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BEVATRON OPERATION AND DEVELOPMENT. 57

January through March 1968

Kenneth C. Crebbin and Robert Frias

August 5, 1968

Berkeley, California

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CONTENTS

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April 5, 1968

ABSTRACT

The beam was on for 86.9% of the scheduled operating time and the Bevatron accelerated 2.32 X 10^{18} protons this quarter. One internal beam experiment was finished this quarter and setup of a new experiment in its place was begun. Setup work continued on the new dual-channel external proton beam channel. Preliminary tests were started on the beam channel to the 25-inch bubble chamber.

There was a one-week shutdown in February. This is the first of several shutdowns planned in order to effect a reduced level in operation and in experimental physics, as dictated by cutbacks in the high energy physics budget.

Work was continued on the resonant extraction system. A new flattop mode of magnet pulsing was tried which is designed to reduce the stresses on the motor-generator poles.

MACHINE OPERATION AND EXPERIMENTAL PROGRAM

The Bevatron operation record is shown in Fig. 1. The beam was off 7.1% of the scheduled operating time because of equipment failure and 6.0% of the time for experimental setup, tuning, and routine checks. The beam was on for 86.9% of the scheduled operating time. During this quarter, the Bevatron accelerated 2.32 X 10^{18} protons.

The Moyer-Helmholz Group's experiment 47A was completed in January. The front end of the beam channel is to be left in place for a new experiment, number 86, which is expected to start running in May. Some preliminary tune-up was done and tests made for this new experiment this quarter. The purpose of the new experiment is to measure the branching ratios for the neutral and charged decay modes of the η. This is a spark chamber counter experiment, and will use an 800-MeV/c π^- beam from an internal target near the north straight section. This new experiment, number 86, is to be done by the Moyer-Helmholz group in collaboration with the Alvarez group.

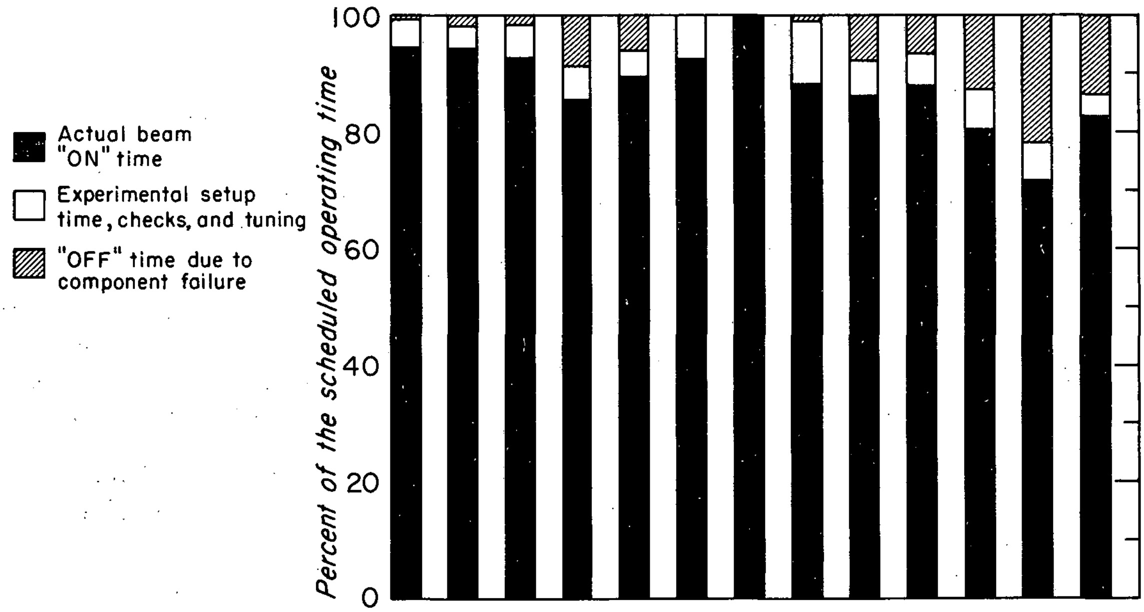
There were two major modes of operation this quarter. One was an 800-msec flattop at 5.3 GeV. The second was a 550-msec flattop at 5.7 GeV. The higher-energy flattop mode was necessary in order to get a higher yield of K^- for the University of Washington's (Davis) experiment (No. 50). The California Institute of Technology Group's experiment (80) used a π^- beam from the same internal target (near the west straight section of the Bevatron) as the University of Washington (Davis) Group's experiment (50). These experiments had been scheduled to be run simultaneously. Because of the above yield problem and use of slightly different target locations in the Bevatron for optimum results for each experiment, the University of Washington (Davis) Group ran on the 5.7- GeV flattop while the California Institute of Technology Group ran on the 5.3-GeV flattop. The Lofgren Group's experiment 67 ran simultaneously with both the University of Washington and the California Institute of Technology groups. Experiment 67's primary running was on the 5.3-GeV flattop mode with the California Institute of Technology Group.

