The problem and possible approaches to the solution of the problem have been outlined in internal reports.[2] A brief statement of the present status and of the immediate steps being taken to reduce the neutron level, both temporarily and permanently is given here.

1. Engineering effort will be directed toward extending previous shielding studies. Both a short - and a long-range improvement program will be evolved. One of the immediate steps will be to improve the integrity of the straight-section shielding to make it equivalent to that of the curved sections. An eventual plan will undoubtedly include canning the whole machine in a concrete tunnel.

2. Beam-aperture clippers were placed within the curved sections of the machine to define and limit the vertical aperture to concentrate the final destination of the beam in regions well shielded by magnet iron. These clippers were subsequently removed as it was determined that they interfered with the useful beam aperture at injection. Radiation background measurements were taken; however, interpretation of the results is difficult because of the large contribution to the background from the poorly shielded straight sections. In any event, the reduction in neutron level was not large.

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[2] Status Report on Bevatron Shielding and Plans, Burton J. Moyer and Nahmin Horwitz, Bevatron-409, Bevatron-415, April 9, 1959.

3. A 1-ft-thick wood shielding wall is under construction to extend the effectiveness of the concrete mezzanine floor which presently roofs over the control, counting, and shop areas and which already is an effective neutron attenuator. The wall, when complete, will be 156 ft long, 15 ft high, and placed between the control area and the concrete shielding wall. A 1-ft-thick wood roof bridges the space between the mezzanine floor and the wood wall. The wall is shown during construction in Fig. 5.

It is expected that the neutron levels will be reduced by a factor of four in the areas already shielded by the mezzanine floor and by a factor of eight in the area between the wood wall and wall of the control and shop area.

MAGNET POWER SUPPLY

Generator Shafts

The following has been abstracted from internal reports by William W. Salsig.[3,4,5]

The generator shafts have been ultrasonically examined to detect and record shaft discontinuities several times in the past two years. The examinations have been cursory. Discontinuities have been detected by inspecting groups from the LRL-Livermore Nondestructive Test Group and from the Westinghouse Sunnyvale Test Group.

In the past, the observed discontinuities were not considered serious. The shafts were scheduled to be re-examined periodically for growth of the reflecting surface.

However, during routine inspection this past December, and again in February, a number of new discontinuities were observed. In addition, an increase in signal attenuation was measured from previously observed discontinuities. This increase possibly indicates a structural change in the metal.

