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OPERATION OF THE 1/4 SCALE MODEL BEVATRON, IV

By
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September 8, 1949

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In August the operation of the Model Bevatron was notably better due to more accurate frequency tracking as well as to the greater circuit stability which was reported last month. Aperture studies have indicated that 2 ft. x 6 ft. for the full scale Bevatron is a very conservative figure. A smaller inflector has increased the efficiency of the machine. Preliminary tests of a new oscillator were made but a report on it will be deferred until the work is carried farther.

Acceleration Time. The errors in frequency tracking have now been brought under our control making it possible to accelerate the beam without undue loss to the limit imposed by the magnetic field, namely 6 Mev. The correction was made by introducing a controllable non-linear circuit between the magnet shunt signal amplifier and the frequency modulator. This circuit consists of a resistor, R, shunted by several diodes, each diode having an adjustable bias voltage and an adjustable plate resistor, r_i. The voltage across R exceeds the bias on each of the diodes in turn causing the resistors r_i to be successively shunted across R. Thus the combined circuit resistance, R', effectively decreases during the magnet pulse and with proper adjustment can be made to just compensate for the saturation errors in the oscillator. The frequency error is displayed on an oscilloscope by subtracting the magnet shunt voltage from a suitably attenuated voltage which is porportional to the frequency. Fig. 1a is this error curve without correction. Fig. 1b shows on the same scale the improvement with 4 biased diodes. Later 6 diodes were used and the error was nowhere greater than 1/2 percent of starting frequency. Curves of beam as a function of acceleration energy using this device are given in Fig. 2 for various apertures. Compare this with Fig. 6 of the previous report, UCRL 412.

Injection. The dimension of the tip of the inflector were reduced by a factor of about two. The new dimensions are given in Fig. 3, the old ones were given in Fig. 7b of the previous report. The beam out of the inflector is reduced from 140 μa by about a factor of 10 but the accelerated beam is increased by 2 1/2 because of the smaller area blocked by the inflector.

There has been a question whether the ion orbits are perturbed by the field of the injector electrode. As reported last month an attempt to provide electrostatic shielding by the inner grounded electrode decreased the beam because it cut the injected beam without allowing more space for ions to clear the inflector. We have now investigated this problem by pulsing the inflector voltage off with a triggered spark gap at an interval of time after the beginning of injection. The cyclotron pulse is 850 μs long and plotted in Fig. 4 is the accelerated beam as a function of inflector off-pulse time. Observations were made alternately with the inflector left on and pulsed off. Each point on the curve is normalized with respect to the average of the preceding and following datum with the inflector left on. From this we see that there is a marked perturbation. With the larger inflector there were similar results but at the peak of the curve the beam was 1.7 rather than 2 times the normal value. This is no doubt due to better electrostatic shielding with the larger inflector.

Aperture. In the second report of this series, UCRL 398, it was pointed out that very little beam seemed to exist adjacent to the tank walls. This was indicated by measurements of the accelerated beam as the vertical half aperture was reduced by means of vanes at 90°, 270°, and 360° around the Bevatron from the point of injection. The data indicated a downward tilt in the plane of the orbits at 360° leading to the belief that the beam hit the tank at the bottom at 360° and the top at 180°. These places were not accessible to measurement and the question remained open as to whether the beam could be made by any means to fill the tank. We have reverted to that problem and because of better operation have more complete and accurate information.

In Fig. 5 is shown the relationship of the space occupied by beam to the tank at the points where measurements have been made under three different conditions. The dotted lines display the data taken from Fig. 7, UCRL 398. If similar measurements are made on a beam accelerated to higher energy and if injection is from a region of $n = 0.6$ rather than $n = 2.0$ then the beam does occupy more of the vertical space in the tank as shown by the solid lines. Under the latter conditions it has been possible to tilt the plane of the beam with currents in the pole face windings and observe the beam as much as 4 3/8 inches above the tank centerline at the 270° position. The half height of the tank at the probe position is 4.45 inches. This is as close as one could expect to come to the nominal position of the tank wall because of inaccuracies in both the tank and the vanes. To do this the pole face windings which are 12 circumferential wires 3 inches apart on each pole face were connected to make a solenoid whose axis was horizontal and whose N pole was towards the center of the Bevatron. Eight amperes were required in the 0 - 90° and 90° - 180° quadrants. The beam was lost at greater currents.

