Title
Operation of the 1/4 Scale Model Bevatron III.

Author
Lofgren, E.J.

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UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

OPERATION OF THE 1/4 SCALE MODEL BEVATRON, III

E. J. Lofgren

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During the period July 15-August 1 the greatest attention has been given to improving operating stability. A marked improvement has been made so that it is now possible to work more easily on the remaining important problem, which is extension of the beam acceleration to long acceleration times.

Jitter. Since the beginning of bevatron operations a lack of reproducibility between successive pulses has been a severe handicap in carrying out experiments. This meant that every adjustment of each control required a statistical observation to determine if there was an improvement, and since there are five critical controls this made a nearly impossible situation. These controls govern the frequency at the time of injection, the rate of change of frequency with magnetic field, the magnetic field at the time of injection, the interval between the time of injection and the time the rf is turned on, and the inflector voltage. In Figure 1 is plotted a distribution of beam pulses according to their size under typically bad conditions. In the middle of July it was decided that it was unwise to attempt any further experiments until this jitter had been cured.

Correlations of beam size with each of the other functions that might vary were looked for. A strong correlation with starting frequency was finally found and is displayed in Figure 2. Here the number of beam pulses of a given magnitude is plotted against the randomly varying frequency for a series of consecutive pulses. The range of variation is 1-2/3 percent. The fault was traced to 60 cycle pickup on an improperly shielded wire between the magnet shunt signal amplifier in the control room and the frequency modulator at the oscillator. The frequency modulator is a current regulator which provides the bias on the Ferroxcube reactor in the oscillator. A correction was made by providing a single ground for the two circuits at the shunt amplifier and removing the wire from proximity with other wires. After this correction the range of starting frequency variation was reduced to 0.6 percent. A typical beam pulse distribution under the improved conditions is shown in Figure 3.

Some of the measurements on other components that proved not to have large errors are of interest. The signal to fire the cyclotron is derived from a permalloy peaking transformer in the magnet circuit. Its signal was compared with that of a similar transformer in the same circuit. While there were very rarely time differences as great as 100 μ sec., the usual differences were well under 50 μ sec., which corresponds to a starting frequency error of .23 kc or .06 percent.

At the end of each magnet pulse when the current is nearly zero the contactor opens. Actually the current may vary from pulse to pulse between limits of about +100 to -100 amp. depending on the exact timing of the generator field reversing relays. This changes the residual field at the beginning of the next pulse. No correlation was found between the beam size and the breaking current. However, the starting frequency error had not yet been corrected and it is possible that a small variation of beam due to differences in the residual field was masked by the larger one caused by the starting frequency error. Consequently an effort is made to keep the breaking current always positive.

The constancy of the cyclotron was never seriously questioned but a check on it as well as on the inflector voltage was provided by observing the jitter of the beam at the first half turn with the magnet on regulated d.c. operation. The horizontal bevatron aperture was reduced to 2 inches and the probe was 4 inches high b

1-1/2 inches wide in this experiment. The pulse height distribution is given in Figure 4.

Cyclotron Energy. With d.c. operation of the bevatron magnet as in the experiment on jitter the energy and the energy spread of the injected beam can also be obtained. In this case the horizontal aperture at 90° was reduced to 1 inch. This opening, the inflector and the probe were all placed on the center of the magnet gap. The current as a function of magnet field is given in Figure 5. The radius at the gap centerline is 138 inches. The ions are deviated $2\text{-}1/2^\circ$ by the fringing field at each end of the 90° magnet sectors. From this the energy can be given as 0.68 Mev. The width of the curve at half value is $\pm$ 1 percent in energy.

Acceleration Time. Only limited progress has been made on this problem because of preoccupation with the jitter problem. With the existing oscillator and modulator the frequency-magnetic field curve is about 5 percent too low even at 770 kc or 75 μ sec. after injection. It has been possible to reduce that error to about 2 percent with a feedback loop in the magnet shunt signal amplifier. Figure 6 shows the resulting increased survival of beam to longer times, however the curve shows no signs of flattening off.

Injection. A change was made on the inflector with the purpose of preventing the penetration of a perturbing electric field from the inflector to the regions occupied by allowed orbits. The geometry of this inflector is shown in Figure 7a. With this arrangement the beam size was reduced by a factor of 4 presumably because of the smaller vertical dimension inside the inflector gap. In view of this result the geometry shown in Figure 7b was restored.

