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Operation of the 1/4 Scale Model Bevatron, II.

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OPERATION OF THE 1/4 SCALE MODEL BEVATRON, II

E. J. Lofgren

July 13, 1949

Berkeley, California

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This report is an outline of what has been learned on the 1/4 Scale Bevatron during June. The previous period was covered by UCRL-373. Up to the present substantial progress has been made in the study of pressure effects, injection, and tank aperture. There has also been improvement in the maximum beam and in the stability of some of the control circuits. On some important problems such as frequency tracking, no improvement has yet been made.

Beam Detection and Magnitude

All the beam currents given in this report were measured on electrical probes which were shielded except for the electrode exposed to the beam. The probes were not covered with foil. The voltage drop across resistors, 50,000 to 1,000,000 ohms, was passed through preamps and then to oscilloscopes. Usually no bias voltage was used. Beam current as a function of probe bias voltage is given in Fig. 1. This shows that our no bias values are about 40% too high, which is not important. In all experiments the largest beam pulses at each setting are recorded. Actually there is considerable jitter in the machine so that the best pulse may occur only once in 5 to 20 pulses. The largest accelerated beam has been $0.4 \cdot 10^{-6}$ amperes. The acceleration was to only 12 milliseconds.

Acceleration Time

If the largest beam pulses at optimum adjustment are plotted for various acceleration times a typical curve is as shown in Fig. 2. The rapid fall off of beam is due at least in part to a poor match of frequency with magnetic field. Temporarily this problem was by-passed by doing most experiments at short acceleration times. We are now taking steps to improve the frequency tracking.

Acceleration Voltage

Fig. 3 shows the variation of beam with r.f. voltage. The three lowest points are normalized with respect to the beam at 980 volts. The rate of change of magnetic field is about 3500 gauss per second and the accelerating electrode is 8.8 electrical degrees in length, giving 235 volts as the expected threshold.

Pressure Effects

The variation of beam with pressure has been investigated again with various acceleration times and vertical apertures. These data show a less rapid drop of beam with pressure than previously reported. The present values are probably more reliable since we were working with larger beams and used direct electrical measurement rather than an ionization chamber.

These curves are given in Fig. 4. As will be explained in the section on aperture the effective aperture when the tank is open is probably about 6 1/2 instead of 9 1/2. In each case the horizontal aperture was 31 inches.

On an occasion after the tank had been pumped on for 5 days and for the preceding 12 hours had no liquid air the average reading of ion gages in the four manifolds was $1.4 \cdot 10^{-6}$ mm. The room temperature was 70° c. One of the two 20 inch diffusion pumps on each straight section was then closed off and the average pressure increased to $2.5 \cdot 10^{-6}$ mm. Then both pumps on 3 sections were closed off and the 2 on the remaining north section were left open. Pressures were: North $4.3 \cdot 10^{-6}$, East $7.9 \cdot 10^{-6}$ West $5.9 \cdot 10^{-6}$, South $8.0 \cdot 10^{-6}$, all in mm. All pumps were then opened and two of the quadrant liquid air traps were filled. After two hours the average pressure was $1.0 \cdot 10^{-6}$ mm.

Injection

If the Bevatron is tuned up for an accelerated beam on an electrical probe and if the acceleration is short enough, 10-20 ms., so that detail can be seen at the time of injection as well as at the end of acceleration we have an oscilloscope picture as in Fig. 5. There is a large first turn signal, then about 3 ms later a betatron or β beam which is independent of the r.f., and after the end of the r.f. the accelerated or α beam. If the firing time of the cyclotron, which is determined by a peaking transformer working from the magnet current, is adjusted for maximum β beam with or without r.f. and if r.f. is turned on and the frequency slope is adjusted it will be found that the firing time is exactly or very nearly at the optimum time for accelerated beam. Under the best adjustment and for the highest beam pulses the height of the α beam is equal to the β beam with r.f. on or to 1/2 the β beam with r.f. off. The optimum timing for the r.f. on is so that it just overlaps the β beam. If the inflector is moved radially and the best beam at each point is observed we find a pronounced peak at about 17 inches outside the center of the tank with a smaller maximum at 12 inches from the centerline. This is shown on Fig. 6 together with values of the field exponent n. The peak is shown to occur at a radius of high and rapidly changing n. We have shown that there are different mechanisms of injection at the 17 inch peak and inside of 13 inches where n is a constant, about 0.6. If the inner grounded electrode of the inflector has a shield added so that it completely prevents any ions passing above or below the inflector then for injection at 17 inches there is no change in the beam. For injection at 13 inches there is only a trace of beam. This shows that in the former case the beam clears the inflector by rapidly spiraling inward. In the latter case most of the beam goes above and below the inflector.

There are single turns of wire spaced every 3 1/16 inches radially along the pole faces of the magnet. If a loop circuit is made of a wire 15 inches inside the center of the pole face and one 15 inches outside and a current passed through in the same direction as that in the main exciting coils, it is possible to increase the change in n with radius. We have found that passing 52 amperes D.C. through this single winding resulted in a fourfold increase of beam for injection at 17 inches. At the time of injection the main magnet current is about 500 amperes through 16 effective turns, hence this auxiliary field is about 0.8%.

The gap between the high voltage and the grounded inflector electrodes is normally 1 1/4". By blocking this off with a probe we have found that only ions traveling within 1/4 inch of inner (with respect to the Bevatron magnet) grounded electrode are effective. This was measured with low n injection and may not be true for high n injection.

Tank Aperture

By means of vanes the vertical half aperture can be reduced from the 4 3/4 inch nominal to any value down to zero from both above and below at azimuthal angles 90° and 270° and from above only at 360°, as measured from the point of injection. With these one can measure beam as a function of half aperture. Figs. 7a to 7e show that as measured at 90° and 270° little if any beam exists in the 1 1/2 inches of space next to the tank walls. These results are typical even if an effort is made to introduce large vertical oscillations by tilting the inflector. In that case there is simply a rapid decrease of beam. An explanation appeared when later a measurement was made at 360°. The knee in the curve there appears 1 1/2 inches lower than at the other points indicating that the plane of the orbits is tipped and the ions are hitting the bottom of the tank at 360° and the top at 180°. We shall later attempt to correct this. The effective vertical aperture with the vanes open is thus about 6 1/2 inches.

