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BEVATRON OPERATION AND DEVELOPMENT. XI

August, September, October 1956

Walter Hartsough

December 13, 1956

Printed for the U.S. Atomic Energy Commission

BEVATRON OPERATION AND DEVELOPMENT. XI

Contents

Abstract 3

Injector 4

Experimental Facilities

- Quadrant-mounted targets 4
- Quadrupole magnets 4
- One-megawatt generator 8

Pole-Base-Winding Field Correction 8

Radio-Frequency Tracking Equipment

- New wide-band rf Driver 8
- Incredcuctor 9

Magnet Power Supply

- Ignitron monitoring 14

Bevatron Shutdowns 14

Operation and Research 14

Acknowledgments 16

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ABSTRACT

Absorption cross sections were measured for antiprotons in hydrogen, Be, C, Pb, U, H_2O, and D_2O during this quarter. The antineutron was detected and identified.

K-meson studies continued using the 10-inch liquid hydrogen bubble chamber, counters, and nuclear emulsions.

Thirty-one target bombardments in the internal proton beam were made for the chemistry group.

The new wide-band rf driver was installed; two new 8-inch quadrupole magnet sets were made available for use by the experimental groups; installation of a 1-megawatt generator, for powering auxiliary bending and focusing magnets, was completed.

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INJECTOR

The Cockcroft-Walton generator accelerating-tube electrodes have been changed from spun stainless steel to spinnings made of mu-metal. This is part of a continuing effort to minimize the effect of the residual magnetic field of the Cockcroft-Walton generator enclosure on the beam in the accelerating tube. This change made an improvement in the day-to-day reproducibility of the injector-tuning parameters.

EXPERIMENTAL FACILITIES

Quadrant-Mounted Targets

Table I lists the quadrant-mounted targets that were available during the latter half of this period.

Quadrupole Magnets

Two new water-cooled 8-inch-diameter quadrupole-magnet sets were completed and placed in service. Each set consists of two 16-inch units and one 32-inch unit. Figures 1 and 2 show one of the magnet assemblies.

The magnetic field at the center of a pole tip and 3-1/2 inches from the axis of the magnet is 7920 gauss; the field gradient is 2260 per inch, The power dissipated is 235 kw.

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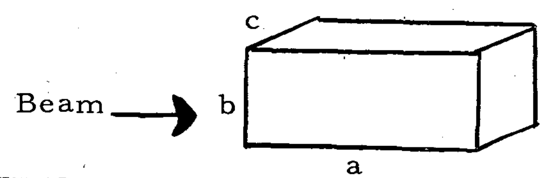
* Preceding reports: UCRL-3519, UCRL-3444.