The groups using the 25-inch hydrogen bubble chamber started secondary-beam channel and bubble chamber tests in March. The π and K beams tuned up satisfactorily, and the bubble chamber should start taking pictures early in April. A power interruption to the Laboratory on March 20 forced a temporary dump of the liquid hydrogen and resulted in slow warm-up of the chamber. Recovery was possible soon enough to prevent much condensed impurity from becoming redistributed in the chamber and collecting on the glass window.

Setup work continued in the new two-channel external proton beam (EPB) facility. Experiments are being set up at the third focus in both channels.

Some preliminary tuning has been done in the two secondary-beam channels by use of a target at the third focus of EPB Channel 1. A complete description of the new two-channel facility will be given in the next quarterly report.

The new EPB hall crane was completed and accepted this quarter, and the roof was installed on the last two bays of the craneway. The new sprinkler system, under the roof of the main-ring-magnet building, was completed and tied into the automatic fire detection system.



Week of	12/31	1/7	1/14	1/21	1/28	2/4	2/11	2/18	2/25	3/3	3/10	3/17	3/24
Crew hours	144	168	168	168	168	168	168	168	168	168	168	168	168
Turnon and maintenance time (h)	12	12	10	10	9	8	0	4	10	11	10	13	10
Scheduled operating time (h)	84	141	146	131	140	144	8	99	132	141	130	129	144
Scheduled Bevatron test time (h)	8	15	12	27	19	16	0	9	26	16	28	26	14
Scheduled shutdown time (h)	40	0	0	0	0	0	160	56	0	0	0	0	0
Holiday	24	0	0	0	0	0	0	0	0	0	0	0	0

XBL 688-3595

Fig. 1. Bevatron Operating Schedule.

On March 15, 1968, the RCA A2332S vacuum tube driving the accelerating electrode in the Bevatron developed a grid-to-filament short. This tube was replaced with the last RCA A2332S in existence. RCA had produced four of these tubes; one was destroyed at the factory, the remaining three were delivered to LRL. The first of the three tubes that were delivered to LRL was used as the final amplifier for 11 years, the second (the one that failed this month) was operated 3 years. The third and final tube is now in use.

Design effort is now proceeding toward eventual replacement of this tube with a system using an Eimac 4CW 100,000 D as the final amplifier. It is expected that the new system will be ready for trial by the second week in May.

A summary of the experimental program for this quarter is shown in Table I.

SHUTDOWN

The Bevatron was shut down from 0800 on February 11 to February 20. The beam was turned off 48 hours before the start of the shutdown work to allow residual radiation levels to drop before work started, and thus reduce the radiation exposure of the workers.

Among the jobs done during the shutdown were the following:

1. One of the perturbation coils on the resonant extraction magnet was moved relative to the magnet septum to provide a slightly different operating point.
2. A scintillator was mounted on the upstream face of the second quadrupole in the EPB extraction system. The scintillator covered the magnet face from the outer edge of the septum to the inner edge of the magnet aperture.
3. A new viewing port was installed in the cover plate of a man-access-port to provide television monitoring of the scintillator. This monitoring of the EPB is very helpful as a diagnostic tool in studying beam loss and various extraction methods for the EPB system. It will also simplify tuning during normal operation when we have solved the camera location problem so that we can leave the television camera in place for extended periods. At present the radiation damage to camera and lens is too high to permit continuous use.
4. During this shutdown, routine maintenance was done on the Bevatron and associated equipment.
5. Setup work continued for the new experiments in the EPB channel.