In the last paragraph in the Injection section of the previous report, UCRL 398, it was reported that only ions coming from within 1/4 inch of the grounded inflector electrode were accepted when the inflector was at 13 inches from the center of the the magnet (where $n \simeq 0.6$). This experiment has been repeated at 17-1/2 inches, where n $\approx$ 2.5, and it has been found that ions are accepted from a region 1/2 inch wide.

Distribution of Beam on Probe. The beam is collected on a probe inserted from the inside of the bevatron. The beam spirals into the probe as the magnetic field continues to increase after the rf is shut off. If the probe is covered by a shield which may be moved radially to expose a variable width one can get an integral curve of the beam distribution away from the probe edge. The curve shows an essentially linear increase from zero beam to maximum as the exposed section of the probe is increased from zero to 1/4 inch in width.

The operating group now consists of W. Chupp, R. Clack, E. Lofgren, D. Nielson, R. Richter, R. Robertson, F. Schmidt, D. Sewell, R. Shankland, W. Stephan. Most of the burden of correcting the jitter fell on the electrical engineers, R. Aiken, G. Farly, D. Mack, H. Owren.

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BEAM ACCELERATED TO 12 M SEC.
FIG. 1 TO 3

TANK APERTURE 9 1/2 x 24
FIG. 1 TO 3

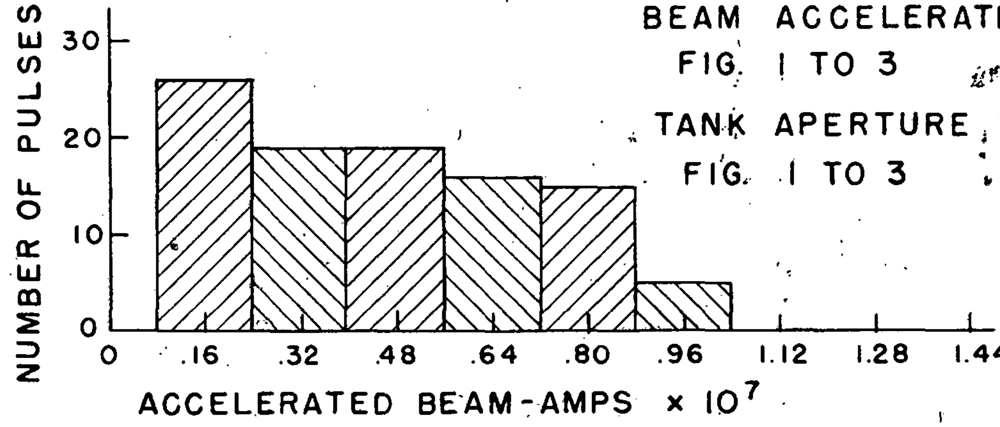


FIG.