Table I

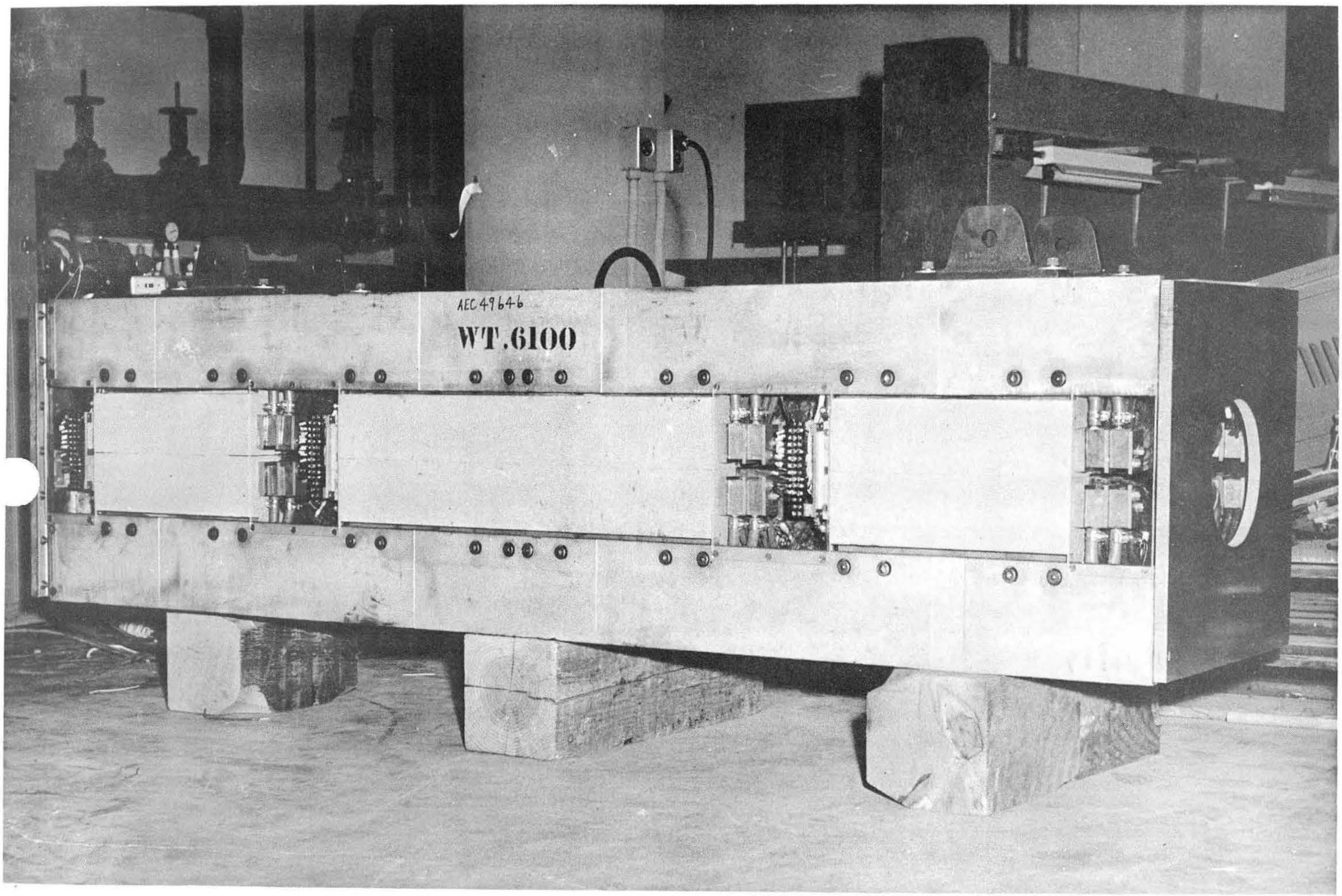
Quadrant-Mounted Targets
September 21, 1956 to End of Quarter

Quadrant	Azimuthal location (Ref: west straight section)	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	1° 59'	599	599-5/8	Polyethylene	9-23/32 x 1/2 x 1
II	3° 02'	598-15/16	599-9/16	Graphite	6 x 1/2 x 1
II	5° 03'	600-11/16	601-3/16	Beryllium	6 x 1/2 x 1
II	13° 09'	601-1/16	601-1/4	Uranium	1 x 1/2 x 3/4
II	13° 57'	601-9/16 max (adjustable)	601-3/4 max (adjustable)	Beryllium	4 x 1 x 11/16
II	16° 19'	605-1/16 in. to inner-radius edge (outer-radius target)	————	Copper	7/8 x 1 x 3/4
II	19° 58'	601-1/8	601-5/16	Polyethylene	1 x 1/2 x 1
III	35° 19'	597-1/16	597-1/4	Carbon	3 x 3/4 x 4
III	69° 56'	599	599-3/8	Aluminium	4 x 1/2 x 1/2
III	73° 00'	598-3/32	598-7/16	Copper	3-1/2 x 1/2 x 1
III	79° 45'	598-15/16	599-7/16	Lead	4 x 1/2 x 1/4



ZN-1655

Fig. 1. Eight-inch quadrupole lens set.



ZN-1656

Fig. 2. Eight-inch quadrupole lens set.

One-Megawatt Generator

A 1-megawatt dc generator has been installed for powering the auxiliary bending and focusing magnets associated with the experimental arrangements. This unit supplements the three 540-kw dc generators that have been in service.

POLE-BASE-WINDING FIELD CORRECTION

During an experiment at the Quadrant III experimental area it was observed that the stray magnetic field from a large bending magnet caused a 50% reduction in the accelerated beam amplitude. This reduction was the result of a perturbation of the Bevatron magnetic field during the injection period. Measurements of the residual field in the beam aperture were made with the bending magnet energized and with it turned off. The measurements indicated that the stray field from the bending magnet was in such a direction as to increase the Bevatron residual field and was a significant field perturbation for about 30° of Quadrant III; the magnitude of this disturbance was as much as 12% of the residual field. This would amount to a 1.4% perturbation of the field during injection.