This shutdown was one of several Bevatron shutdowns planned for the latter half of this fiscal year. These shutdowns are to be made in order to effect a reduced level in operation and in experimental physics, as dictated by cutbacks in the high energy physics budget.

An unscheduled shutdown of the Bevatron occurred at 0130 on March 20, 1968, when power feeding the Laboratory was interrupted following the collapse of a P.G. and E. transmission-line tower. The tower in the hills east of the Laboratory had been dynamited. Power was restored that evening at 2130. Bevatron operation was resumed at 0230 on March 21. During the period while normal power was out, standby power to essential equipment was supplied by a 200-kW automatic-start emergency generator.

Table I. Summary of Bevatron experimental research program, January through March 1968.

Groups	Dates: Run	Dates: Start	Dates: End	Experiment	Beam time: This quarter (Jan.–Mar.): 12-Hour periods	Beam time: This quarter (Jan.–Mar.): Hours	Beam time: Start of run through March 1968: 12-Hour periods	Beam time: Start of run through March 1968: Hours	Pulse schedule	Primary or secondary experiment
Internal Groups										
Moyer–Helmholz (Parker)	47A	5/19/66	1/11/68	Neutral decay rate $K_L^0 \rightarrow 2\pi^0$	14	159	293	3332	1:1	P
Lofgren (Wenzel)	67	6/7/67	In progress	Ke_2 branching ratio 0.5-GeV/c separated K^+ beam	68	753	112	1281	1:1	P
Powell–Birge (Kalmus)	72	2/21/67	In progress	π^+p Interactions	46	512	46	512	1:1	P
Moyer–Helmholz (Kenney) Group A (Pripstein)	86	8/14/67	In progress	Branching ratios for the neutral and charged decay modes of the η	3	28	3	28	1:1	P
Nuclear Chemistry (Hyde, Poskanzer)	104 {98, P-13}	9/21/66	In progress	Production of light fragments from P-nucleon collisions	62	710	78	991	1:1	P
Alvarez (Smith-Abolins)	P-25	11/2/67	In progress	Counter and spark chamber tests for Experiment 83	16	200	18	247	1:1	S
Lofgren (Cork) U. of Michigan (Murthy)	P-26	11/11/67	1/25/68	Test of relativistic rise $\left(\frac{dE}{dx}\right)$ with proportional counter	10	142	17	228	1:1	S
Health Physics (Stephens)	P-27	11/28/67	1/30/68	Spectral and angular measurements of particles produced by 6.3-GeV protons	½	8	¾	11	1:1	S
External Groups										
U. of Washington (Davis)	54	7/21/66	In progress	Ξ^0 Decay parameters	64	723	87	1047	1:1	P
U.C.–San Diego (Piccioni)	71A	3/15/68	In progress	K regeneration amplitudes 1- to 1.5-GeV/c separated $K^\pm$ beam	6	74	6	74	1:1	P
U.C.–San Diego (Masek)	79	3/27/68	In progress	$K_2^0(e_3)$ Charge asymmetry	3	28	3	28	1:1	P
Calif. Inst. of Technology (Tollestrup)	80	8/11/67	In progress	Leptonic decay, $K \rightarrow \pi^\pm, e^+, \nu$ Determination of $\Delta S/\Delta Q$ in 2- to 3-GeV/c π^- beam	88	865	161	1895	1:1	P
Jet Propulsion Laboratory (Metzger)	P-10	9/21/67	In progress	Lunar γ-ray emission simulation	0	0	4	59	1:1	S

BEVATRON DEVELOPMENT AND STUDIES

Resonant Extraction

The major development effort this quarter was on the resonant-extraction system. Some iron radiation shielding, near the main Bevatron magnet, was removed in December 1967. This shifted the closed orbit in the Bevatron and reduced the radial ν value. These changes caused a shift in the operating point and basic characteristics of the resonant-extraction system.