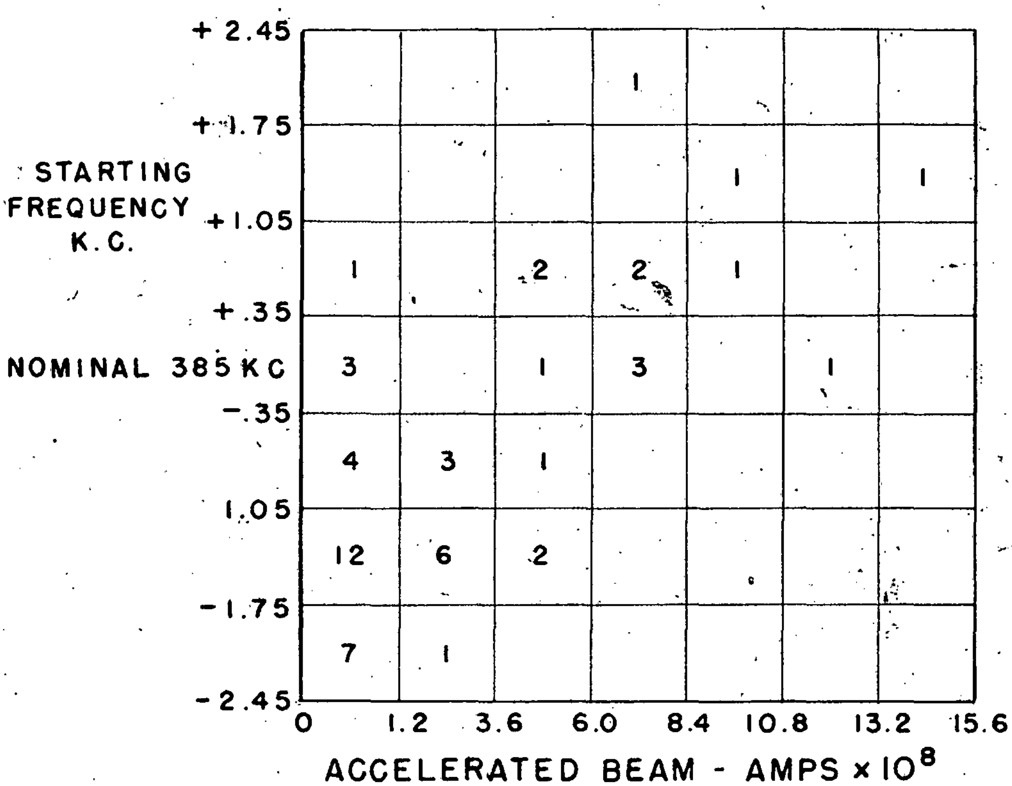


FIG.