To cancel this stray field at injection, a programmed field correction was applied by energizing the windings on eleven pole bases in the affected area; 110 ampere-turns was the largest correction.

It was observed that with the bending magnet turned on, the beam amplitude returned to normal when the pole-base corrections were applied. It was further noted that with the bending magnet turned off the beam amplitude increased 20% above the normal value when the field correction was applied. It is believed that this local field correction perturbs the beam orbit, during injection, in such a manner that a larger fraction of the injected beam misses the inflector. This suggests that a further increase in beam amplitude might be realized if this method of beam-orbit correction were extended to adjacent pole bases and the ampere-turn excitation optimized for each pole base.

At the present time this method has not been explored further.

RADIO-FREQUENCY TRACKING EQUIPMENT

New Wide-Band rf Driver

A new wide-band driver (Fig. 3) has been incorporated into the radio-frequency system of the Bevatron as the driver for the final amplifier.[1]

The original driver was a saturable-reactor-tuned power amplifier. The reliability of this unit was not exceptionally good, as the over-all circuit complexity was great and the accessibility of the components for service was poor. The new driver is an untuned, wide-band video amplifier, a unit whose simplicity and serviceability are considerably better than those of the original driver.

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[1] Walter Hartsough, Bevatron Operation and Development. X, UCRL-3519, Oct. 1956.

The new driver is gated on and off by a new "modulator" chassis, which keys the screen voltage of the output stage.

Automatic tuning of the final amplifier, through the frequency range 350 kc to 2.5 Mc, is accomplished in the same manner as with the original driver; the grid and plate rf signals of the final amplifier are sampled and compared in phase to derive an error signal for the saturating-current supply of the final amplifier reactor. A resistance divider, involving a noninductive water-cooled resistor and a smaller noninductive resistor, was used to sample the driver output rf. During the test of the driver, reported previously,[1] a phase lag on the order of 1 radian was observed between the driver output rf and the final amplifier grid signal. This phase shift apparently was caused by the high dielectric constant of the cooling water associated with the water-cooled resistor. The grid-rf sampling signal is now derived from a nonreactive resistance divider.

Incredurctor

An incredurctor (Type 62AQ3), a commercially available controllable inductor, has been used alternately with the shaper[2] (amplifier and saturable reactor) to provide a frequency-correction signal for the primary frequency generator at the high end of the frequency range. The advantage of the incredurctor is its simplicity and compactness. Figure 4 shows in simplified form the original circuit using the shaper. Figure 5 represents the circuit using the incredurctor.

The performance of the incredurctor proved satisfactory for operation if the input correction signal were not altered from pulse to pulse. However, when the operational requirements were such that the beam steering were different from pulse to pulse--as is quite often the case when beams are provided for two or more independent experiments in a programmed sequence--the incredurctor exhibited hysteretic effects which resulted in erratic operation. These hysteretic effects could probably be eliminated by introducing an erase pulse between Bevatron pulses.

For the present, although the incredurctor is not normally used, it is available and can be used as a substitute in the event of a failure in the shaper equipment of the rf system.

MAGNET POWER SUPPLY

The magnet-pulsing record appears in Table II.

During this period, three ignitrons were replaced because of failure of the anode bushings to hold plate voltage.

Many of the generator stator-winding end wedges have continued to move. These are driven back into place periodically. No satisfactory means of holding the wedges in place has yet been found.