We have also found ions right up to the tank wall with the more sensitive scintillation counter probe by inserting it from above in one of the tangent tanks. There were, in fact, 3 or 4 counts per millisecond even when the probe was 2 1/4 inches above the top of the tank aperture. These counts persisted out to 60 ms. in time or to about 2 Mev. Qualitatively, at least, they can be accounted for by scattering.

The best data on beam loss with reduced aperture has already been given in Fig. 2 where it will be seen that in reducing from 9 in. x 26 7/8 in. to 6 in. x 18 7/8 in. (6 in. x 18 in. would be an accurate scaling down from the proposed 24 in. x 72 in. in the Bevatron) there is a loss of a factor of 7 in the accelerated beam. There is a further loss of a factor of 8 in going to 4 1/2 x 16 7/8 inches.

With the horizontal aperture set at 18 inches by placing the inflector 9 inches outside of center and the probe 9 inches inside of center each of the five vertical aperture vanes have been moved separately as in the earlier work at 31 1/2 inches horizontal aperture reported in UCRL 398. For each vane position the beam accelerated to 5.7 Mev was recorded. In Fig. 6 these observations normalized to the aperture open values are plotted as a function of half aperture. The indication is that with 18 inches as an approximately fixed dimension (72 inch full scale determined by structural features) very little beam would be gained by making the vertical aperture more than 6 inches. It is also clear that under these conditions, i.e., using only the central part of the field where there is little variation in n, the beam is very well centered in the tank. This data is also displayed in Fig. 5 by the dashed lines.

In another experiment we compared the best beam at a 6 in. x 18 in. aperture with that at 5 1/4 x 19 1/8. The ratio was 20 to 9. This would, however, due to the smaller gap, increase the energy by about 1/2 Bev in the full scale machine.

All of the experiments on horizontal aperture were carried out by moving the inflector and the probe. The aperture is given as the distance from the center of the inflector exit to the tip of the probe. Actually this does not completely define the aperture and on one occasion both sets of horizontal defining vanes were brought up to where they just failed to attenuate the accelerated beam to see how much additional space was used. The results are given in Table I.

Table I

Inflector position	+ 8 5/8"	90° outer vane	+ 8 3/4	270° outer vane	+ 9 3/4
Probe position	- 10 1/4	90° inner vane	- 10 3/4	270° inner vane	- 10 3/4
Horizontal aperture	18 7/8"	Aperture	19 1/2	Aperture	20 1/2

Sensitivity to Controls. There are five chief operating controls which must always be checked to see that they remain at optimum setting. These are: inflector voltage, bias of the peaking transformer which operates on the magnet current and triggers the cyclotron, time of rf after injection, starting frequency of rf, slope of frequency vs. magnetic field curve. The sensitivity of the machine to the first four of these controls has been determined. This was done with a 9 in. x 26 in. aperture and before the change in inflector described in the second section was made. The machine was peaked up on all controls then the individual ones were changed in each direction to reduce the accelerated beam by a factor of two. For an inflector voltage nominally at 65 Kv the change was $\pm$ 1.5 percent. For the peaking transformer which triggered at 558 amperes the change was +0.27 percent or -0.22 percent. The change in rf on time was +0.2 or -0.15 ms out of 0.35 ms. The starting frequency change was $\pm$ .4 percent.

During the past month the operating group consisted of R. Clack, E. Lofgren, D. Nielson, R. Richter, R. Robertson, F. Schmidt, D. Sewell, R. Shankland, and W. Stephan.