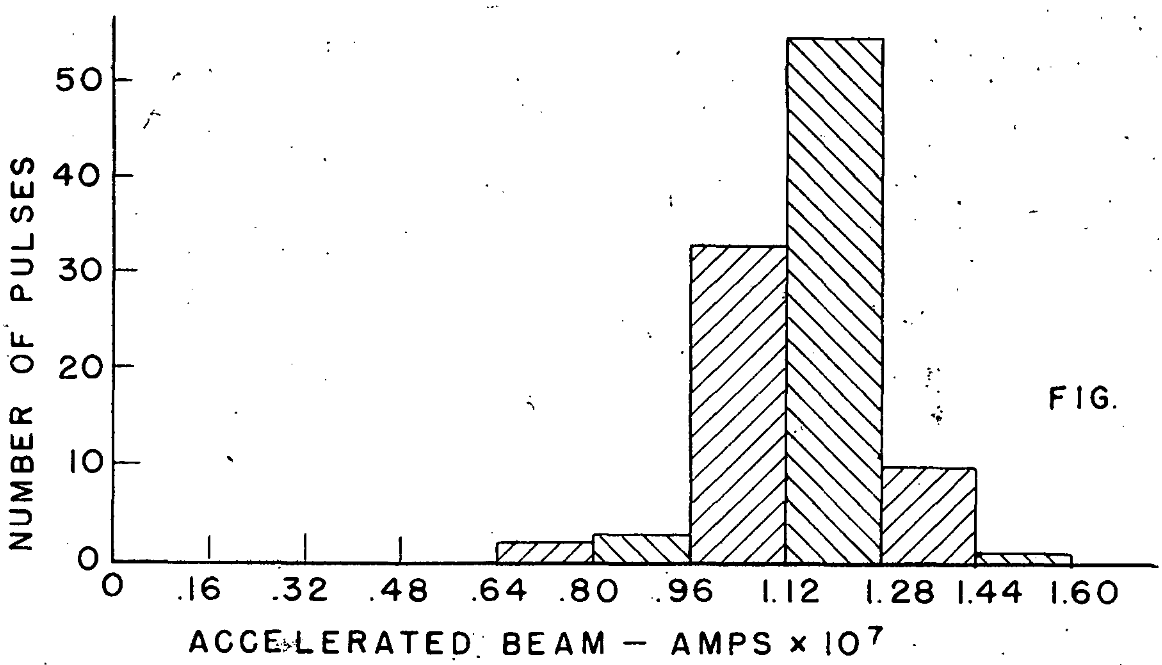
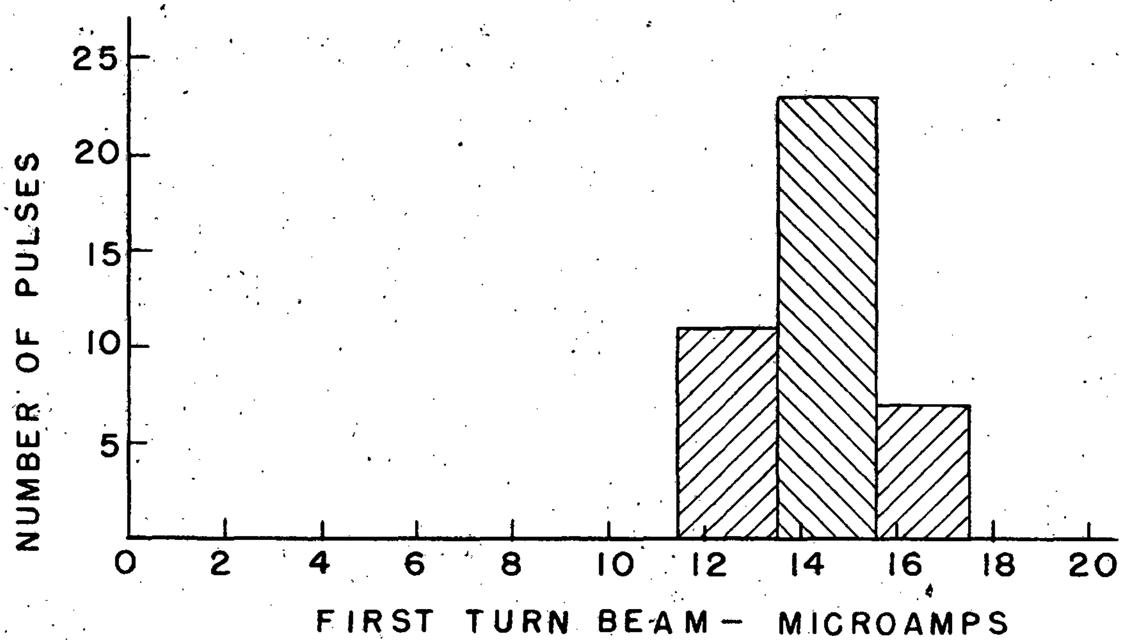