Theoretical studies and measurements indicated that part of the problems in the resonant extraction were caused by nonlinearities in the Bevatron field. To further study this effect, some of the pole-face windings, used to correct the n value at injection, were pulsed to about 100 A. By use of the pulsed currents, all particles in the circulating beam can now be fed into similar resonant-growth trajectories at $\nu = 2/3$. The orderly growth of amplitude is detected by observing the successive positions of the shadow of a (radially) narrow target placed to intercept some of the spiraling beam. The shadow may be seen (on a scintillating surface), on every third turn for a total of about 20 turns. At about 6 in. betatron amplitude the growth per three turns is from 0.75 to 1.25 in., and the beam produces a spot this wide and about 1 in. high. With a 0.5-in.-thick septum, the present extraction efficiency is about 35%. Studies of resonant extraction will continue.

Flattop Pulsing-Mode Tests

Since detection of the cracks in the new generator poles, various methods of reducing the flattop pulsing speed range have been studied and several techniques tested. In the original flattop pulsing mode the cyclic speed range during a pulse was as much as 117 rpm. To reduce cyclic centrifugal stress, which is believed to be a major contributor to fatigue failure of the pole laminations, maximum speed change was limited to 100 rpm. This limit was established last summer when the Bevatron resumed operation. This made it necessary to reduce the flattop length. (The flattop at normal operating energy was reduced from 1000/to 800 msec.) With the detection, since then, of new cracks, it was apparent that the range must be reduced even further, and new methods of flattopping the magnet pulse are being explored.

Figure 2 shows the existing electrical connection for Bevatron operation. For flattop pulsing one generator combination of four rectifier cubicles is inverted while the second generator's rectifiers remain in rectification. The inverted generator-fly wheel combination is accelerated while the rectifying, combination decelerates during the energy transfer.

Figures 3 and 4 show possible electrical combinations in which the gross energy exchange does not take place during the flattop period. However, they do exhibit additional problems that must be completely understood before either of the systems can be considered feasible for continuous operation.

The Fig. 2 flattop pulsing mode would require few changes as far as power supply modifications are concerned. In this mode two of each generator's four rectifier cubicles are inverted so that the voltages of the power supplies are effectively zero. Actually the supply voltage at this time equals the magnet resistance drop or 1500 V at a 6000-A flattop. This mode limits the change in speed during the actual flattop to that demanded by system losses. A 6500-A 1-sec flattop would require a 7-rpm change during the flattop period, compared with an approximate 67-rpm change for the present system.