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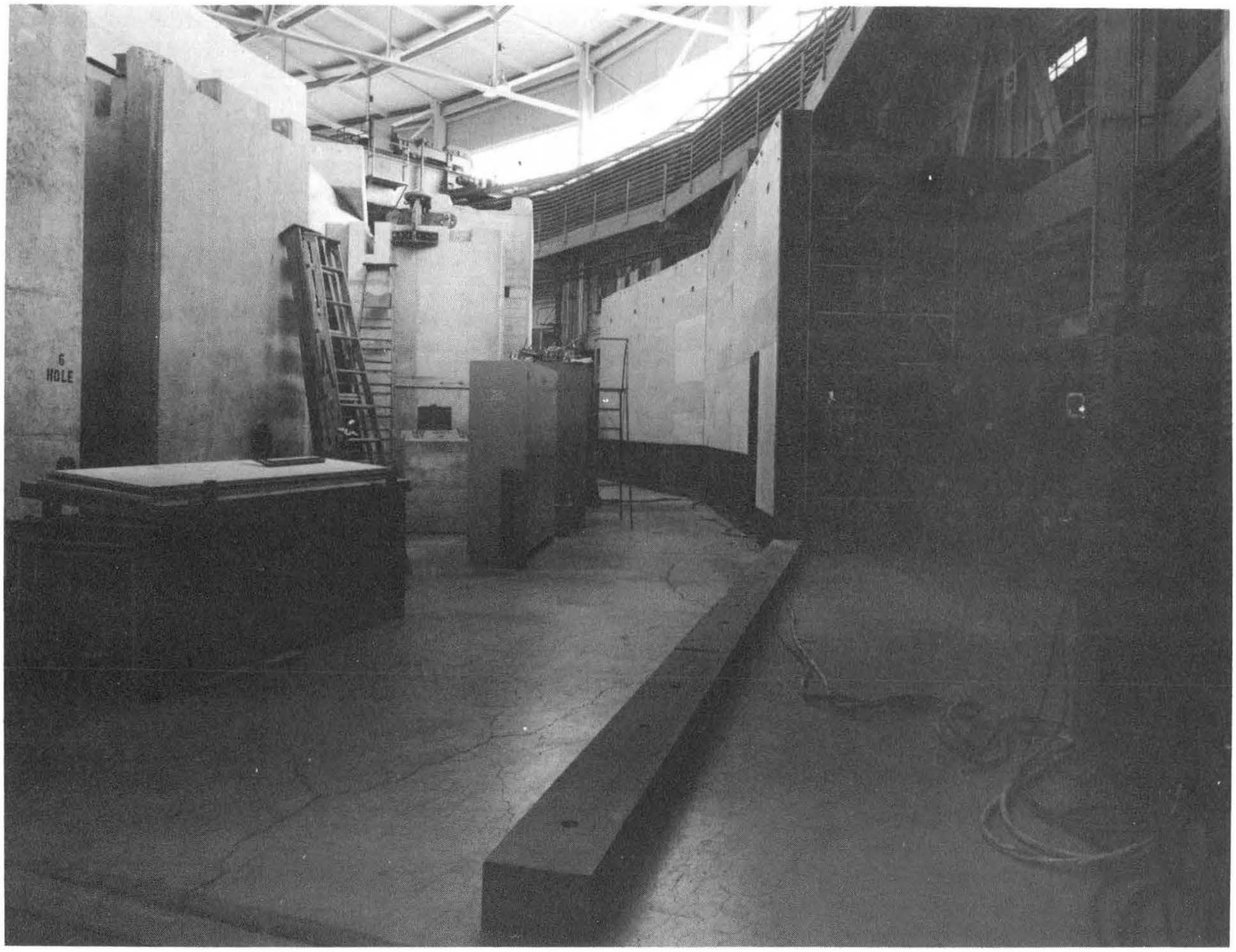
[3] W. W. Salsig, Engineering Note UCID-676, March 3, 1959

[4] W. W. Salsig, Engineering Note UCID-677, March 25, 1959

[5] W. W. Salsig, Engineering Note UCID-678, March 20, 1959



ZN-2262

Fig. 5. New 1-ft-thick wood personnel-shielding wall pictured during construction.

In order to better evaluate the condition of the shafts, it was decided that comprehensive ultrasonic survey should be made immediately. This was carried out by the LRL-Livermore group and by Westinghouse factory representatives. The results of the inspection indicate that the discontinuities in the west machine shaft are smooth, probably inclusions or gas bubbles, and that they were most likely present at the time of forging. The largest discontinuity is estimated to have a reflecting surface of 1/32 in. $\times$ 1 in. long. This shaft is considered acceptable, according to Westinghouse's present inspection standards, for new-machine installation.

The fault indications in the east generator shaft seem more serious. The ultrasonic discontinuities circle the axis and are included in a 6-in.-diameter circle at the point of greatest radial extent. The reflected signal behavior from this region is characteristic (according to Westinghouse representatives) of a condition of centerline interdendritic shrinkage. This shaft, according to today's standards, would not be acceptable for installation in new equipment.

The following points were established, after the results of the ultrasonic inspections had been weighed and the available design and metallurgical data concerning the shafts had been considered:

1. The maximum allowable axial bore for these shafts is 5 in. diameter. Such a bore would not remove all the flaws from the east generator shaft.

2. The ultrasonically observed discontinuities were most likely present at the time of forging and have not grown in service.