Information Division
scb/9-29-49

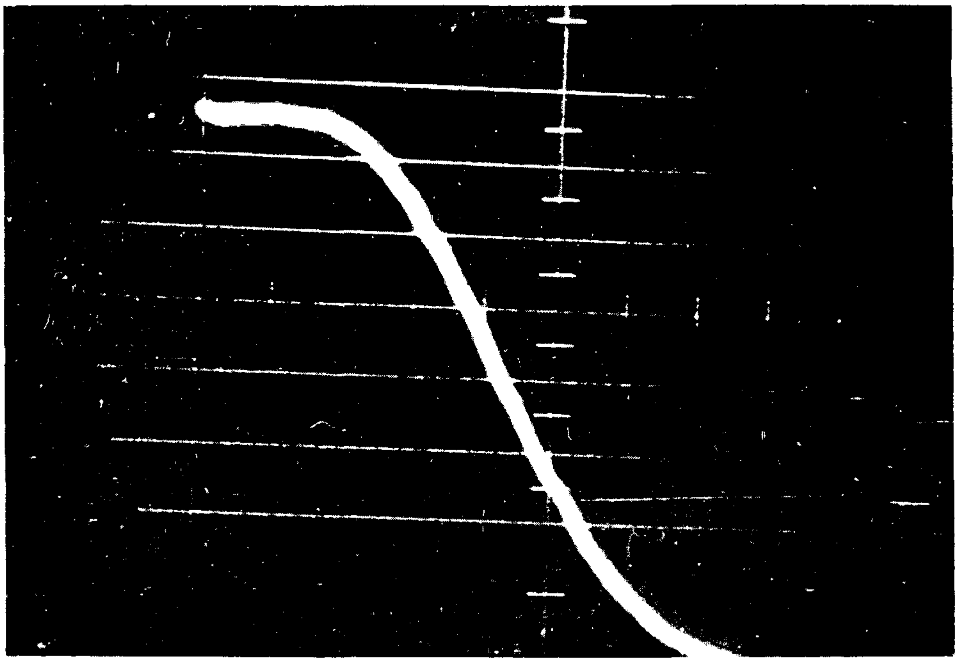

FIG. 1A

FREQUENCY ERROR, UNCORRECTED

VERTICAL: 4% OF STARTING FREQUENCY PER CM.

HORIZONTAL: 25 MILLISECONDS PER CM.