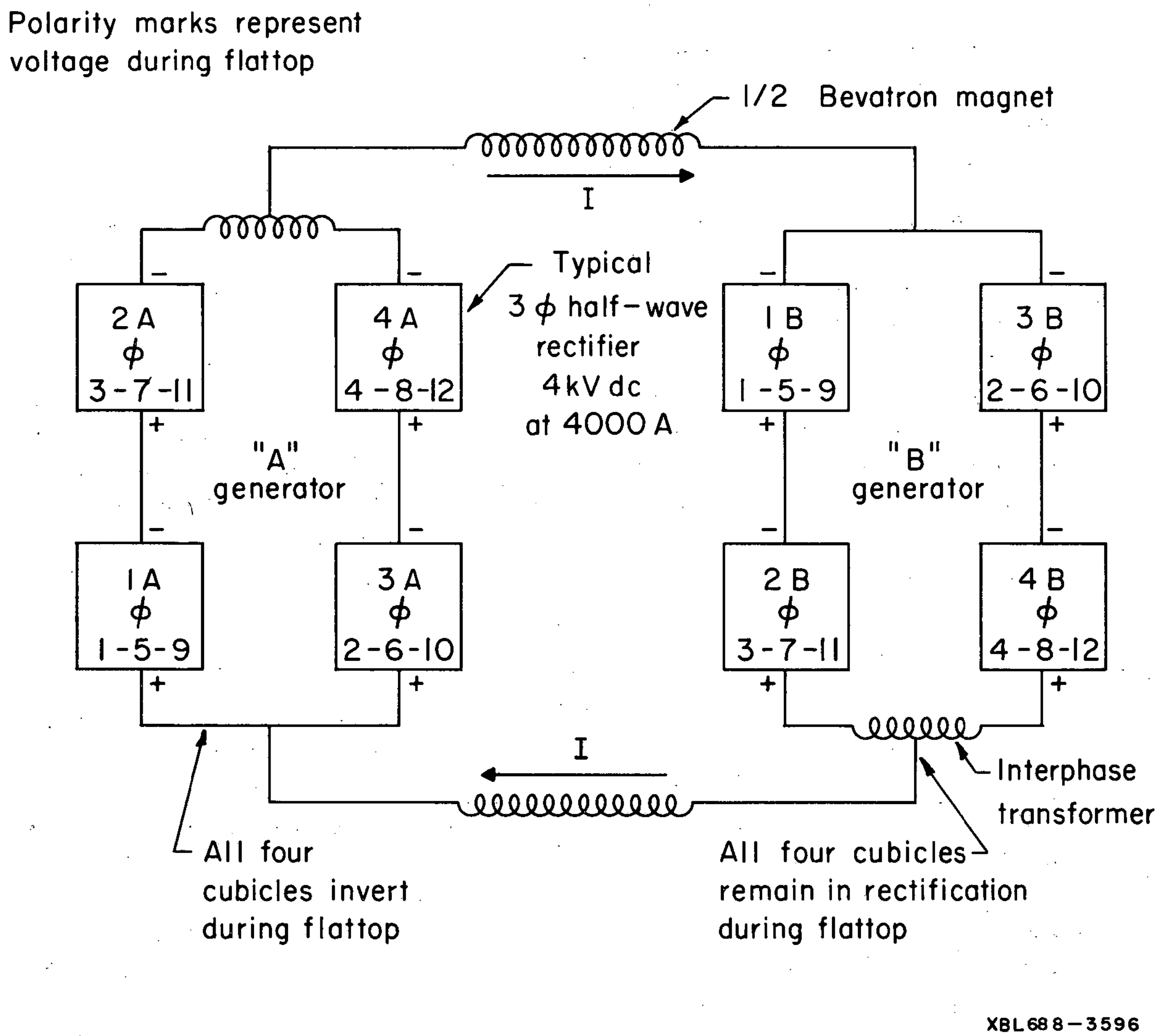


Fig. 2. Existing flattop mode at Bevatron.