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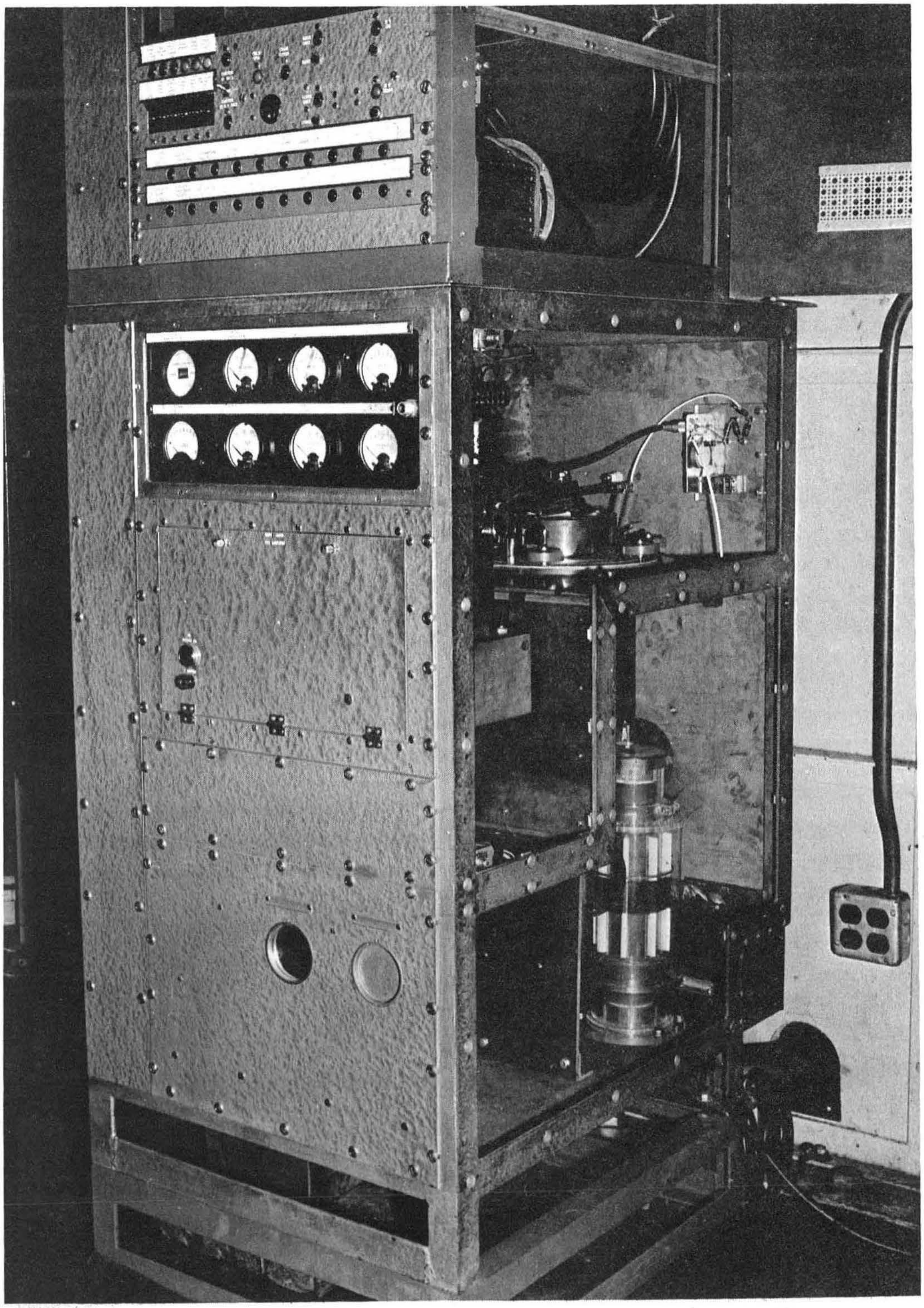
[2] C.N. Winningstad, The rf System of the Bevatron, UCRL-2593, June 1954.



ZN-1657

Fig. 3. New wide-band rf driver.