3. Weekly ultrasonic inspection of the shafts should detect any growth in defect sufficiently early to prevent an accident.

4. The possibility of a sudden brittle shaft failure was ruled out. The nil-ductility transition temperature for the generator shaft steel has been estimated to be -20°F, well below the operating-temperature range for the generators.

5. Cores should be taken from near the axis of the shafts and Charpy vee-notch tests made to evaluate the notch brittleness condition of the shafts.

Core samples were taken from the east generator shaft near the axis and from the flywheel coupling between the bolt circle and the outer rim of the coupling. Charpy tests were made at Hale Testing Laboratories and at the Westinghouse Material Testing Laboratory. These tests confirmed the Westinghouse position that the shafts, during all operating conditions, are operated above the nil-ductility temperature. However, the margin of safety was not considered sufficient.

For added insurance, therefore, it was decided to preheat the shafts before startup after any prolonged shutdown. The minimum start-up temperature is established as 70°F; the desired start-up temperature as 90°F.

Magnet Pulse Record and Fault Report

The magnet pulse record and fault report appears in Table III.

SHUTDOWNS

Two scheduled shutdowns occurred this quarter for maintenance, target modifications, and installation of new equipment. The first was from February 15 through 21, the second occurred from April 19 through 25. During the period February 22 through 28, — a period of scheduled operation following the February shutdown —— Bevatron operation was suspended in order to complete investigations of generator shaft discontinuities (see preceding section).

OPERATION

Tables IV and V and Fig. 6 summarize the operation record this quarter. The maximum recorded injected beam was 540 μa; the maximum beam at full energy was 1.8×10^{11} protons per pulse.

RESEARCH

The research activity is summarized in Table VI.

Table III

Ignition Fault Rate

	5 - 6 pulses per minute						7 - pulses per minute						10 - 17 pulses per minute					
	1500-6000 amps			6100-9000 amps			1500-6000 amps			6100-9000 ampe			1500-6000 amps			6100-9000 amps		
Month	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F	Pulses	Faults	P/F
1 9 5 7																		
June	1144		144	12799	23	550	1744	1	1744	36648	80	458	17929	9	1992			
July	72		72	5012	11	456	1372	2	686	48854	70	6979	33027	35	945	106896	124	878
August	2711	5	542	7463	14	533	536	1	536	81217	89	912	20918	5	4183	89439	53	1686
September	959	2	479	5674	10	567	1053	3	351	22926	40	573	11644	18	647	98469	97	1015
October				1335	5	267	1124			129138	114	3133	14070	4	3515	22967	25	918
November							2419	4	605	117513	124	948	23379	4	5695	56409	50	1128
December				359						4082	3	1360	11855			167868	175	1530
1 9 5 8																		
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
May	10340	2	5170	-	0	-	10337	8	1292	-	0	-	216	0	-	-	0	-
June	53897	34	1585	-	0	-	232988	111	2099	-	0	-	279	0	479	-	0	-
July	6498	0	6498	759	0	759	8873	4	2218	2922	0	0	110652	35	3161	79836	51	1565
August	13	0	-	10381	8	1297	-	-	-	-	-	-	95616	8	11952	230,139	40	5753
September	-	-	-	1990	-	-	-	-	-	3649	-	-	14803	-	-	276,169	41	-
October	-	-	-										9249			237,340	43	5520
November	3931	-	-	1619	1	-	91	-	-	2769	-	-	9500	-	-	278,548	26	-
December	-	-	-	361	-	-	-	-	-	-	-	-	3371	-	-	151,642	9	-
1 9 5 9																		
January	-	-	-	320	-	-	1515	-	-	1146	-	-	7621	-	-	301420	44	-
February	-	-	-	630	-	-	-	-	-	-	-	-	38215	3	12738	267220	32	8351
March	1012	-	-	6601	-	-	457	-	-	723	-	-	7518	1	7518	235053	41	5733
April	41	-	-	1475	-	-	110	-	-	67300	8	8412	36938	5	7387	227555	39	5834