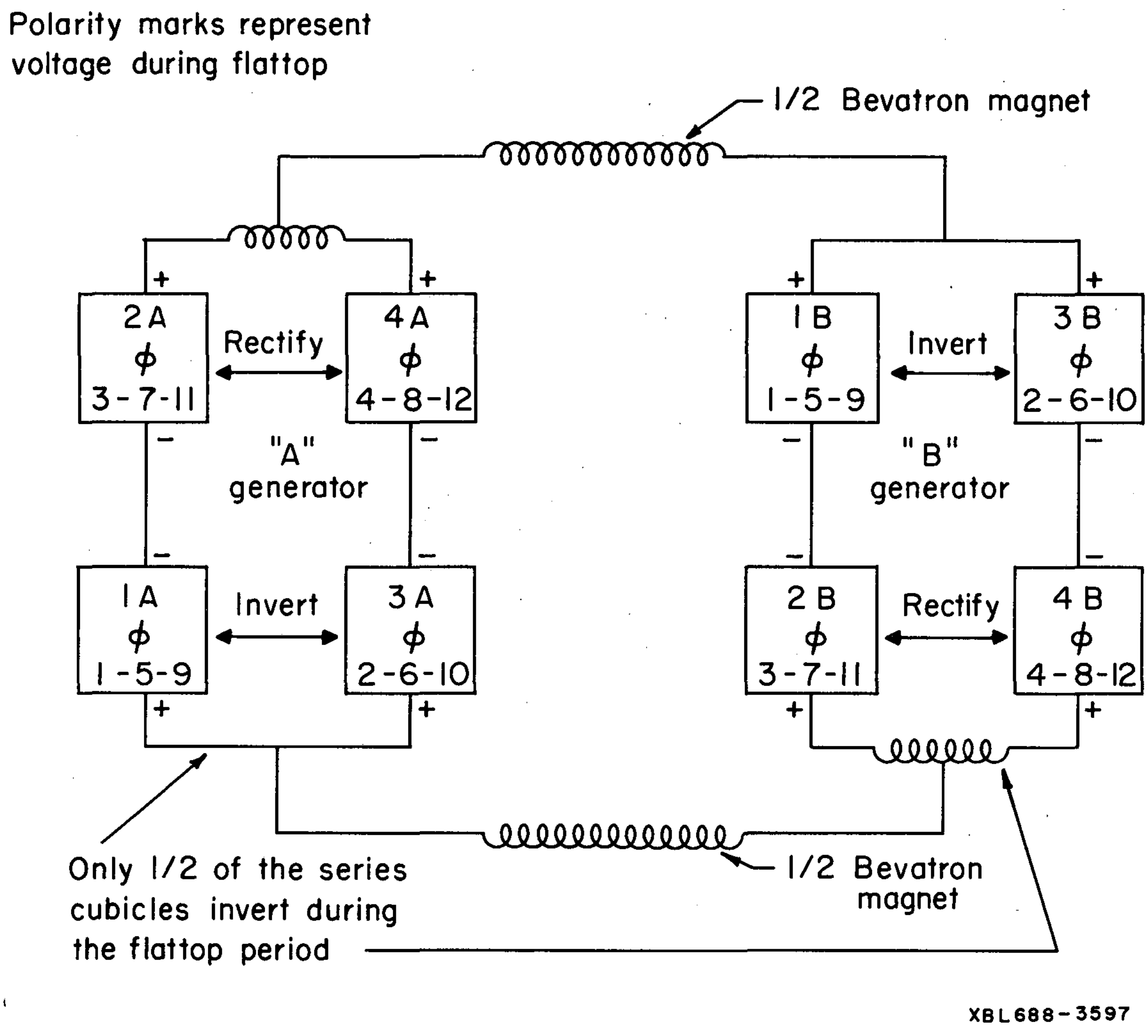


Fig. 3. Proposed and tested flattop mode.

