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SLAC HIGH POWER QUANTAMETER

INTRODUCTION

We have built a non-saturating quantameter for use with the full SLAC photon beam (maximum intensity obtained so far is several KW) and SLAC electron beams up to levels of about 10KW. The quantameter is fully evacuated and utilizes secondary emission to sample the shower produced by the beam in the 1/2-inch thick copper plates of the quantameter (thus the name secondary emission quantameter or SEQ).[1] As in a gas quantameter an SEQ responds to the total energy in the beam. However, the SEQ is free of saturation effects observed in a gas quantameter at higher intensities due to recombination. Since the duty cycle at a linac is about 1000 times worse than at a synchrotron, these effects will set in at correspondingly lower intensities with a linac. Thus, the gas quantameter used widely at electron synchrotrons is useful with only very weak beams at SLAC. The maximum operating power level of the SEQ is set by the heat dispersion of the copper plates. At about 10KW the plates get very hot in the center and may crack due to thermal stress. The useful area of the quantameter is a square about 8" × 8". The quantameter has been used extensively in a ρ^o photoproduction experiment to monitor the SLAC photon beam and appears reliable to the fractional percent level.

CONSTRUCTION

Fig. 1 shows a simplified drawing of the quantameter. Omitted in the drawing are the cooling tubes and manifolds, the vacuum pump and

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the support structure. The support structure and the lifting lugs are mounted from the heavy stainless steel plate in the rear. The large seal to the vacuum enclosure is made by welding together the thin stainless steel collars. This omits the need for a large expensive seal but allows one to remove the vacuum cover if necessary. Since no organic materials are used, the quantameter is bakeable.

The quantameter is composed of 20 one-half inch thick copper plates alternated with 19 foils of 1/2 mil aluminum gold plated. The square plates and foils are assembled so that any single plate or foil can be removed without disturbing the others. The copper plates are water cooled and run at high voltage. The thin foils act as collectors and are connected to an integrator so they run very nearly at ground potential. The support structure for the plates and foils forms a ground plane and avoids leakage between the collector foils and the H.V. plates.

The thin foils abosrob 0.04% of the shower (4 watts at 10KW). This heat is conducted from the foils to the support frame and then through a 3/4 inch diameter solid copper feed through to the outside of the vacuum enclosure. There the heat is dissipated by an aluminum finned heat exchanger. A temperature rise of 50 to 100°C will cause the foils to bow sufficiently to touch the copper plates and short the HV on them. Thus it is important that the primary beam is not allowed to hit the frame holding the thin foils because of its limited heat dissipation capability. An electrostatic shield on the heat exchanger reduces the effects of the ionization in the air.

Table I shows the calculated percentage of the beam deposited in each copper plate by a 1-GeV and by a 20-GeV beam. The water cooling is increased for the plates near shower maximum.

The whole assembly is sealed, baked, and pumped with an eight liter ion pump. Within 24 hours of starting the evacuation and baking procedure a vacuum of 3×10^{-7} Torr was obtained with the ion pump. After several weeks the vacuum reached 1×10^{-8} Torr. We monitored the vacuum continuously in the SEQ during an experiment and found with a 1KW incident photon beam the vacuum would rise to 4 or 5×10^{-8} Torr.

RESPONSE OF SEQ TO ELECTRONS AND PHOTONS

First consider the response of the SEQ to electrons. Consider N electrons of energy E incident on the quantameter. The charge collected by the collecting foils is

$$Q = bNq \pm M_{\pm} NEq$$

Where q equals the charge on the electron and NE equals the total energy, U_e, in the beam. Thus, we can write

$$Q = bNq \pm M_{\pm} U_e q \qquad \ldots(1)$$

The first term represents that fraction of the charge in the incident beam collected by the foils (for a photon beam b is zero). For an electron beam b should be very closely 1/3000 (the ratio of mass in the thin foils to that of the thick plates). $M_{\pm}$ is the quantameter constant. The $\pm$ refers to the sign of high voltage applied to the thick plates. $M_{\pm}$ will depend on the sign of the HV in that for negative HV copper is the emitting surface and for positive HV gold is the emitting surface.

Note b will be opposite in sign for a positron beam incident. Since $M_{\pm} \sim 2$ electrons/GeV and for use at SLAC U_e is 3 to 20 GeV, the first term in (1) contributes less than 0.1% of the total charge collected by the SEQ. Thus the difference in the response of the SEQ to electrons and positrons is negligible.