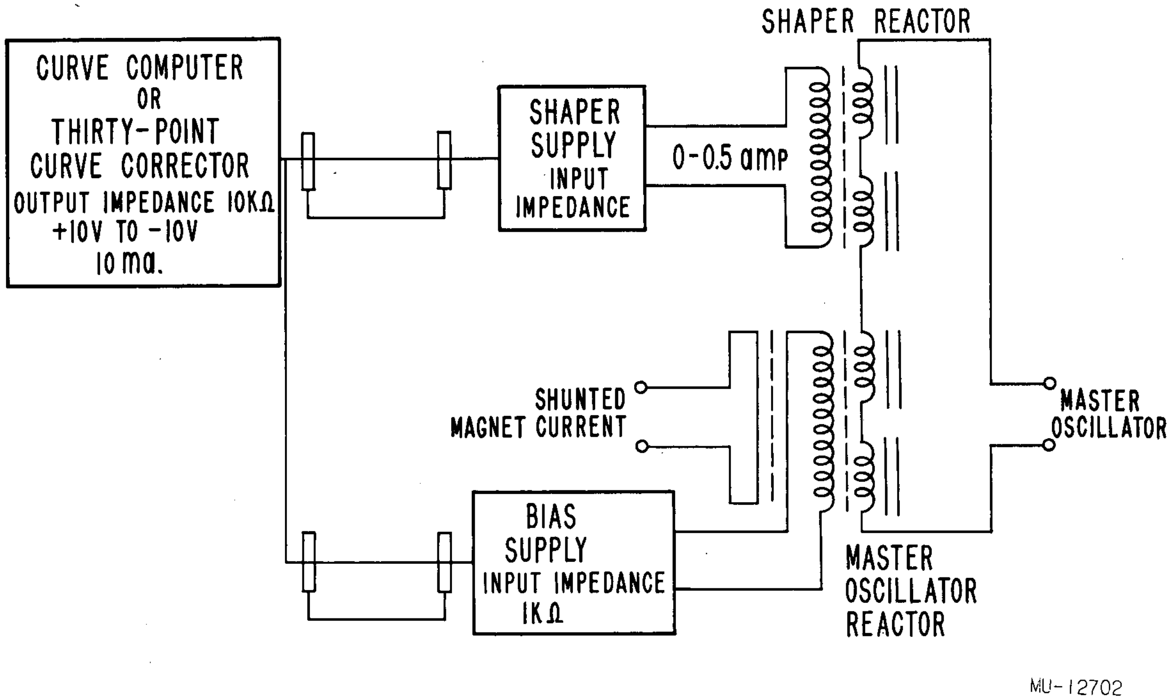


Fig. 4. Simplified frequency-correction system using the shaper supply and shaper reactor.

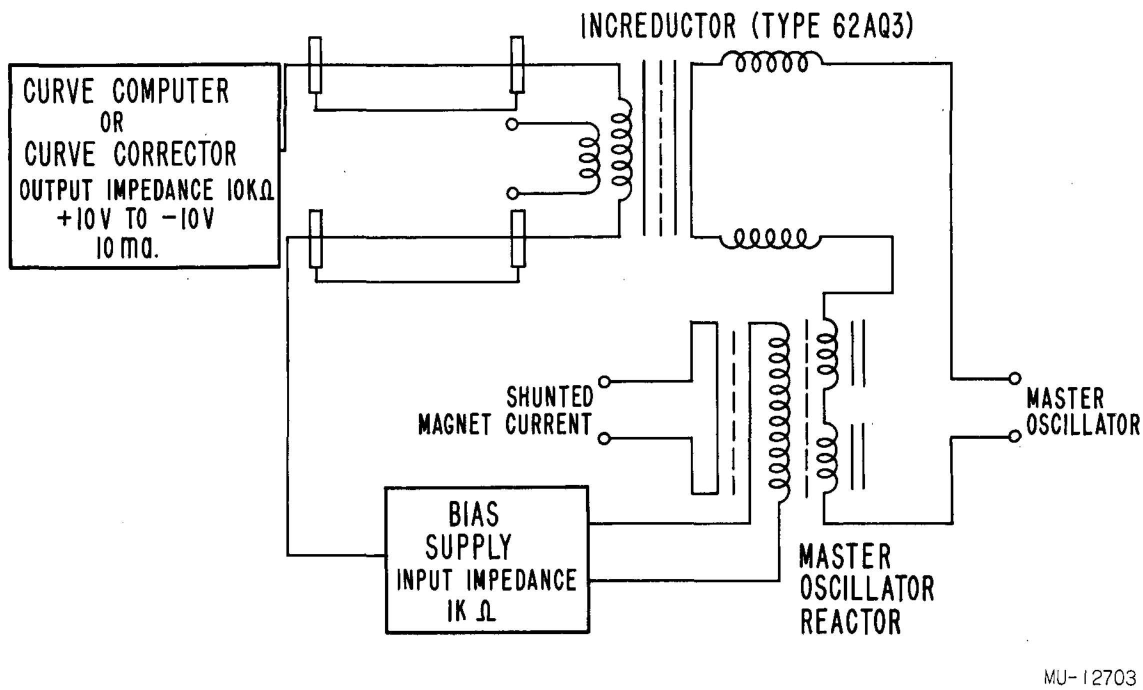


Fig. 5. Simplified frequency-correction system using an incredutor in place of the shaper supply and reactor.