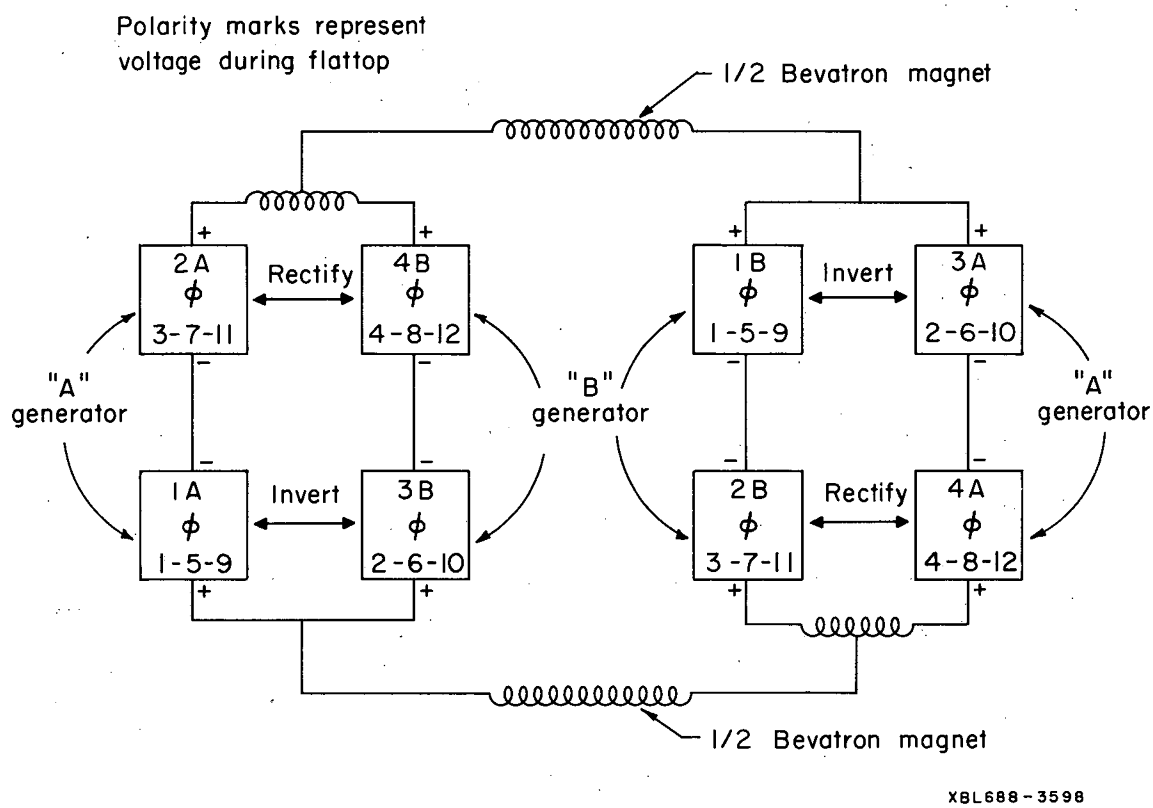


Fig. 4. Proposed flattop mode——will allow reduction of shaft oscillation.

There are two adverse effects encountered in this mode. One is the inability to provide the torsional oscillation-damping step changeover period between rectification and inversion. In this mode the shaft must be allowed to oscillate at the system's natural frequency during the flattop period. This condition adds shaft stress at a 20-Hz rate. A study is now being made to determine if this mechanical ringing would prompt shaft damage.

The second adverse condition was detected during actual testing. It was observed that the generators responded mechanically to a 180-Hz excitation. This would shake the generator and foundation in a mode not previously experienced. Further testing is in progress in a search for complete understanding of this harmonic response.

The unpredicted machine response to the 180-Hz components has reinforced the interest in the wiring diagram shown in Fig. 3. In this connection a step changeover can be allowed, and the voltage distribution on the magnet windings can be exactly the same as now. The major difficulty encountered in this mode is the necessity for exact synchronization between the two machines to provide the normal 720-Hz 12-phase rectifier ripple. Various synchronizing techniques have already been tried, with encouraging success. The rectifier reconnection will be tested in the near future unless a method to reduce the 180-Hz vibration is developed.

The interest in developing a new flattop mode is undiminished. A long flattop will continue to be an experimental demand on the Bevatron. At the same time it is recognized that any reduction in cyclic load on the poles will substantially increase their life. Initial tests of the Fig. 2 flattop mode showed a total speed change of 46 rpm during a 6400-A 1-sec flattop pulse. This range is exactly half of the 92-rpm range presently encountered during a normal 6400-A 800-msec flattop pulse.

BEVATRON MOTOR GENERATOR

The magnet pulsing record is shown in Table II.

Table II. Bevatron motor generator set monthly fault report.

1968	4 to 6 pulses/min								7 to 8.7 pulses/min								9.3 to 17 pulses/min								Total				
	1.5 to 6.9 kA				7.0 to 9 kA				1.5 to 6.9 kA				7.0 to 9 kA				1.5 to 6.9 kA				7.0 to 9 kA				Pulses	Arc-backs (AB)	Arc-through (AT)	P/F	Ignitrons replaced
	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F	Pulses	Faults AB	Faults AT	P/F					
Jan.	–	–	–	–	200	–	–	–	4 956	–	–	–	9 182	1	1	4 591	414 210	9	27	11 506	4 289	1	2	1 430	432 837	11	30	10 557	0
Feb.	–	–	–	–	1 625	–	–	–	–	–	–	–	25 816	2	8	2 582	195 627	6	9	13 042	55 162	2	10	4 596	278 230	10	27	7 520	1
March	1 834	0	–	–	–	–	–	–	687	–	–	–	15 065	1	7	1 883	293 760	46	7	5 543	88 108	14	13	3 263	399 454	61	27	4 539	2
April																													
May																													
June																													
July																													
Aug.																													
Sept.																													
Oct.																													
Nov.																													
Dec.																													

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