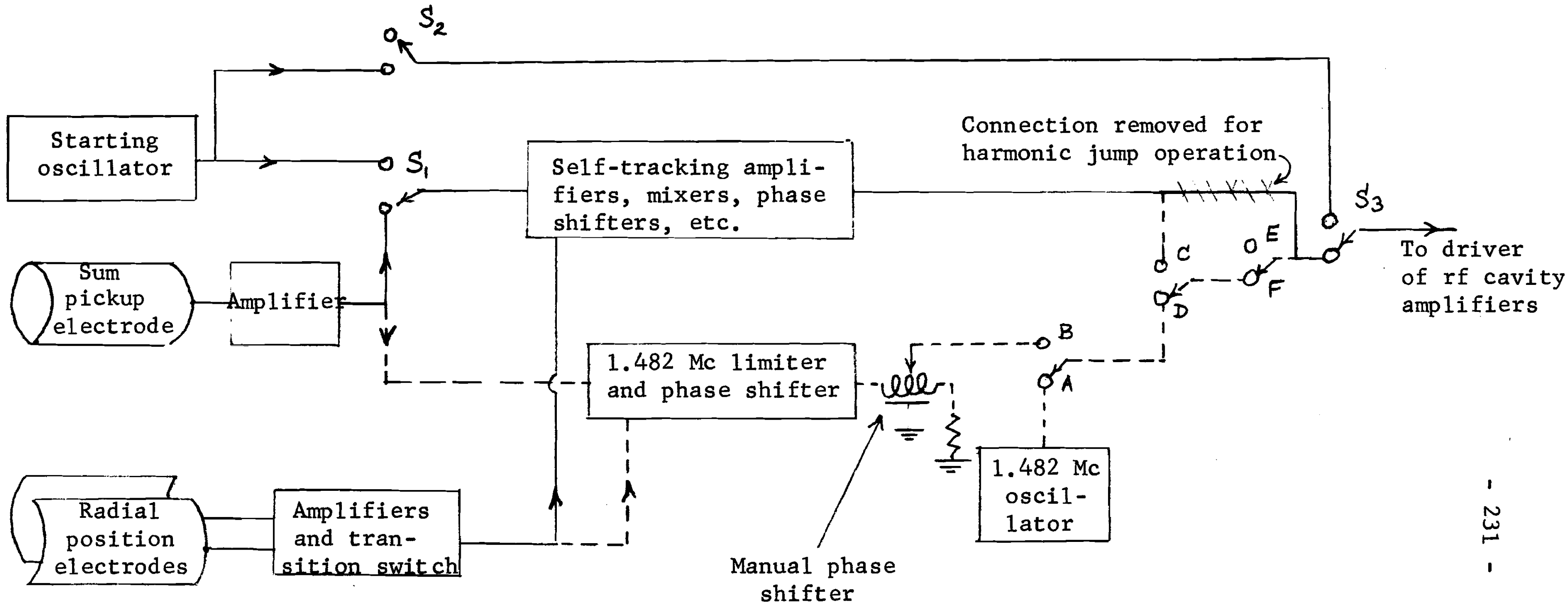
INITIAL TESTS OF PROTON STORAGE IN THE AGS

J. W. Bittner
Brookhaven National Laboratory

Interest has been shown in how long protons could be stored in the AGS. A method has been developed to store a single pulse and now works reliably and repeatedly. Single pulses have been stored for several minutes. However, as yet there has not been an opportunity to investigate the mechanisms of the observed beam losses.

In order to operate the AGS as a storage ring, several problems were involved. Thermal and other limitations of the AGS magnet and its power supply limit the continuous dc operation of the magnet, on a very long magnet flattop, to a current equivalent to about 16 Bev. Since under these conditions the voltage required is only that due to the IR drop, it amounts to only a few hundred volts and the short commutation times of the ignitrons introduce large ripple currents at fields corresponding to energies below 14 Bev. For these reasons, an energy slightly above 14 Bev was chosen.

Because of very slow drift in the magnet current under continuous dc operation it was found desirable to keep the beam bunched and, by means of the "bootstrap" rf system, control the particle energy to keep the beam centered in the vacuum chamber. Under these conditions, the ferrite-loaded accelerating cavities, tuned to the twelfth harmonic (4.446 Mc) of the revolution frequency, are operating at nearly their maximum frequency, requiring an excessively high average current from the ferrite saturating supplies. In order to reduce this average current under dc operation, Dr. J.P. Blewett suggested that the rf harmonic be changed from the twelfth to the fourth after the beam had been accelerated. Fig. 1 shows in a block diagram the



Switching Schedule	Time after start of magnet cycle	Switch Position		
Start of magnet flattop	434 msec	A	C	F
Debunch (rf off)	575 "	A	D	E
Bunch	600 "	A	D	F
Bootstrap	610 "	B	D	F
Reset	at end of flattop	A	C	F

Position of switches S_1, S_2, S_3 are shown in position corresponding to flattop operation.