Table II

Ignitron Fault Rate*

	5 to 7 pulses per minute						7 to 10 pulses per minute						10 to 17 pulses per minute						Total		
	1500 to 6000amp			5000 to 8000 amp			1500 to 6000 amp			6000 to 8000 amp			1500 to 6000 amp			6000 to 5000 amp					
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	Pulses	Faults	P/F
1956																					
Jan	----	-	---	-----	--	---	----	--	----	6,718	7	960	11,148	1	11,148	3,433	1	3,433	21,299	9	2,367
Feb	177	-	---	7,468	15	498	2,922	4	730	38,146	95	401	23,624	3	7,874	6,735	15	449	79,072	132	599
Mar	678	6	113	3,208	7	458	207	1	207	43,782	71	616	30,358	9	3,373	119,065	162	735	97,298	256	771
Apr	13,193	1	13,193	26,778	43	622	35,831	3	11,943	31,209	57	547	16,297	6	2,716	16,024	17	942	39,332	127	1,097
May	165	-	---	3,054	1	3,054	2,062	1	2,062	59,288	115	515	35,595	6	5,932	72,777	92	790	72,876	215	804
June	120	-	---	285	--	----	3,198	0	----	123,197	187	657	17,759	16	1,109	3,070	3	1,023	147,629	206	717
July	----	-	---	-----	--	----	----	--	----	90,655	131	684	14,036	2	7,018	90,375	83	1,088	95,066	216	903
Aug	----	-	---	-----	--	----	----	--	----	7,755	7	1,107	10,938	1	----	190,009	208	91[illegible]	08,702	216	966
Sept	----	-	--	----	--	----	1,677	--	----	12,447	10	1,245	6,273	1	----	95,784	71	1,346	16,186	82	1,417
Oct	----	-	---	-----	--	----	----	--	----	59,320	4	14,830		--	----	144,463	111	1,302	03,783	115	1,772

* Refer to previous Quarterly Reports for information on 1954 and 1955 Fault Rates.

MU-12674

Ignitron Monitoring

In an effort to trace the source of ignitron failures and ignitron faults during inversion, monitoring has been installed as follows: arc-back indicators on each generator phase bus to the ignitrons; automatic photographic recording of the various voltage waveforms of an ignitron on pulses on which an ignitron fault occurred. The information obtained from this monitoring system indicates that faults during inversion are initiated at either the grid or the anode of the tube. The grid of the tube is positive during inversion when the anode must hold off forward voltage. That the ignitrons generally fail because of a matallic plating on the anode bushing indicates that glow discharges occur in this region. Such a discharge could trigger the tube during inversions. Which of the above conditions is, in fact, responsible for inversion faults has not been determined.

The monitoring system also indicates that the ignitrons generally recover from inversion faults. The evidence indicates, however, that if the tube continues to conduct when the plate swings negative--that is, if an inversion arc-back occurs--the tube remains in a conducting condition for many cycles. All the inversion faults that result in an interruption of magnet pulsing appear to be due to inversion arc-backs.

BEVATRON SHUTDOWNS

The Bevatron was shut down from September 17 through 23, 1956 for maintenance, repair, and revision of the quadrant-mounted targets, for general Bevatron and magnet-power-supply maintenance, and for installation of new equipment. A brief shutdown occurred on September 30, 1956 for repair of the Quadrant III 73° flip-coil target mechanism.

OPERATION AND RESEARCH

The Bevatron operation during this quarter is summarized in Fig. 6. The operating hours were increased from 92 per week to 99 per week on September 16, 1956, by extending the 4 p.m. - 12 p.m. shift one hour each day. In addition, a 7-hour shift, 1 a.m. to 8 a.m. one day per week, was started during the week of October 28 for motor generator circuit development and testing, and for limited testing of the radio-frequency accelerating system.

The maximum recorded beam amplitude at full energy was 4×10^{10} protons per pulse (the injected proton beam was 245 microamp).