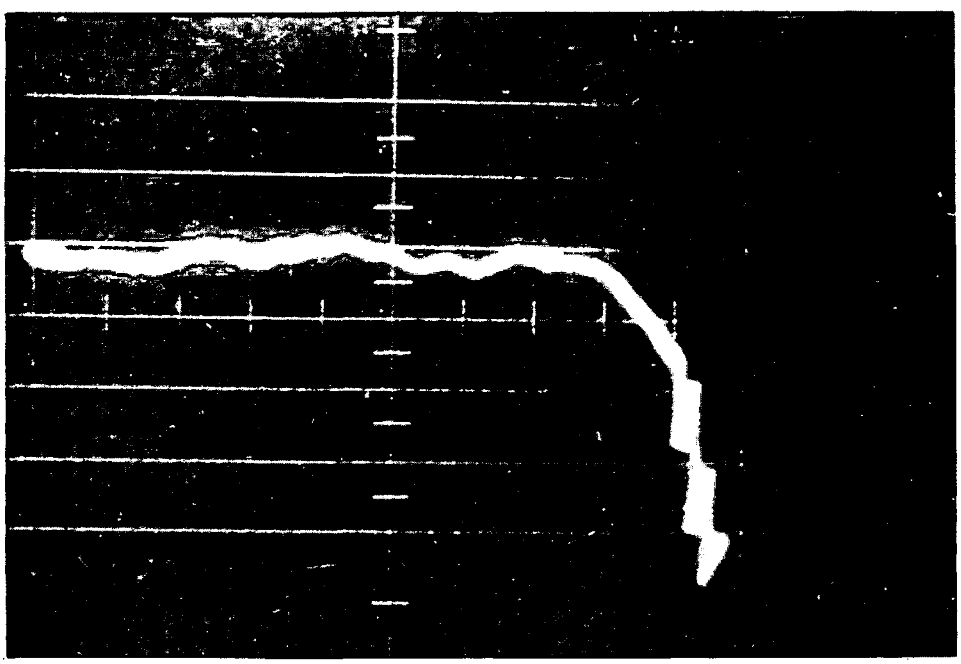

FIG. 1B

FREQUENCY ERROR, CORRECTED

SAME SCALE

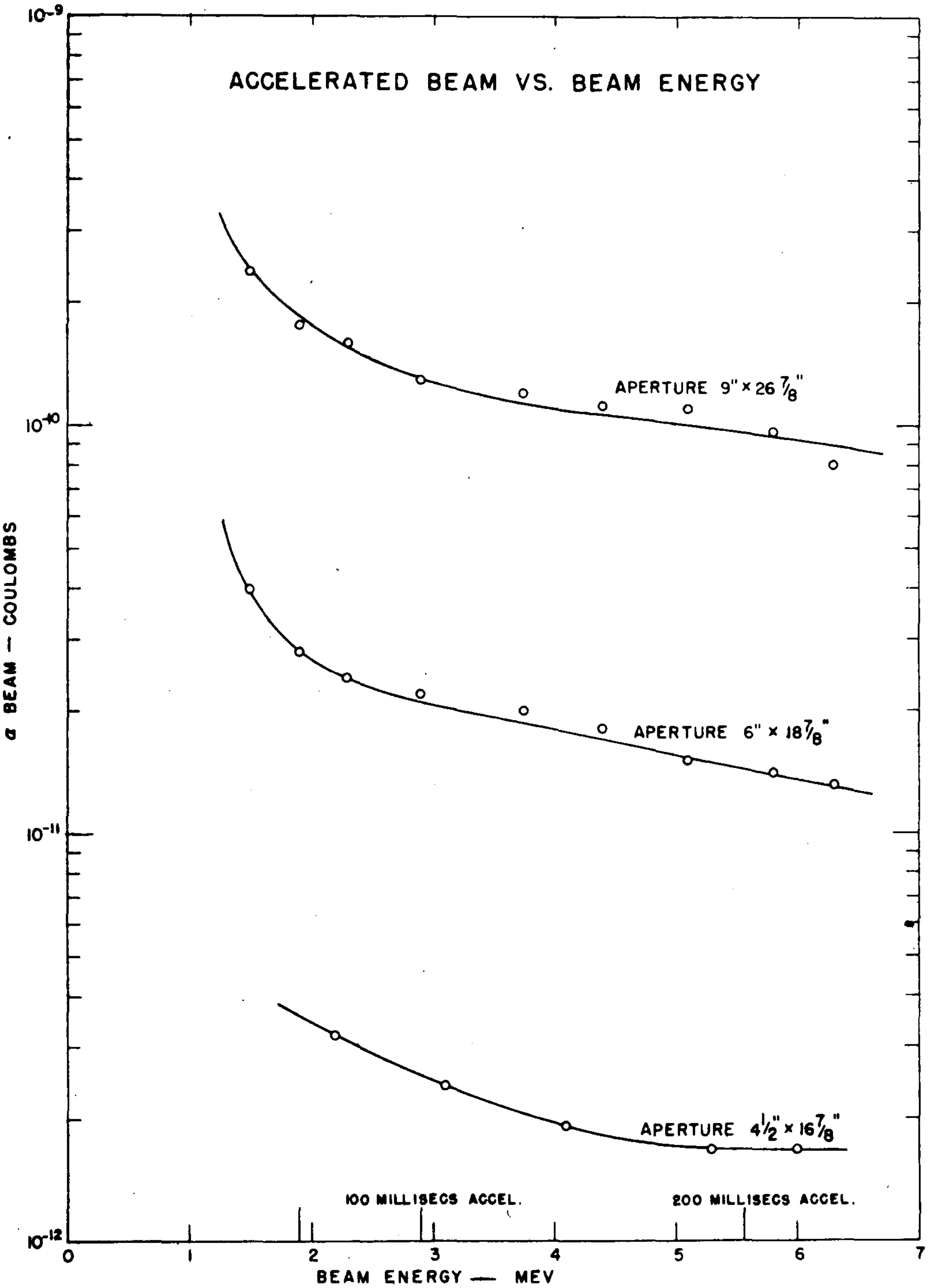
ACCELERATED BEAM VS. BEAM ENERGY
APERTURE 9" × 26 7/8"
APERTURE 6" × 18 7/8"
APERTURE 4 1/2" × 16 7/8"
100 MILLISECS ACCEL.
200 MILLISECS ACCEL.
α BEAM — COULOMBS
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
0
1
2
3
4
5
6
7
BEAM ENERGY — MEV