Another similar set of data is plotted in Fig. 8 to show more points at small apertures. It will be seen that 10% of the beam gets through a total vertical opening of 3 inches.

With injection from regions of large n it has not yet been possible to reduce horizontal aperture below about 24 inches without drastic loss of beam. See Fig. 6. With the inflector at 6 inches outside the tank center line where there is a loss by a factor of 2 to 4 compared with injection from large n, the probe on the inside of the tank can be moved towards center as shown in Fig. 9 giving 10% of the maximum beam even at 3 inches inside of center or a total horizontal aperture of 9 inches. This is for full vertical aperture, effectively about 6 1/2 inches. This of course is at small acceleration times, about 12 ms, and we must provide improved frequency tracking to reduce the tank width for long accelerations. Adjustment of the frequency becomes very difficult at this small radial aperture due to the jitter.

The operating group during this interval consisted of: W. Chupp, R. Clack, E. Lofgren, D. Nielsen, R. Richter, R. Robertson, D. Sewell, R. Shankland and W. Stephen. Operational help has been given by others, especially: W. Brobeck and G. Farley.

Information Division
7/18/49:hw

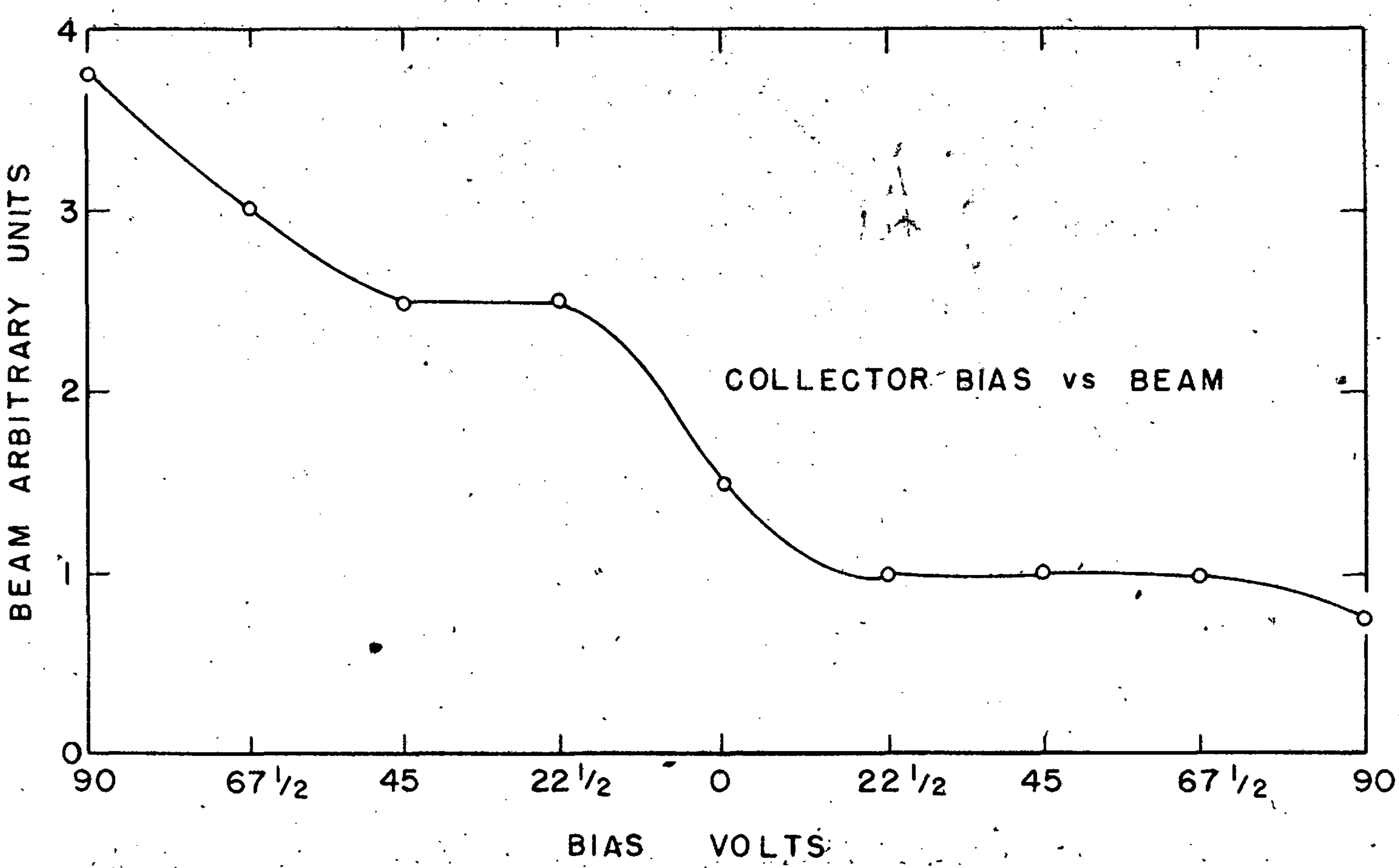

COLLECTOR BIAS vs BEAM
BEAM ARBITRARY UNITS
0
1
2
3
4
90
67 1/2
45
22 1/2
0
22 1/2
45
67 1/2
90
BIAS VOLTS

FIG. 1

13900-1

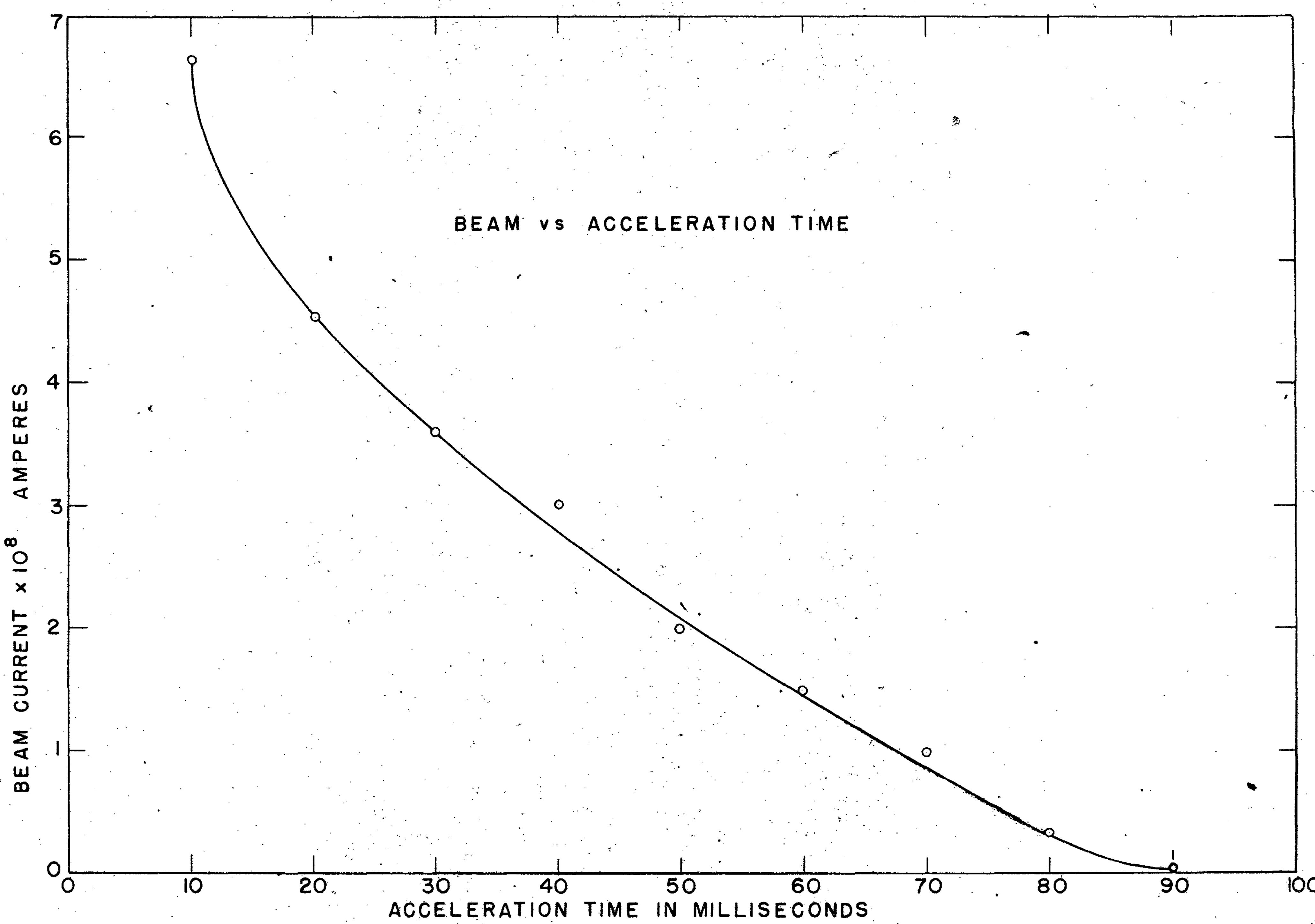

BEAM vs ACCELERATION TIME
BEAM CURRENT x 10^8 AMPERES
ACCELERATION TIME IN MILLISECONDS
0
1
2
3
4
5
6
7
10
20
30
40
50
60
70
80
90
100