Fig. 1 - Low-level rf block diagram with the addition of harmonic jump circuits (dotted lines).

modifications made to the low-level rf system to produce the required harmonic jump. About 140 msec after the magnetic field had reached a steady value, the rf signal was removed from the accelerating cavity amplifiers and the beam was allowed to debunch. After a debunching time of 25 msec, the rf system was driven for 10 msec from a fixed oscillator (1.482 Mc) and the beam rebunched at the fourth harmonic. The input to the rf system was then switched back to a signal derived from the bunched beam, and the bootstrap system re-established. This time, however, a voltage limiter and phase shifting circuit tuned to a fixed frequency (1.482 Mc) was substituted for the self-tracking amplifiers in the radial control portion of the low-level system, to reduce transient effects during the jump. The added circuits were all simple adaptions of circuits previously designed by H. Halama for the low-level system.

The rf cavities, while not placed uniformly around the ring, are connected so as to act in phase on a circulating bunch of protons when operating at the twelfth harmonic. At the fourth harmonic, however, their effects tend to cancel, producing a total voltage equivalent to only two cavities operating in phase. This equivalent voltage was increased by turning off two of the accelerating cavities prior to acceleration and a third after flattop had started, but before the harmonic jump was made. This resulted in a net voltage gain per turn equivalent to 4.4 stations operating in phase at the fourth harmonic.

The bunched beam, before and after the harmonic jump, was monitored by means of an oscilloscope using the sum and difference pickup electrodes. The relative amplitude and the decay of the total circulating current were measured by means of an ionization chamber consisting of a chart recorder connected in series with a 90-volt battery across a pair of horizontal position pickup electrodes. Fig. 2 shows the bunch structure about 40 msec after the beam controlled bootstrap system was re-established after the harmonic jump, and Fig. 3 the bunch structure several minutes after the harmonic jump. It was found that, during this jump, over 60% of the beam was recaptured into bunches at the fourth harmonic. This value is comparable with the initial capture after injection. Fig. 4 illustrates the decay of the beam measured with the chart recorder and using the horizontal pickup electrodes at position F7 as an ionization chamber. It corresponds to a decay time constant of about 180 seconds. The initial intensity corresponded to about 10^{11} protons. The phase lock was able to keep track of the surviving beam for about 8 minutes. This was the longest survival time we have measured to date. The average of the ion gauge readings around the ring was about 0.9×10^{-6} torr. Since, however, most of these gauges are very close to the Evapor-ion pumps, they do not indicate the average pressure. The relationship is complicated by the fact that the pumping speed of these pumps is not constant but depends upon the titanium and gettering cycle. At the time these measurements were made, there were no facilities available for determining the composition of the residual gas, although such will be available in the near future. Thus it is difficult to tell if this decay rate is consistent with gas scattering. The short decay time constant suggests the presence of other loss mechanisms. However, there has as yet been no opportunity to pursue this problem further.

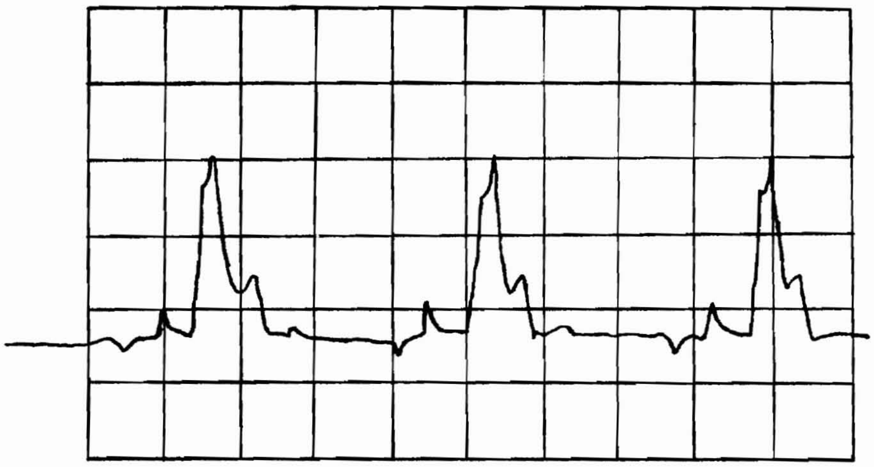
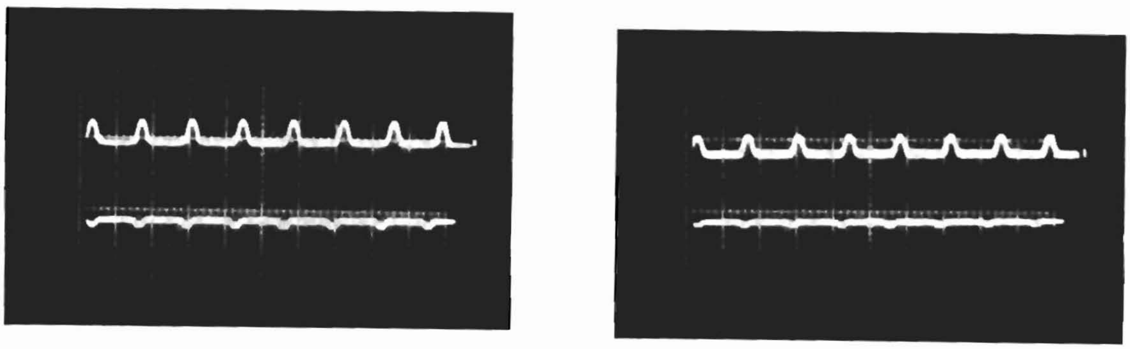


Fig. 2 - Rebunched beam 40 msec after re-establishment of bootstrap system on the fourth harmonic of the revolution frequency, 0.2 μs/cm (drawing from photograph of scope trace).