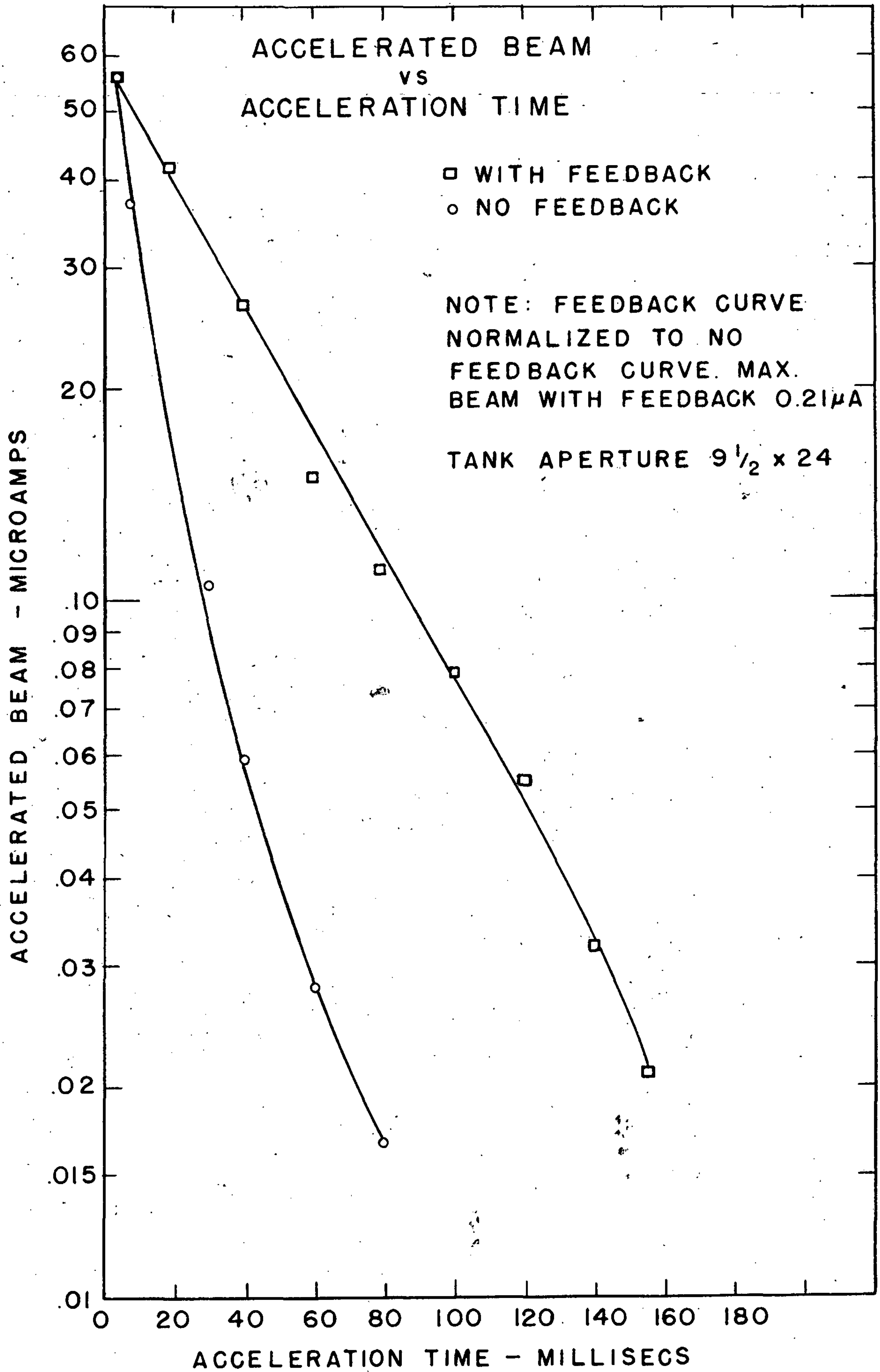