FIG. 2

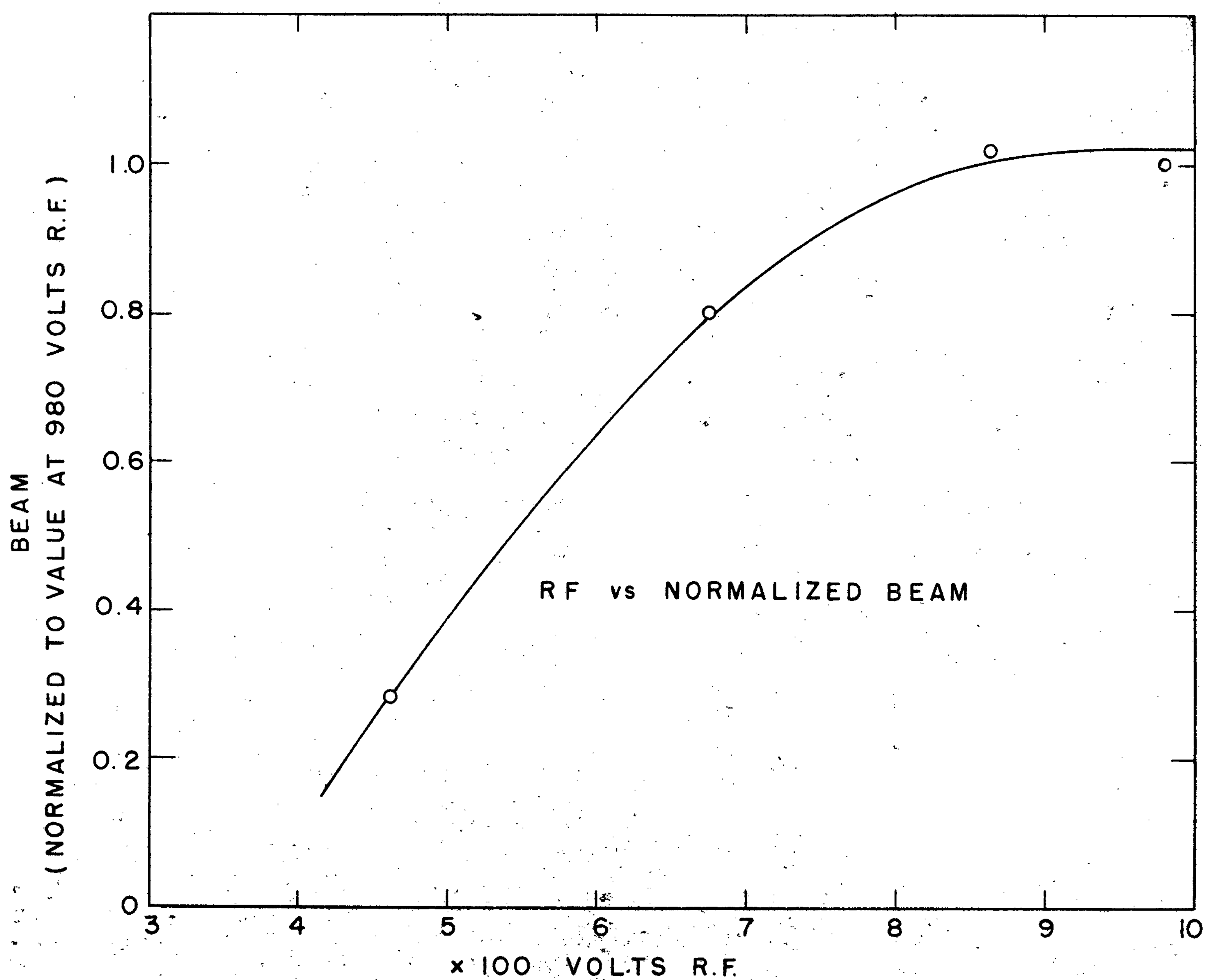
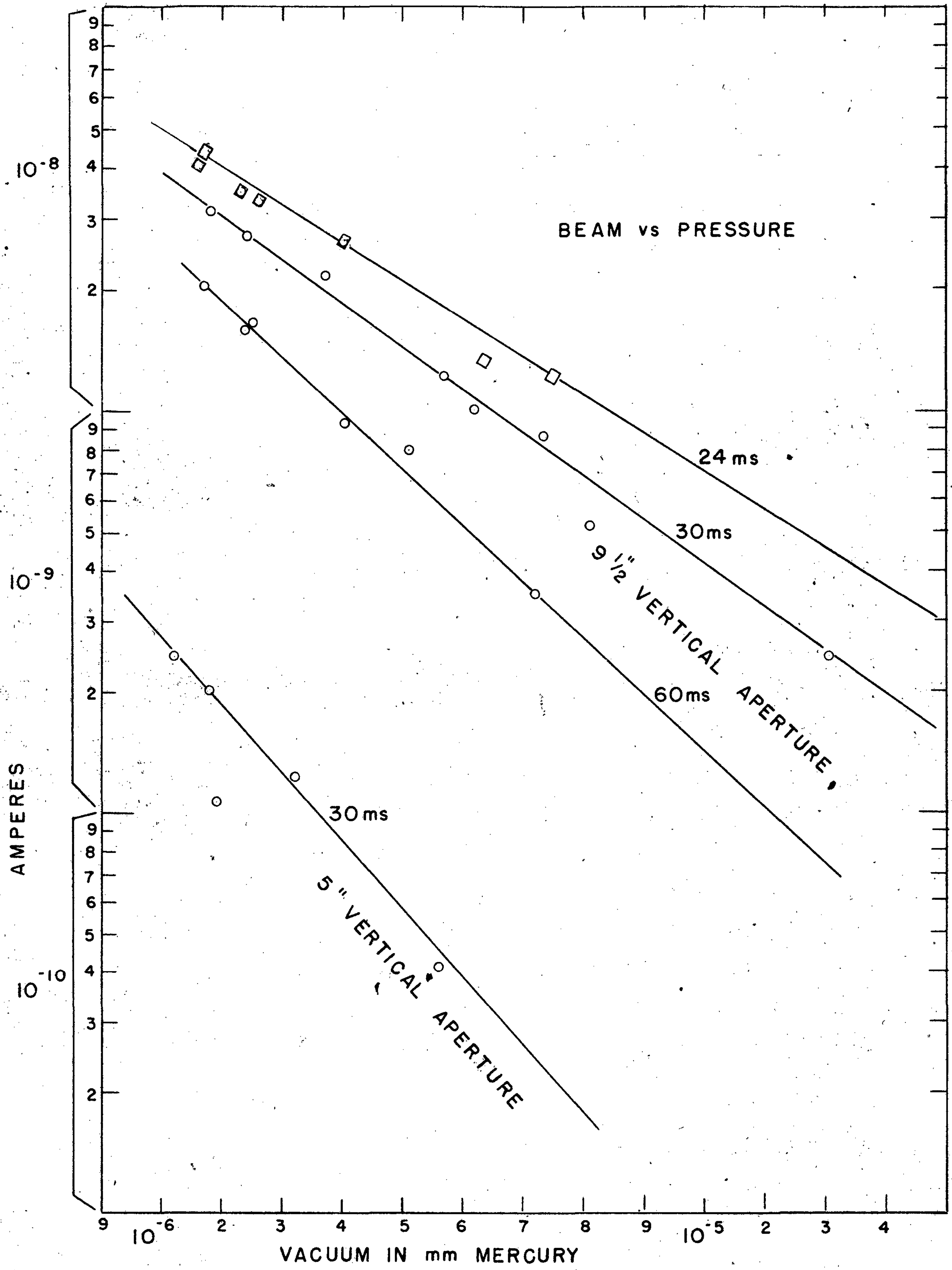

BEAM
(NORMALIZED TO VALUE AT 980 VOLTS R.F.)
1.0
0.8
0.6
0.4
0.2
0
3
4
5
6
7
8
9
10
RF vs NORMALIZED BEAM
x 100 VOLTS R.F.