(a) (b)

Fig. 3 - Bunched beam about 4 minutes after harmonic jump (0.5 μs/cm).

(a) Upper trace: sum signal 0.1 v/cm; lower trace: difference signal 0.05 v/cm; vertical position electrodes F15.

(b) Upper trace: sum signal 0.1 v/cm; lower trace: difference signal 0.05 v/cm; horizontal position electrodes F15.

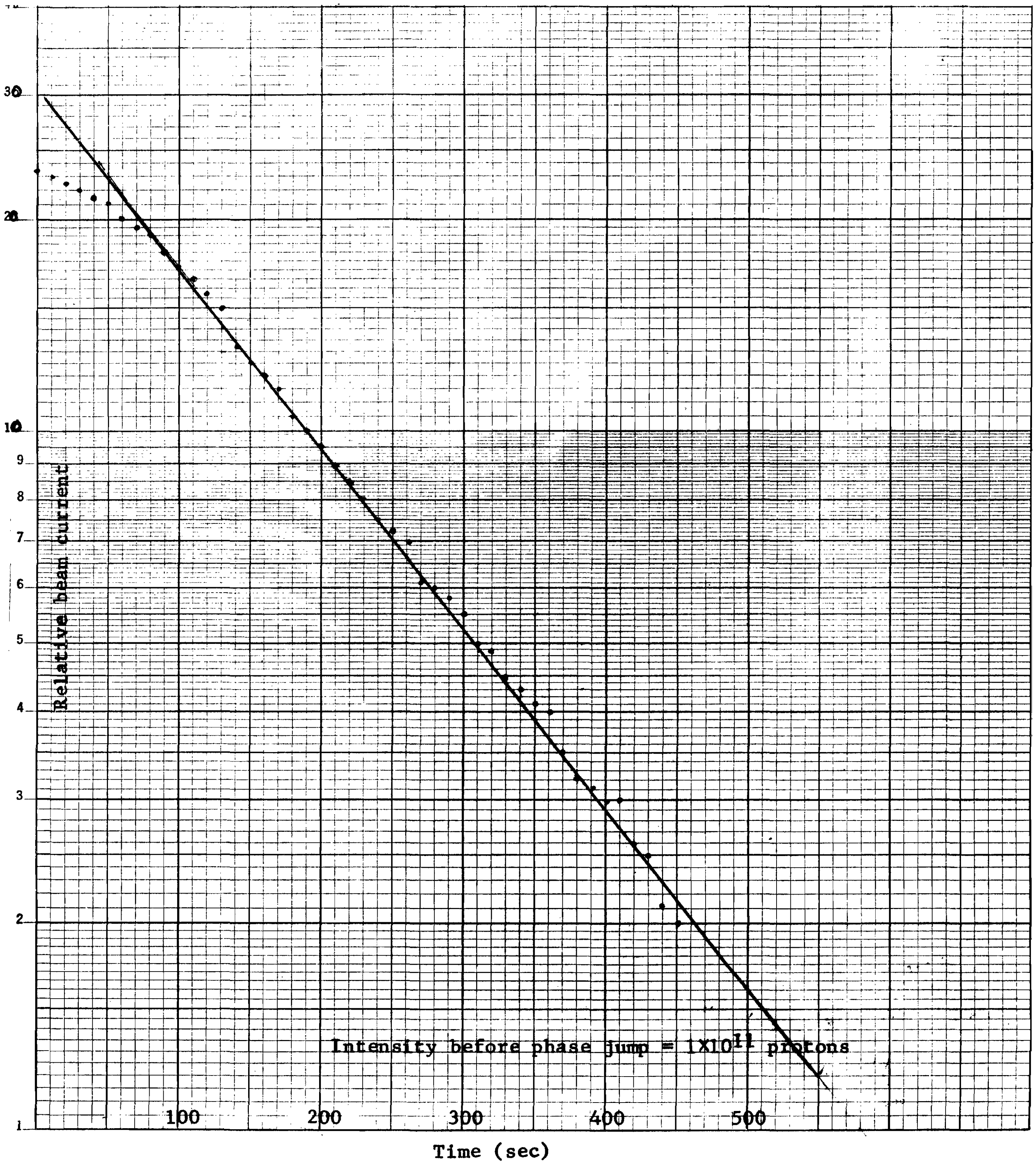

30
20
10
9
8
7
6
5
4
3
2
1
Relative beam current
100
200
300
400
500
Time (sec)
Intensity before phase jump = 1X10¹¹ protons

Fig. 4