Totals

Month	Number of pulses	Number of faults: Arc-backs	Number of faults: Arc-throughs	P/F
1 9 5 7				
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
1 9 5 8				
January	206,823	31	93	1668
February	174,093	74	107	951
March	265,790	22	152	1476
April	187,155	13	34	3982
May	20,893	6	4	2089
June	287,364	23	122	1981
July	209,540	38	52	2320
August	336,149	12	44	6003
September	296,611	16	25	7234
October	246,583	23	20	5734
November	296,458	11	16	10979
December	155,374	5	4	17,263
1 9 5 9				
January	312022	11	33	7091
February	306065	8	27	8745
March	5 3362	9	33	6032
April	336936	15	37	6479

Table IV

Beam Record

Week of	Number of 8-hr shifts	Total integrated beam (no. of protons)
March 15-21	12	2.1×10^{15}
March 22-28	20	5.4×10^{15}
March 29-April 4	20	4.5×10^{15}
April 5-11	21	4.8×10^{15}
April 12-18	18	2.5×10^{15}
April 19-25	10	2.0×10^{15}
April 26-May 2	11	0.8×10^{15}

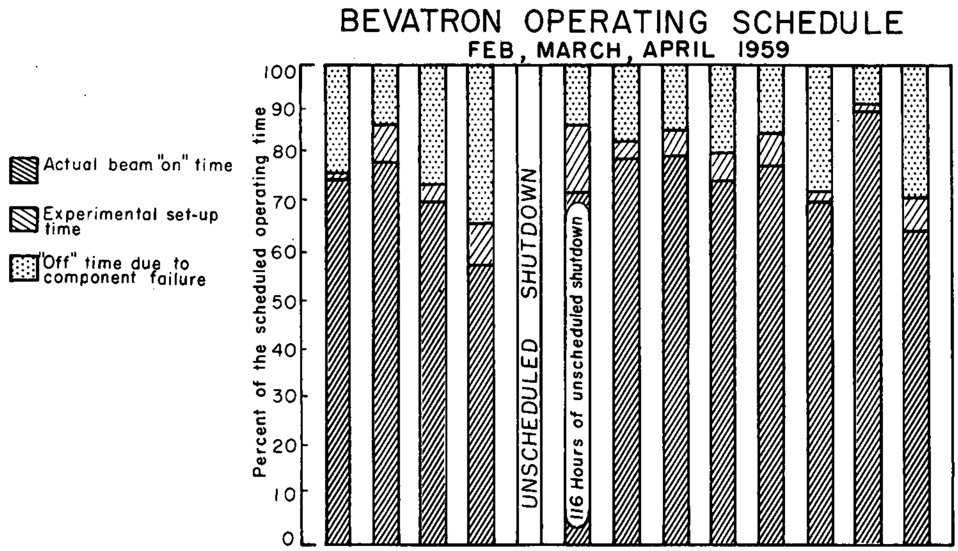
Average beam per 8-hour shift = 2×10^{14} protons

Table V

Analysis of total lost beam time due to component failure (percent)

Month, 1959	Injector	Magnet power supply	rf accelerating system	Other
February	29	49	6	16
March	49	9[a]	12	30
April	61	10	20	9

[a]The time lost as the result of the generator shutdown is not included in this analysis.



Week of	(Hr)	2/1	2/8	2/15	2/22	3/1	3/8	3/15	3/22	3/29	4/15	4/12	4/19	4/26
Crew hours	(Hr)	168	168	168	144	168	168	168	168	168	168	168	168	168
Turn on & maintenance time	(Hr)	9	9	—	9	9	4	9	4	9	9	9	—	9
Scheduled operating time	(Hr)	159	159	88	135	159	48	159	159	159	159	159	80	159
Scheduled Bevatron test time	(Hr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Scheduled shutdown time	(Hr)	0	0	80	0	0	0	0	0	0	0	0	88	0
Holiday	(Hr)	0	0	0	24	0	0	0	0	0	0	0	0	0

MU-18568

Fig. 6. Bevatron operating schedule for February, March, April 1959.