FIG. 2

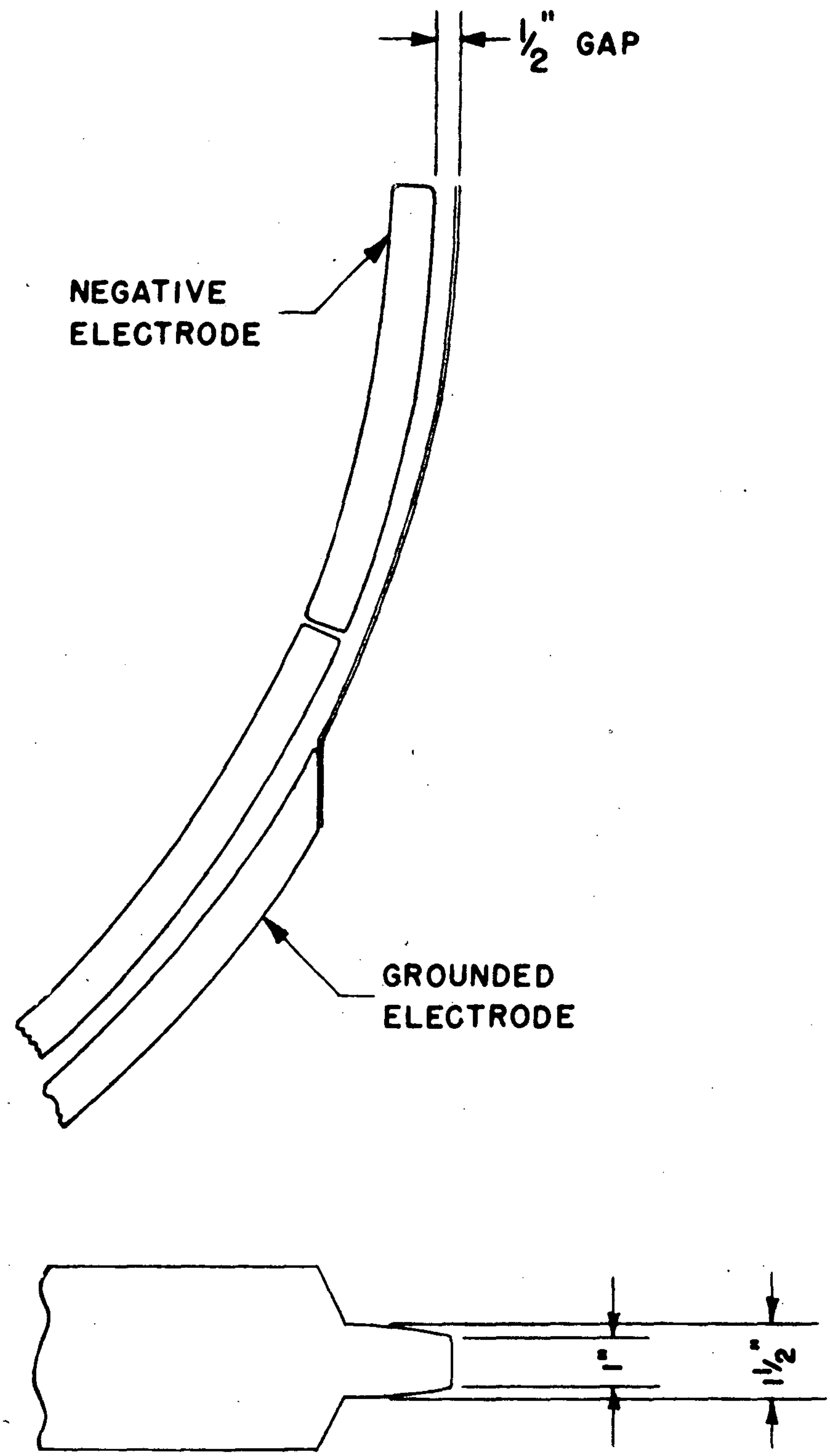

FIG. 3

PLOT SHOWING EFFECT OF PULSING OFF INFLECTOR AT VARIOUS TIMES DURING CYCLOTRON BEAM

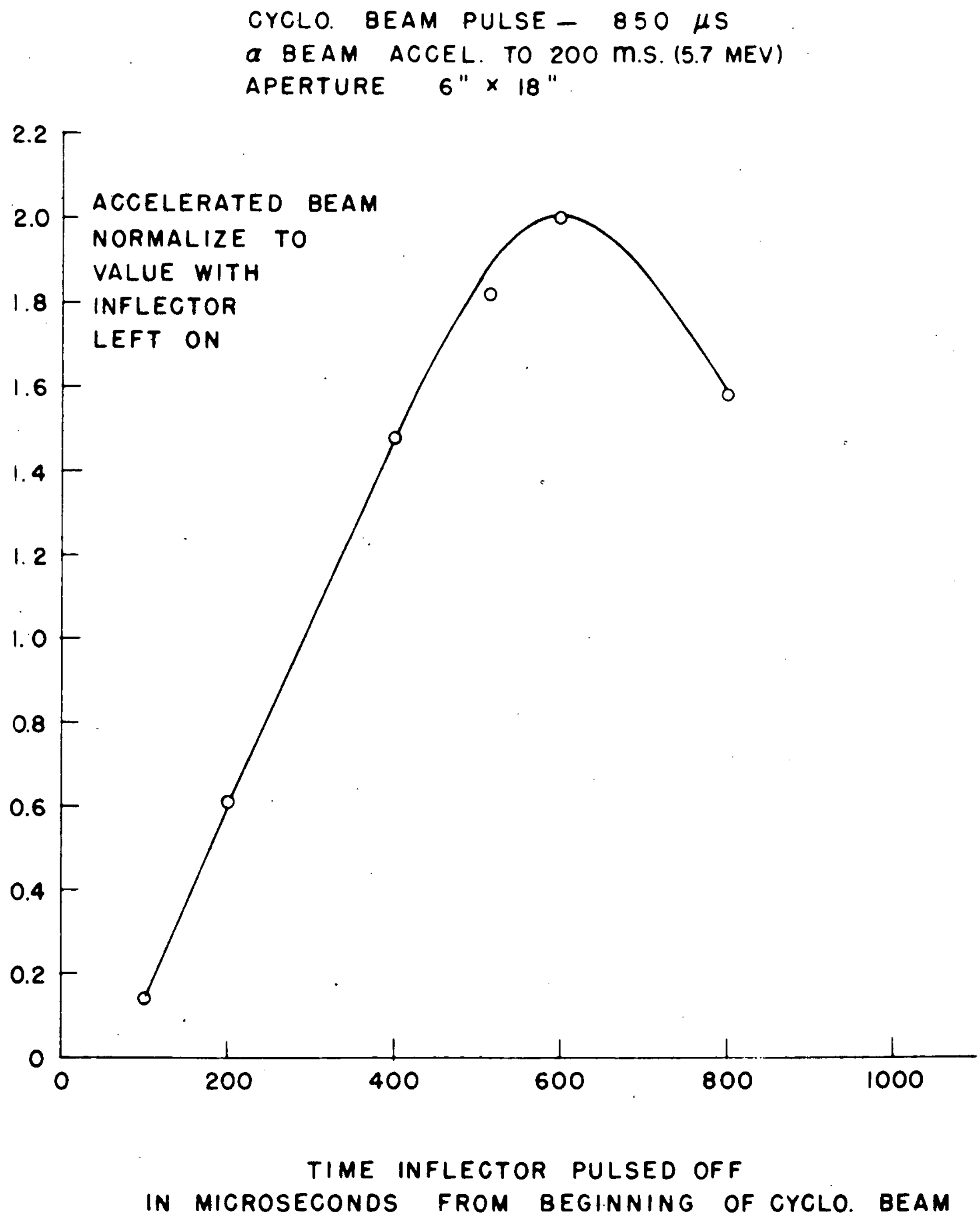

FIG. 4

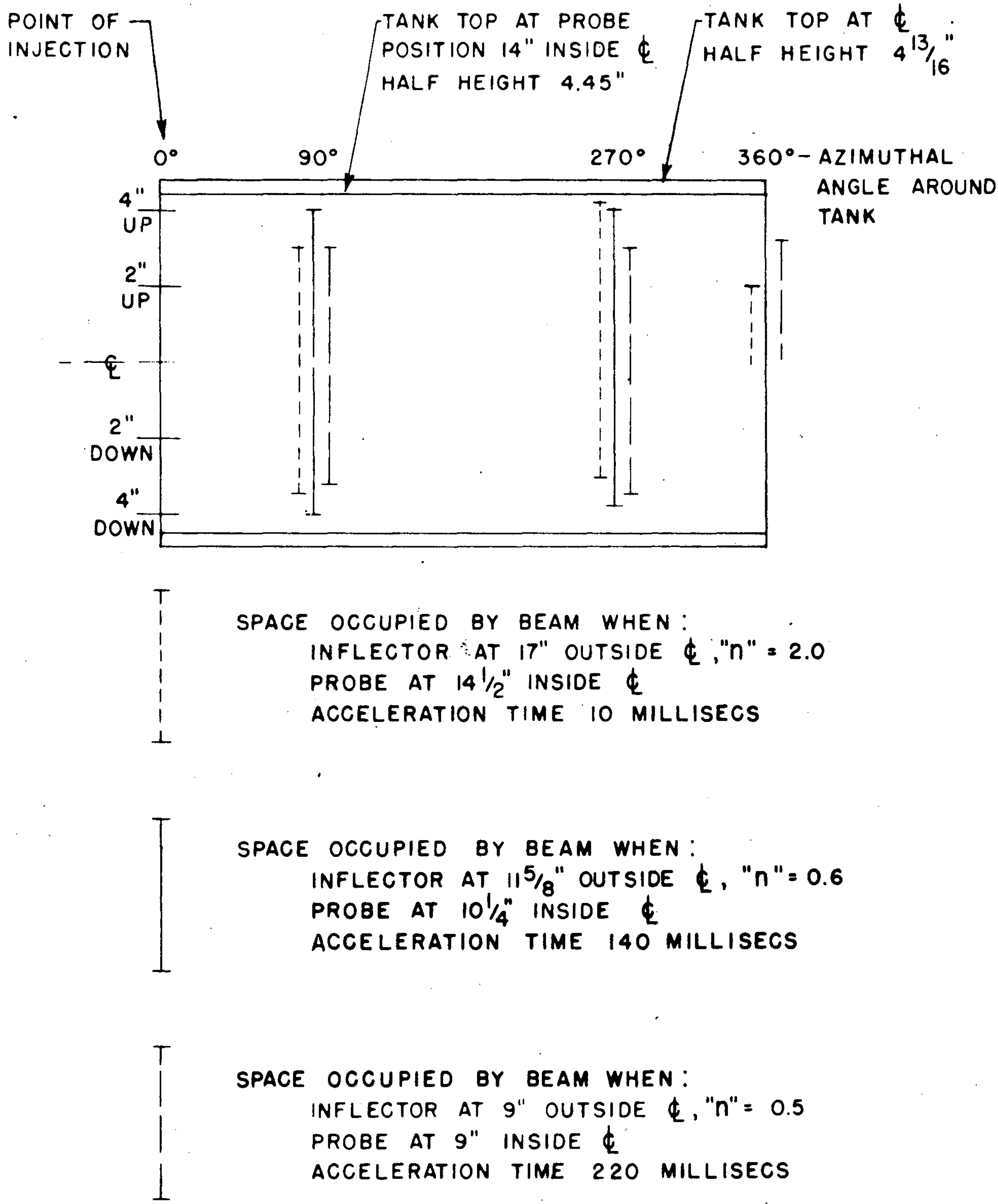
POINT OF INJECTION
TANK TOP AT PROBE POSITION 14" INSIDE ℄ HALF HEIGHT 4.45"
TANK TOP AT ℄ HALF HEIGHT 4 13/16"
0°
90°
270°
360° - AZIMUTHAL ANGLE AROUND TANK
4" UP
2" UP
℄
2" DOWN
4" DOWN
SPACE OCCUPIED BY BEAM WHEN:
INFLECTOR AT 17" OUTSIDE ℄, "n" = 2.0
PROBE AT 14 1/2" INSIDE ℄
ACCELERATION TIME 10 MILLISECS
SPACE OCCUPIED BY BEAM WHEN:
INFLECTOR AT 11 5/8" OUTSIDE ℄, "n" = 0.6
PROBE AT 10 1/4" INSIDE ℄
ACCELERATION TIME 140 MILLISECS
SPACE OCCUPIED BY BEAM WHEN:
INFLECTOR AT 9" OUTSIDE ℄, "n" = 0.5
PROBE AT 9" INSIDE ℄
ACCELERATION TIME 220 MILLISECS