The major physics research effort was directed toward the investigation of antiparticles. Absorption cross sections for antiprotons were measured by two groups using counting techniques. The Lofgren Physics Research Group (Cork, Lambertson, Piccioni, and Wenzel) detected and counted antineutrons created by charge exchange in a Be target.[3] A large lead glass

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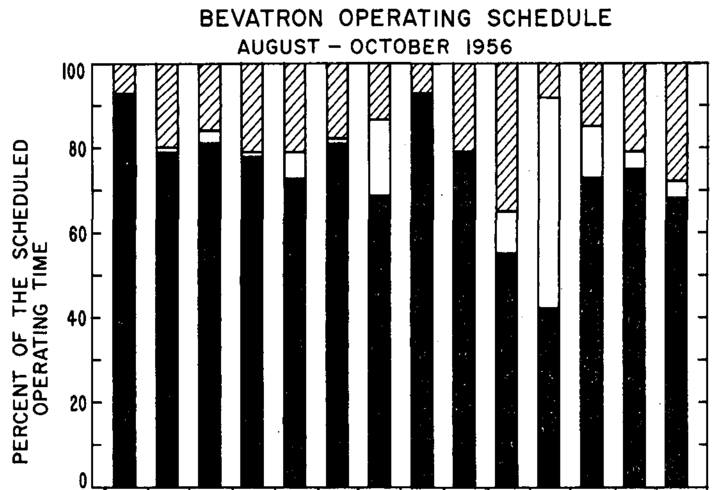
[3] Bruce Cork, Glen R. Lambertson, Oreste Piccioni, and William A. Wenzel, Antineutrons Produced from Antiprotons in Charge-Exchange Collisions, UCRL-3533, Sept. 1956.



WEEK OF	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	10/7	10/14	10/21	10/28
CREW HOURS	112	112	112	112	112	96	112	112	118	119	119	119	119	119
TURN-ON & MAINTENANCE TIME (hr)	20	20	20	20	20	18	20	1	11½	20	20	20	20	20
SCHEDULED OPERATING TIME (hr)	92	92	64	92	92	78	53	14	66½	99	93	99	72	99
SCHEDULED BEVATRON TEST TIME (hr)	0	0	28	0	0	0	39	0	0	0	0	0	27	0
SCHEDULED SHUTDOWN TIME (hr) *HOLIDAY	0	0	0	0	0	*16	0	96	40	0	6	0	0	0

ACTUAL BEAM "ON" TIME — EXPERIMENTAL SETUP TIME — "OFF" TIME DUE TO COMPONENT FAILURE

MU-12701

Fig. 6. Bevatron operating schedule.

Cerenkov counter was used to observe the antineutron annihilation events. Announcement of the detection and identification of the antineutron was made on September 14, 1956.

Table III summarizes the research activity during this quarter.

ACKNOWLEDGMENTS

The Bevatron Group leader is Edward J. Lofgren, and under him Harry Heard, with Walter Hartsough assisting, is in charge of operations. The Bevatron operators are Robert Anderson, Wendell Olson, and Robert Richter as crew chiefs; William Boyd, G. Stanley Boyle, Baird Brandow, Gary Burg, Duward Cagle, Norris Cash, Frank Correll, Frank Durbin, Robert Gisser, William Kendall, Fred Lothrop, Ross Nemetz, Frank Ulbrich, Glenn White, and Emery Zajec as crew members. Harold Vogel was the engineer in charge of the motor generator sets. Special development projects were carried out by Warren Chupp and Harry Heard. The mechanical engineering group was headed by William Salsig; the electrical engineering group by Clarence Harris and Marion Jones. Jerome Russell directed the electronic development group. Lorenzo C. Eggertz was in charge of the electrical maintenance group.