FIG. 3

13902-1



BEAM vs PRESSURE
24 ms
30ms
60ms
9 1/2" VERTICAL APERTURE
30 ms
5 " VERTICAL APERTURE
AMPERES
10^{-8}
10^{-9}
10^{-10}
10^{-6}
10^{-5}
VACUUM IN mm MERCURY

FIG. 4

13903-1

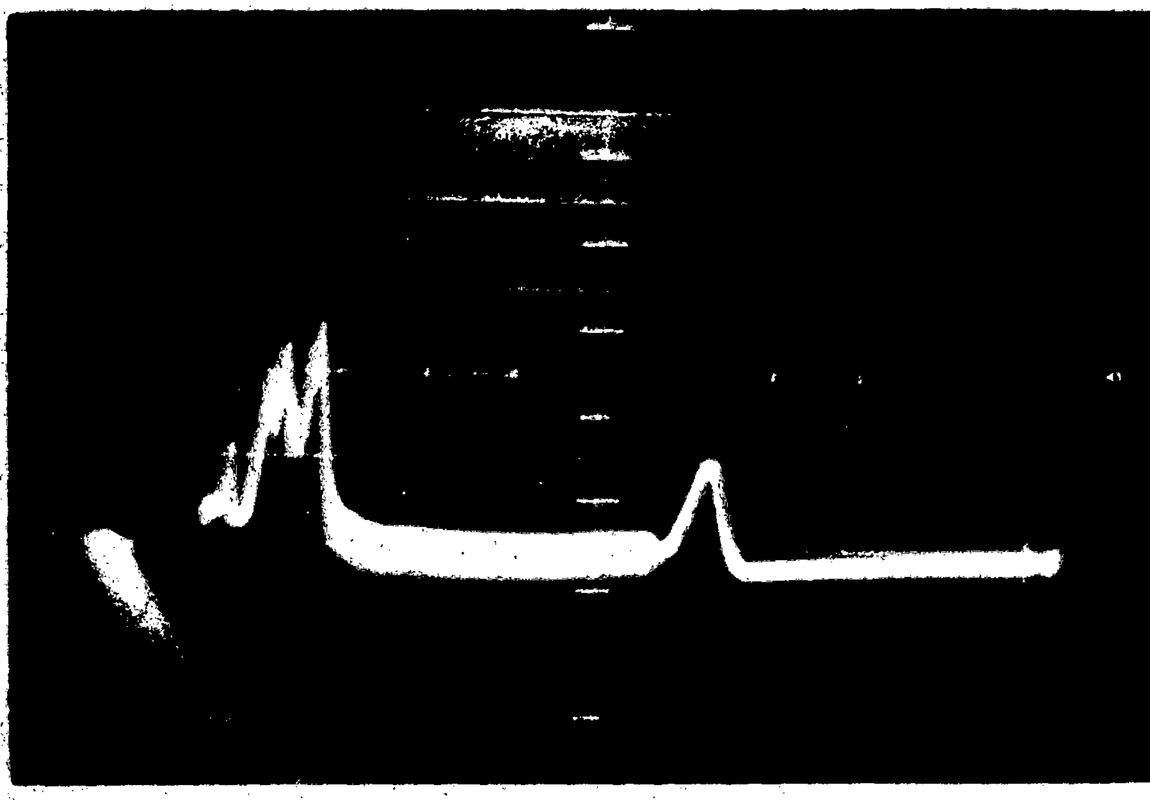


FIG. 5

OSCILLOSCOPE TRACE SHOWING FIRST TURN, β, & α BEAMS HORIZONTAL DIVISIONS ARE 2 MILLISECONDS, VERTICAL DIVISIONS ARE 0.8×10^{-7} AMPERES. THE r.f. IS SHOWN AS A THICKENING OF THE TRACE