FIG. 5

HALF APERTURE V.S. BEAM

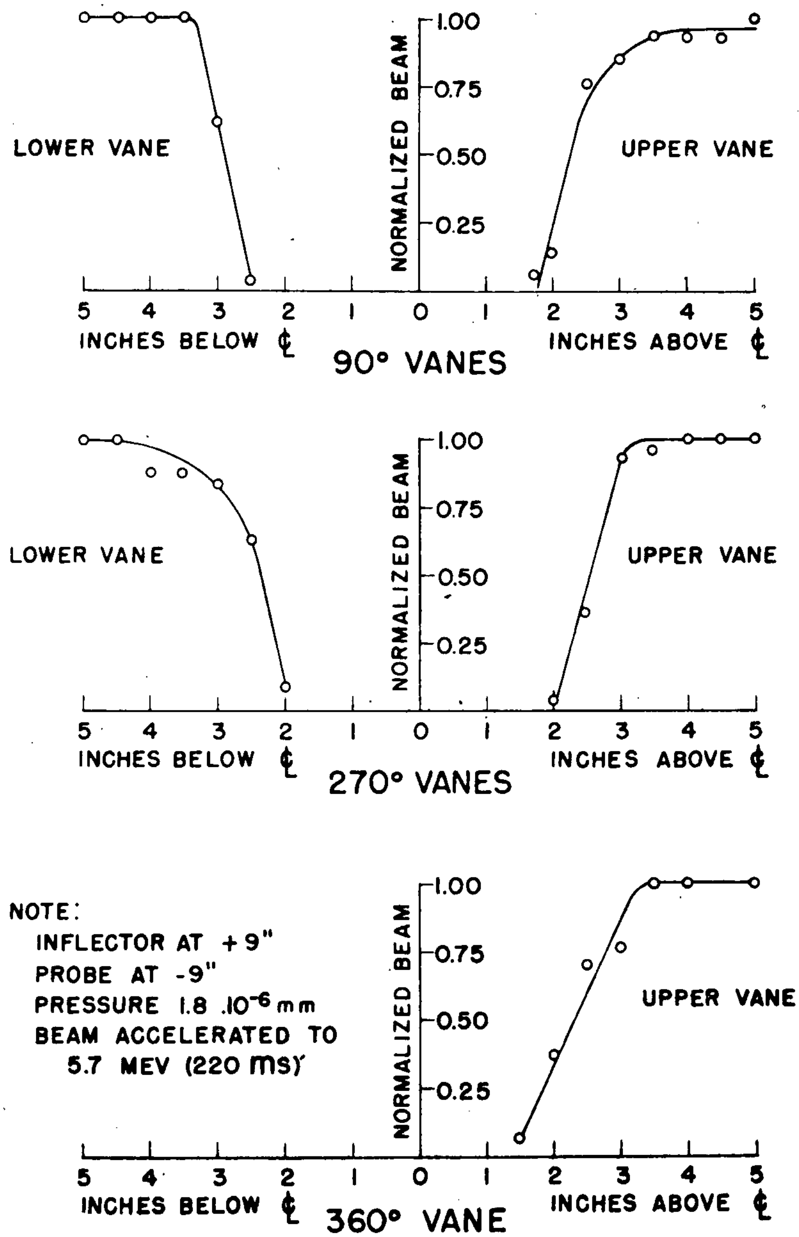

FIG. 6

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