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

Table III

Bevatron experimental research program
August, September, October 1956

INTERNAL GROUPS	
Experimenters	Experiments
Group	
ALVAREZ	
Gow, Rosenfeld, and Tripp	K^-- meson absorption in hydrogen, using the 10-inch liquid hydrogen bubble chamber with magnetic field (430 Mev/c).
Bradner	Search for magnetic monopoles, using nuclear emulsions.
BARKAS	
Dudziak, Giles, Heckman, Inman, Mason, Nickols, and Smith	Study of the momentum spread of π and μ mesons in the Quadrant III negative particle beam, using counters.
	Emulsion exposures (2) in the focused and separated 300-Mev/c K^-- meson beam.
	Emulsion exposure in the focused 494-Mev/c K^-- meson beam.
	Emulsion exposure in the focused and separated 430-Mev/c K^+- meson beam.
BIRGE	
Kerth, Kycia, and Van Rossum	K^+ scattering by hydrogen and deuterium, using focused 560-Mev/c K^+ mesons.

INTERNAL GROUPS

Experimenters / Group	Experiment
LOFGREN	
Cork, Lambertson, Piccioni, and Wenzel	Antiproton absorption cross section in hydrogen, using a time-of-flight selection spectrometer and a liquid hydrogen target (0.75, 0.9, 1.15, 1.40 Bev/c). Cross sections were also measured for C, Be, and Pb.
	Detection and identification of antineutrons produced from antiprotons in charge-exchange collisions.
Horwitz and Murray	Detection and measurement of x-rays from π^- mesonic atoms, using counters.
Chupp, Heard, and Wenzel	Internal-proton-beam deflection experiments.
POWELL	
W. Fowler, Lander, and Piccioni	Observation of θ^0_2 mesons, using a propane bubble chamber with magnetic field.
E. Fowler and W. Fowler	K-meson and hyperon production by neutrons, using a propane bubble chamber with magnetic field.
SEABORG (Chemistry Group)	
Barr	Cu, Al foil bombardment (5.7 Bev).
Benioff	Oxalic acid–teflon–Al target bombardment (5.7 Bev); 5-aminotetrazole–teflon–$(CH_2)n$–Al target bombardment (5.7 Bev).
	$(CH_2)n$–$(CF_2)n$–Al target bombardment (5.7 Bev).
	CN_5H_3–$(CF_2)n$–Al target bombardment (5.7 Bev).
Caretto	U–Cu–Al foil bombardment (2.0, 6.0 Bev).
	Au–Ag–Al foil bombardment (4.5, 6.1 Bev).

INTERNAL GROUPS

Experimenters Group	Experiments
SEABORG (Cont.)	
Caretto	Al-Pb foil bombardment (6.2 Bev).
	Al-Cu-Ag foil bombardment (4.5 Bev).
	Al-Pb-U foil bombardment (4.5 Bev).
Carnahan	U-Al foil bombardment (5.7 Bev).
Grover	Ta-Al foil bombardment (5.7 Bev).
Nethaway	In foil bombardment (2.0, 6.2 Bev).
Turkevich	Cu-Al foil bombardment (1.0, 4.5 Bev).
	Cu-Au-Bi-Al foil bombardment (6.2 Bev).
Turkevich and Winsberg	Cu-Al; Au-Bi-Al foil bombardment (2.0, 3.2 Bev).
Winsberg	Au-Bi-Al foil bombardment (3.0, 6.2 Bev).
SEGRE	
Chamberlain, Steiner, Wiegand, and Ypsilantis	Measurement of the absorption cross section for 1.175-Bev/c antiprotons on Pb, U, H_2O, and D_2O.
G. Goldhaber	Emulsion exposure in the focused and separated 300-Mev/c K^--meson beam.

EXTERNAL GROUPS

Experimenters / Institution	Experiments
FIREMAN Brookhaven National Laboratory	Fe target bombardment in the internal 6.2-Bev proton beam.
KING University of Tennessee	Two nuclear emulsion exposures to the internal 6.2-Bev proton beam.
LEVI-SETTI, TELEGDI Enrico Fermi Institute of Nuclear Studies	K^0, $\bar{K}^0$ production and lifetime at 90^o (lab) to a Cu target in the 6.2-Bev proton beam, using nuclear emulsions.
FRY University of Wisconsin	
ASCOLI University of Illinois (two emulsion stacks)	Emulsion exposures in the focused and separated 300-Mev/c K^--meson beam.
FRY, SWAMI University of Wisconsin	
GOTTSTEIN Max Planck Institute, Göttingen	
GLASSER Naval Research Laboratory	
HOANG, KAPLON Rochester University	
POWELL Bristol, England	
WHITE Livermore Nuclear Emulsion Group	
WILKINSON Cambridge University, England	