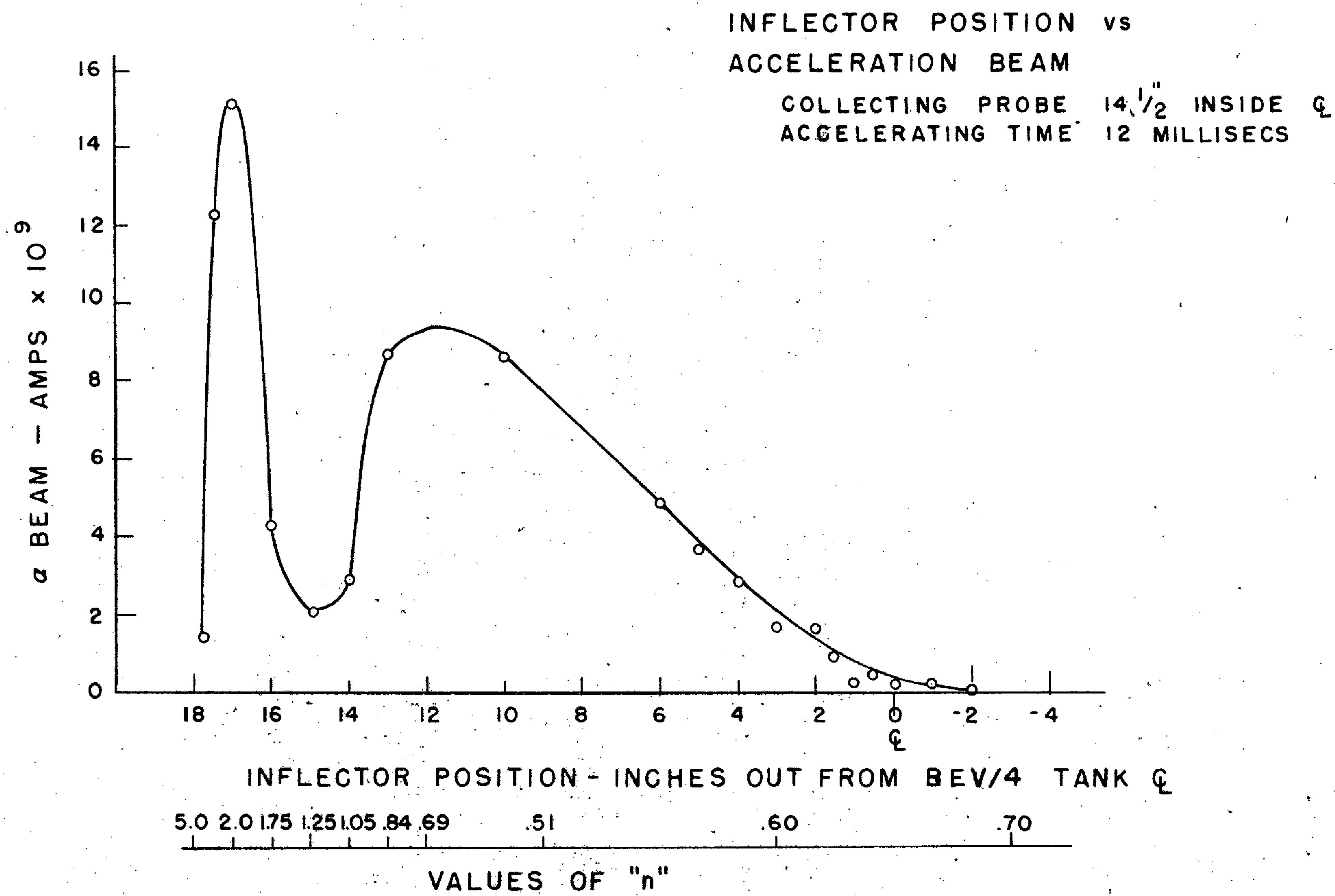

INFLECTOR POSITION vs
ACCELERATION BEAM
COLLECTING PROBE 14 1/2" INSIDE ℄
ACCELERATING TIME 12 MILLISECS
α BEAM — AMPS x 10^9
16
14
12
10
8
6
4
2
0
18
16
14
12
10
8
6
4
2
0
℄
-2
-4
INFLECTOR POSITION - INCHES OUT FROM BEV/4 TANK ℄