FIG.



NUMBER OF PULSES
25
20
15
10
5
0
2
4
6
8
10
12
14
16
18
20
FIRST TURN BEAM – MICROAMPS

FIG. 4



ACCELERATED BEAM
VS
ACCELERATION TIME
□ WITH FEEDBACK
○ NO FEEDBACK
NOTE: FEEDBACK CURVE NORMALIZED TO NO FEEDBACK CURVE. MAX. BEAM WITH FEEDBACK 0.21μA
TANK APERTURE 9½ x 24
ACCELERATED BEAM - MICROAMPS
60
50
40
30
20
.10
.09
.08
.07
.06
.05
.04
.03
.02
.015
.01
0
20
40
60
80
100
120
140
160
180
ACCELERATION TIME - MILLISECS

FIG. 6

13939-1

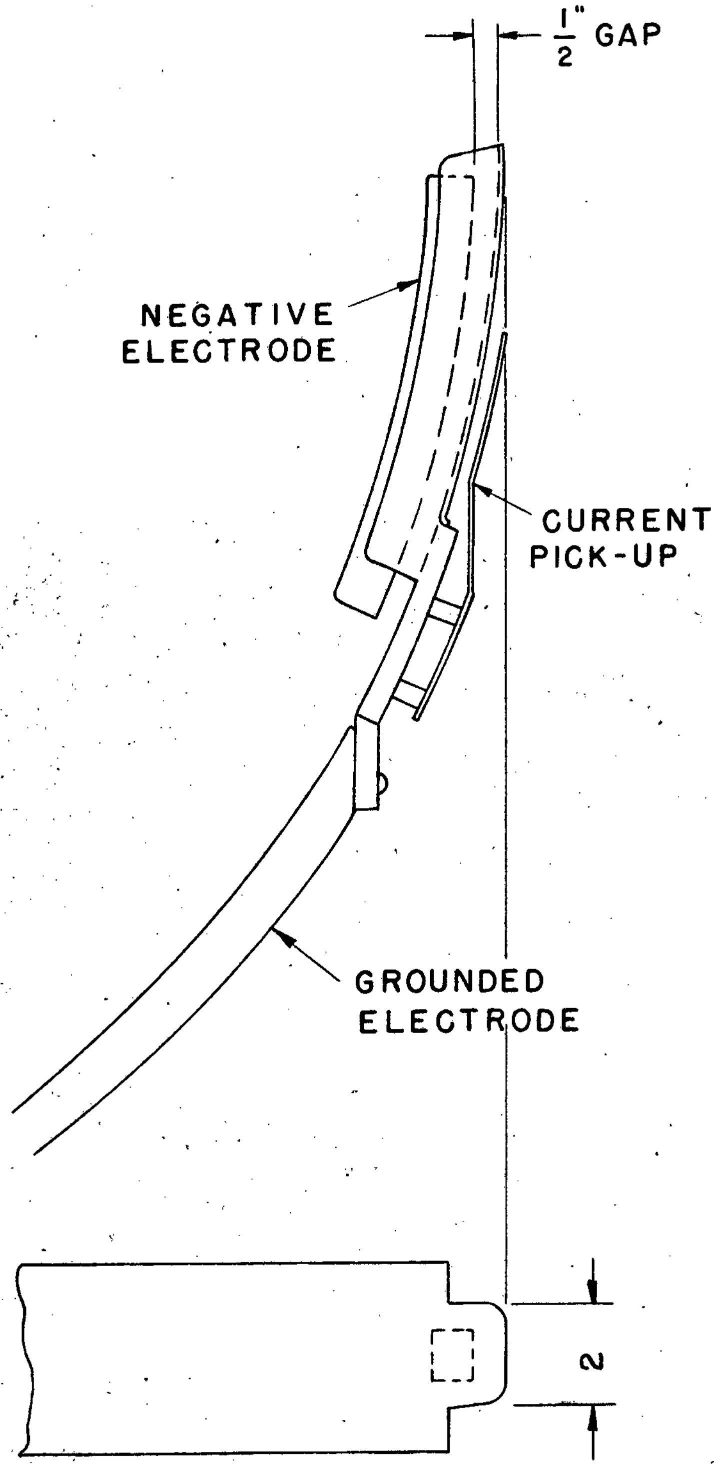


FIG. 7-A

13941-1

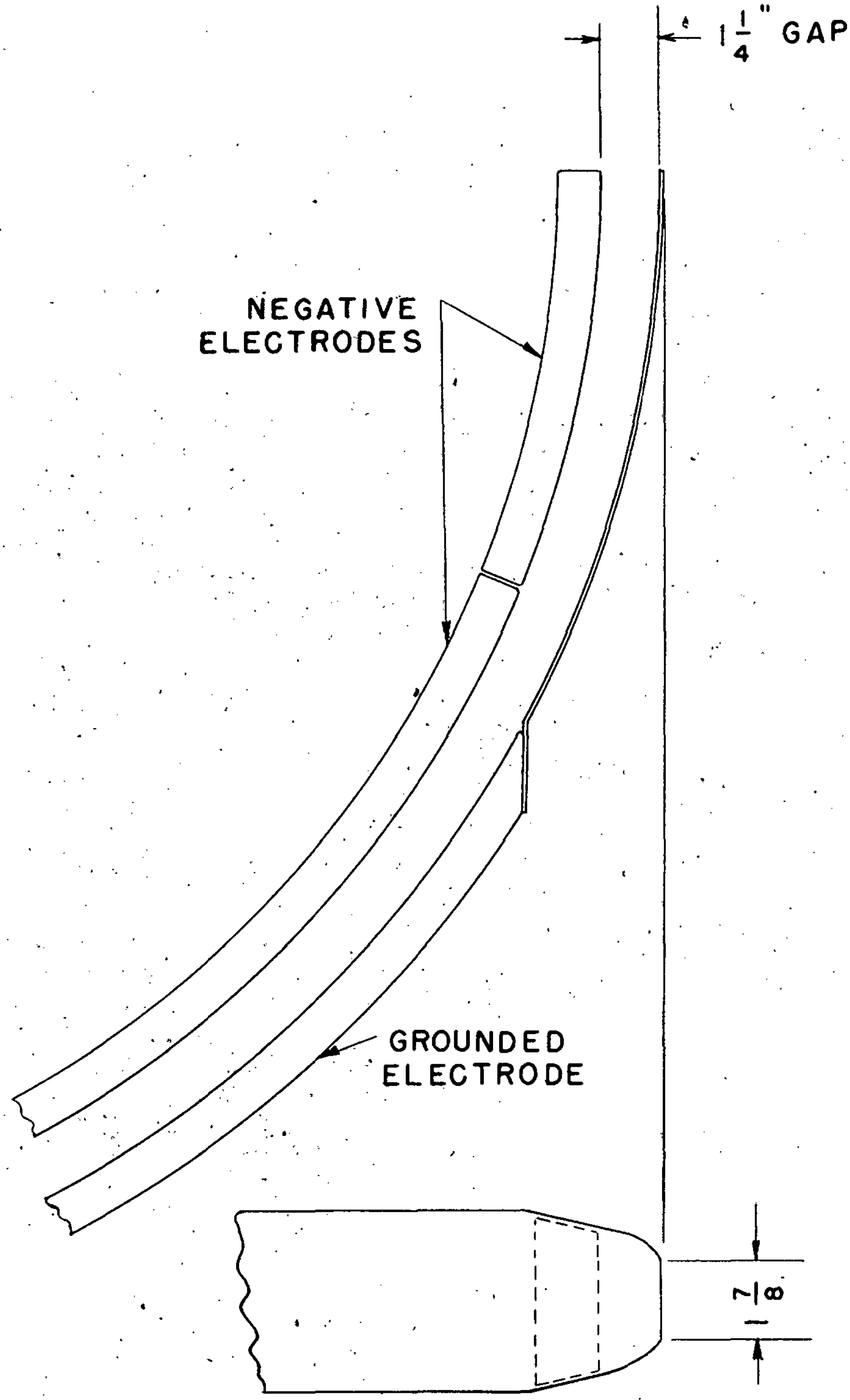


FIG. 7-B