Table VI

Bevatron Experimental Research Program
February, March, April 1959

INTERNAL GROUPS

Group	Experimenters	Experiments
ALVAREZ	Miller, Murray	Study of K^--meson interactions in deuterium by using the 15-in. liquid deuterium bubble chamber (430 Mev/c).
	Stevenson	Preparation of a 3.0-Bev/c π^--meson beam for future tests of the 72-in. liquid hydrogen bubble chamber.
BARKAS		Emulsions exposed to the internal 6.1-Bev proton beam.
LOFGREN	Chupp, Cork, Lambertson, Wenzel	External beam studies.
MOYER	Health Physics Group	Radiation surveys.
	Hess	Calibration of a liquid Freon Čerenkov counter.
MOYER-HELMHOLZ	Atkinson, Hess, Perez-Mendez	Measurement of the attenuation mean free path of 5-Bev neutrons in various materials by using counters.
POWELL	Birge, Fowler	Study of K^--meson interactions by using the 30-in. propane bubble chamber in the focused and separated 1.1-Bev/c K^--meson beam.
	Birge, Fowler, Piccioni	Investigation of θ_2^0 decay and interactions in the 30-in. propane bubble chamber; 1.4-Bev/c π^- beam.

SEABORG	Alexander, Winsberg	Fe, Al, Cu target bombardment; 6.2 Bev, 1.3×10^{14} p^+.
SEGRÉ	Chamberlain, Elioff, Steiner, Wiegand, Ypsilantis	$\bar{p}$ production vs angle in various materials; H_2 and D_2 cross sections (1 to 1.8-Bev/c $\bar{p}$).

EXTERNAL GROUPS

Experimenter	Institution	Experiment
AMALDI	Istituto di Fisica Rome, Italy	Emulsion exposure in an antiproton beam. Search for antihyperons.
CAMERINI, FRY	University of Wisconsin	Neutral-particle emulsion exposure. Emulsions were exposed to a neutral-particle beam at 90 deg to the incident proton beam.
FURTH	UCRL - Livermore	Emulsions were exposed in a pulsed high magnetic field to a focused and separated 430-Mev/c.
PROWSE	UCLA	K^--meson beam.
LORD	University of Washington	Emulsion stack exposed to the internal 5.1-Bev proton beam, 6×10^6 p^+.
PETERS	Universitetets Institut Copenhagen, Denmark	Emulsion stack exposed to the 6.1-Bev internal proton beam, 2.5×10^6 p^+.
ZORN	Brookhaven National Laboratory	Emulsion stack exposed to the 6.1-Bev internal proton beam, 1.5×10^6 p^+.

ACKNOWLEDGMENTS

Edward J. Lofgren is the Bevatron group leader; William A. Wenzel is alternate group leader. Harry Heard with Walter Hartsough and Wendell Olson assisting is in charge of operation. The Bevatron crew supervisors are Robert Anderson, Duward Cagle, Ross Nemetz, and Robert Richter; crew members are Robert Allison, G. Stanley Boyle, Gary Burg, Norris Cash, Charles Coombes, Frank Correll, Raleigh Ellison, Robert Gisser, William Kendall, Otho Kinsley, Wayne Logan, Kenneth Morgan, Seth Shepard, and Glenn White. Support and development projects were carried out by Trancuilo Canton, Warren Chupp, Bruce Cork, Harry Heard, Glen Lambertson, Fred Lothrop, and Emery Zajec. William W. Salsig and Jack Gunn were in charge of the Mechanical Engineering Group, Ivan Lutz the Electronic Development Group, and Lorenzo C. Eggertz and Donald Milberger the Electronic Maintenance Group.

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