5.0 2.0 1.75 1.25 1.05 .84 .69
.51
.60
.70
VALUES OF "n"

FIG. 6

13904-1

HALF APERTURE vs BEAM

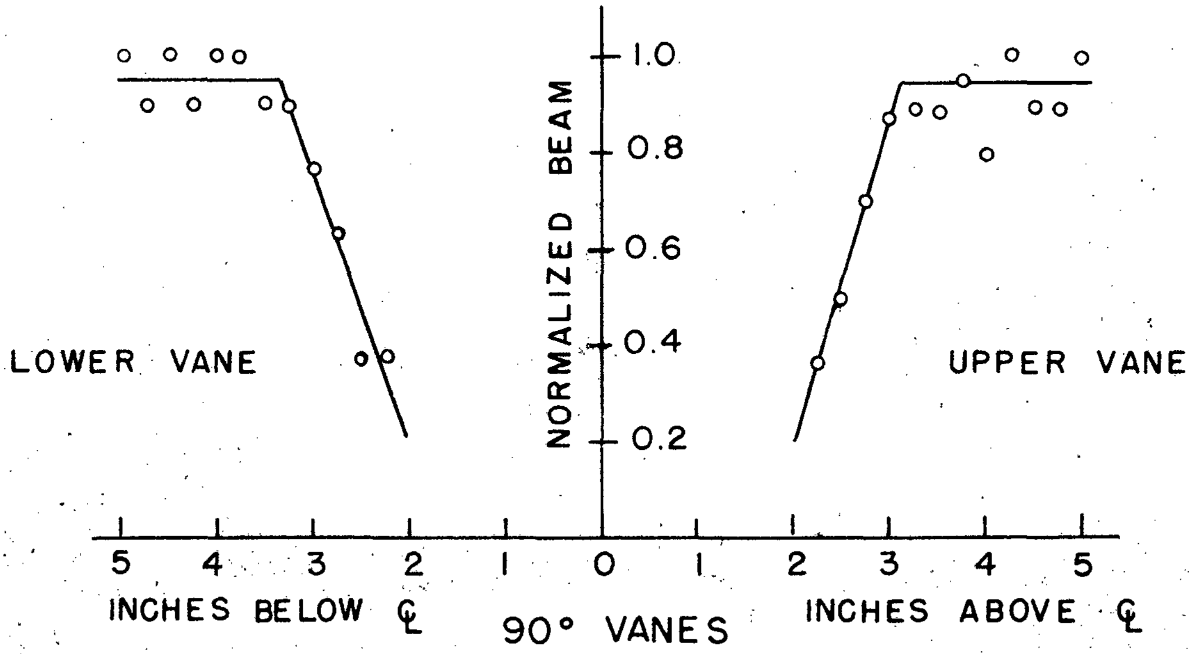


FIG. 7(a) FIG. 7(b)

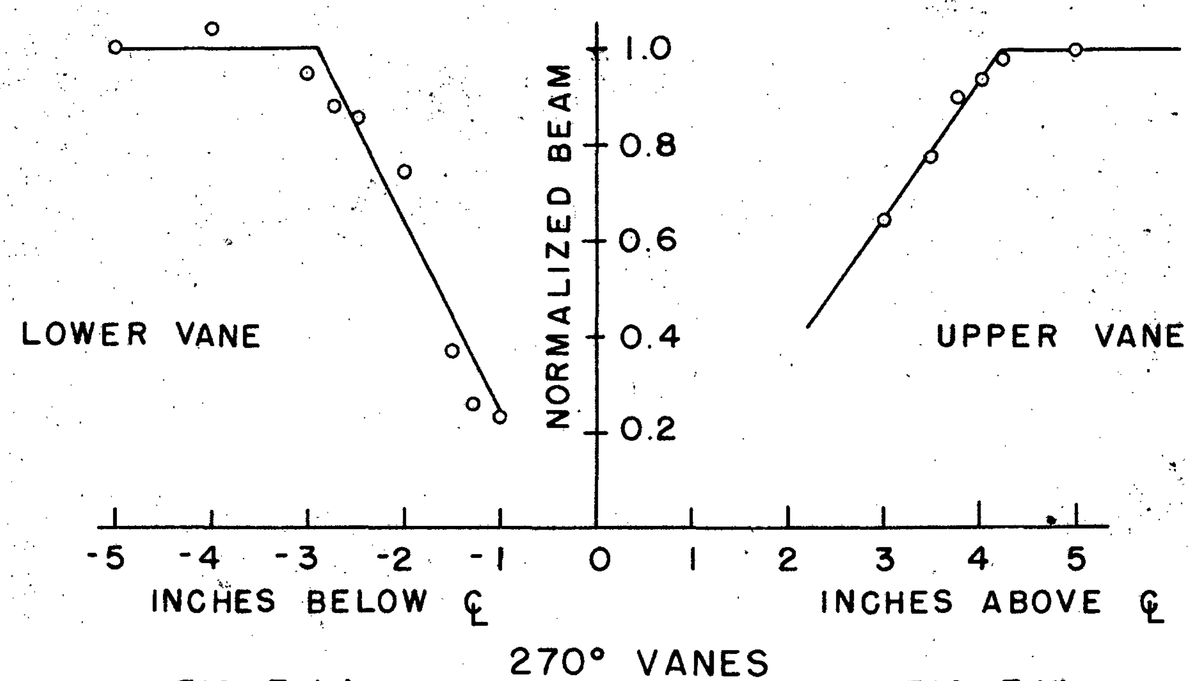


FIG. 7 (c) FIG. 7 (d)

HALF APERTURE vs BEAM

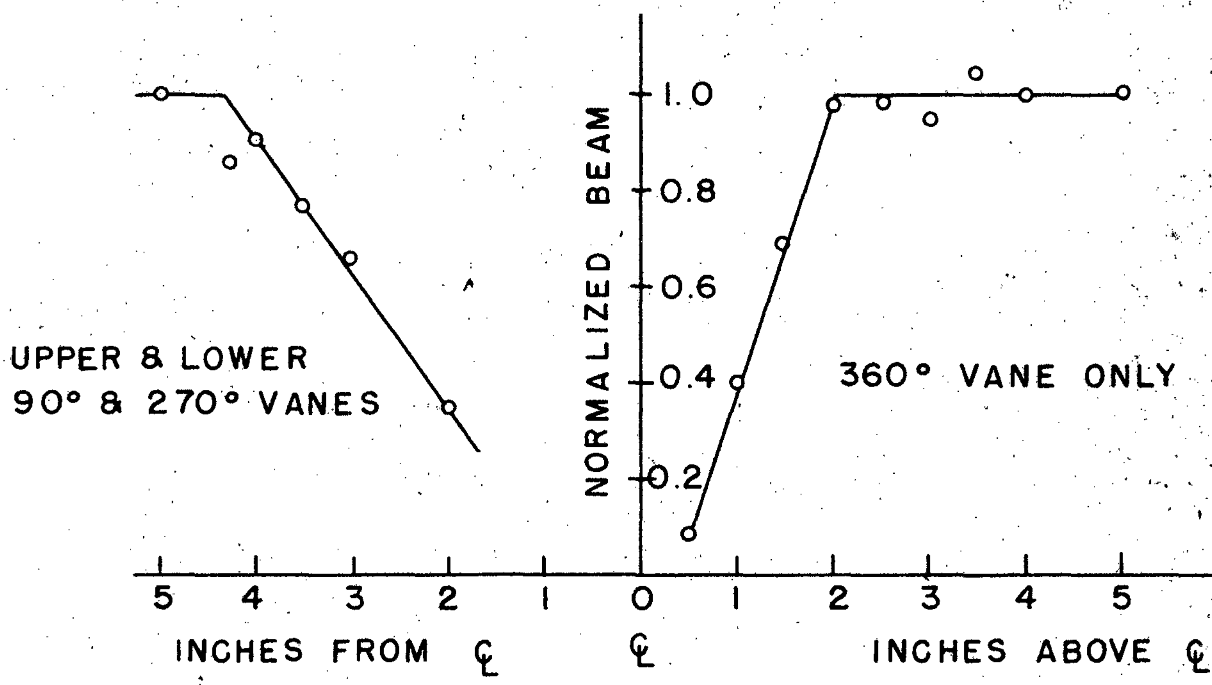
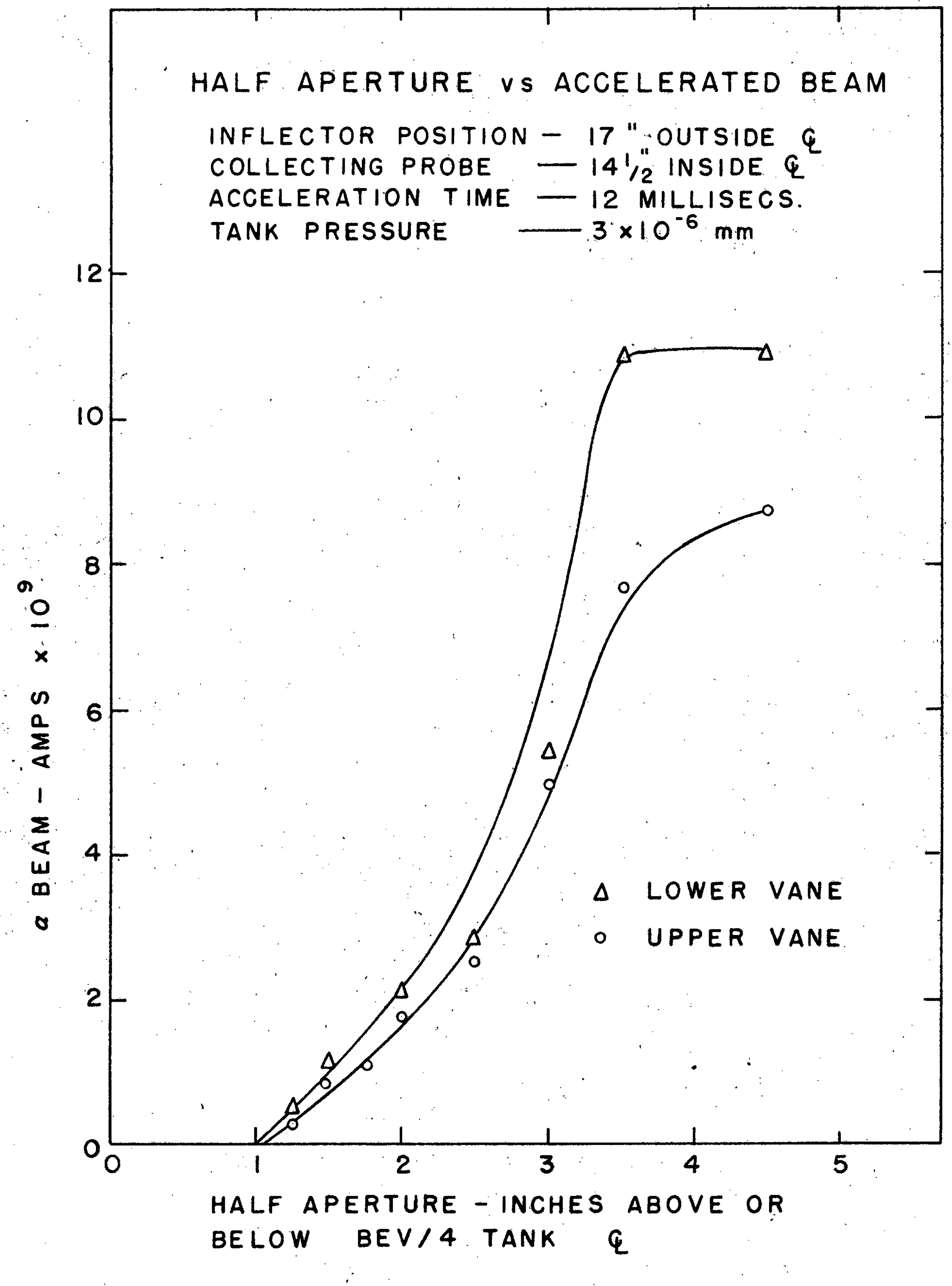


FIG. 7 (e)

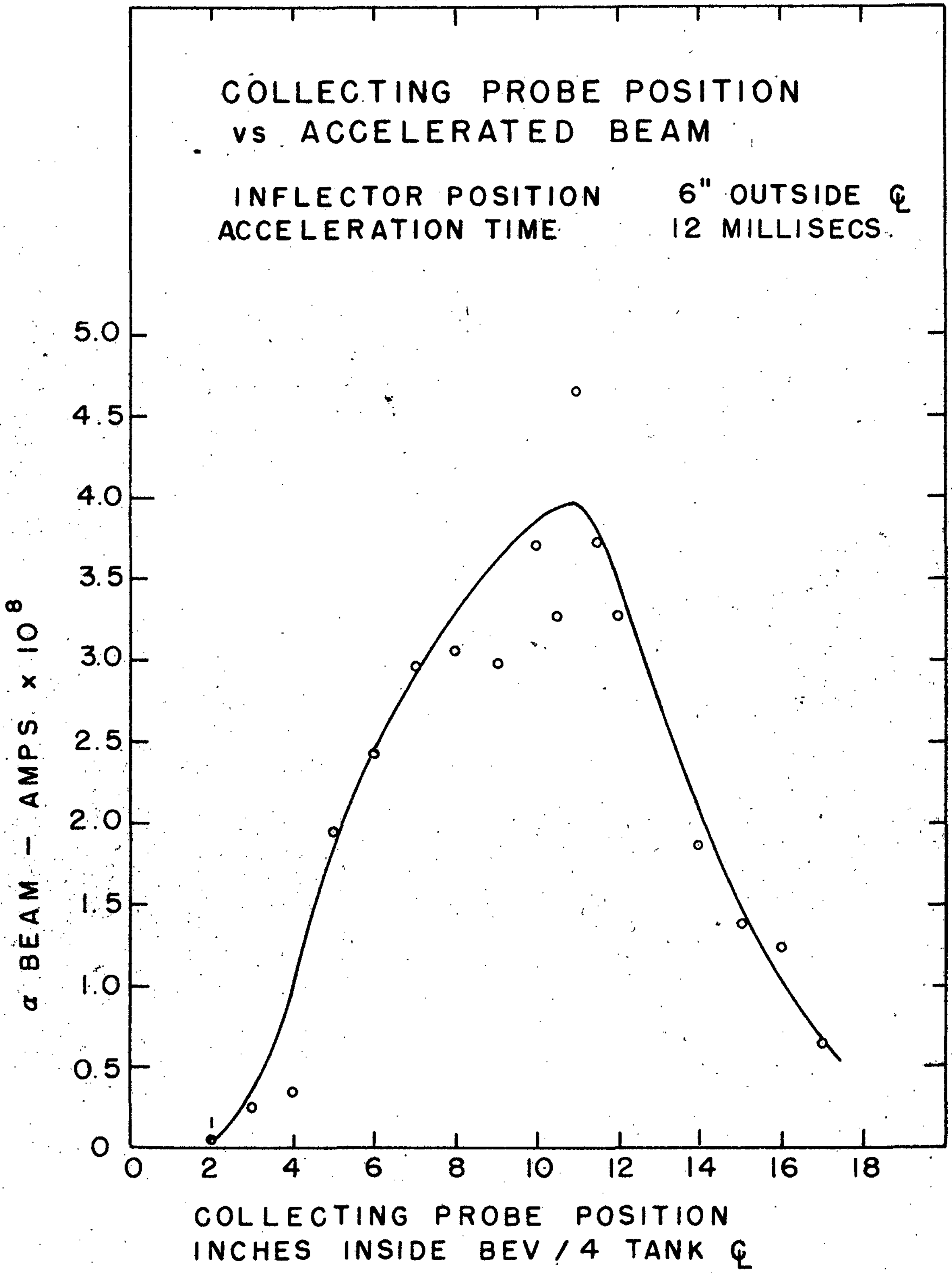
FIG. 7 (f)



HALF APERTURE vs ACCELERATED BEAM
INFLECTOR POSITION — 17" OUTSIDE ℄
COLLECTING PROBE — 14 1/2" INSIDE ℄
ACCELERATION TIME — 12 MILLISECS.
TANK PRESSURE — 3 x 10⁻⁶ mm
α BEAM — AMPS x 10⁹
Δ LOWER VANE
○ UPPER VANE
HALF APERTURE - INCHES ABOVE OR BELOW BEV/4 TANK ℄

FIG. 8

13907-1



COLLECTING PROBE POSITION
vs ACCELERATED BEAM
INFLECTOR POSITION 6" OUTSIDE ℄
ACCELERATION TIME 12 MILLISECS.
α BEAM — AMPS x 10^8
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
0
2
4
6
8
10
12
14
16
18
COLLECTING PROBE POSITION
INCHES INSIDE BEV/4 TANK ℄

FIG. 9

13908 - 1