For photons since b is zero, we have

$$Q = \pm M_{\pm} NEtq \qquad \ldots(2)$$

where $M_{\pm}$ should be the same as that for electrons, E is the energy of the electrons making the photon beam and t is the radiator thickness used to produce the photon beam. For a thick radiator we have a correction to Eq. 2,

$$Q = \pm M_{\pm} NEtq\, f(t), \quad \underset{t \to 0}{f(t) \to 1} \qquad \ldots(3)$$

assuming 100% of photon beam strikes SEQ. f(t) is near one and is of interest only if one tries to calibrate the SEQ with an electron beam and known radiator thickness. This can only be done if 100% of the Bremsstrahlung beam can be made to hit the SEQ. f(t) is easy to determine from the known Bremsstrahlung spectra. For photons we have therefore

$$Q = \pm M_{\pm} U_{\gamma} q$$

where U_{γ} is the total energy in the photon beam and is equal to NEt f(t).

We have calibrated the SEQ by comparing it to the SLAC silver calorimeter over a period of two weeks during an experiment using the SLAC Cerenkov photon beam monitor as an intermediate standard. Table II shows the results of these measurements. The average of all the measurements is $M_- = 2.07$ electrons/GeV. No appreciable energy dependence of the measurements was observed. However, the calorimeter and the SEQ both are expected to have losses due to their finite size of about 1% at higher energies so a slight energy dependence of the SEQ may not be noticed in the comparison. The value we obtained for M_+ from several measurements was 2.92 electrons/GeV. Since gold is the emitting surface with positive HV, there is a chance the SEQ is more reproducible when used in this mode.

During this period we have repeated many times counting rates in the counters of the SLAC 1.6 GeV/c spectrometer relative to the SEQ and have found them reproducible to their statistical accuracy of 1% or better. Also under stable beam conditions we found the SEQ and the photon beam Cerenkov monitor tracked to the 0.5% level.

Fig. 3 shows the change of response of the SEQ with HV. A change of HV from 500 to 1000 volts makes only a 1% change in the response of the SEQ. Fig. 4 shows the horizontal position dependence of the SEQ to the beam. With a 1-inch wide photon beam the response of the SEQ is flat to 1% over a distance of about 5-inches.

CONCLUSIONS

The SEQ described here is capable of monitoring the high power photon beam at SLAC on the 1% level in a reliable and convenient way. The SEQ responds to the total power in the beam independent of the peak photon energy. The response of the device is not sensitive to HV, beam position or beam intensity. Its calibration depends on a comparison with some other absolute standard such as a Faraday cup or calorimeter. Its calibration may change in time, so it must be recalibrated from time to time. However during the course of a two weeks of continuous use no change was noticed. Although it has operated so far at a maximum beam power of 2-3 KW, it is designed for use up to 10KW.

ACKNOWLEDGEMENTS

It is a pleasure to thank Dick Messimer who supervised the construction and helped in the design and John Grant and Nelson Hower who helped assemble and put the SEQ into operation. I would like to thank Ed Garwin for some useful conversations concerning the construction of the SEQ. Also, I would like to thank Jud Jurow for doing a calculation to estimate the temperature rise in the cooling water and the subsequent temperature rise in the copper plates themselves.

FOOTNOTES AND REFERENCES

*Work supported by the U.S. Atomic Energy Commission.

1. H. Fischer and C. Schaerf, Rev. Sci. Instr. 35, 615 (1964).

TABLE I

PLATE	1-BeV	20-BeV	WATER CKT
1	1½%	0.3%	1
2	7	2	1
3	14	4	1
4	16	8	1
5	15	10	2
6	12	14	2
7	8	16	2
8	5	14	3
9	4	10	3
10	3	8	3
11	2½	6	4
12	2	4	4
13	1½	3	4
14	1	2	4
15		1	4
16		0.8	4
17		0.5	4
18		0.3	4
19		0.2	4
20		0.1	4

TABLE II

RUN	E_o	POWER LEVEL	J/SEQ (Joules/coul)
2664	14.5	1.1KW	4.830×10^8
2666	14.5	0.063	4.825
2743	13.0		5.180
2777	13.0		4.825
2796	6.5	0.10	4.858
3031	5.5	0.150	4.839
3156	17.8	1.10	4.793
3285	16.0	0.80	4.785
3397	11.5		4.836

Average(excluding run 2743) . . . . 4.821×10^8 or

$$M- = 2.07\left(\frac{\text{electrons}}{\text{BeV}}\right)$$

Mean deviation 0.4%

FIGURE CAPTIONS

Figure 1 - Simplified drawing of the SEQ, omitted are cooling tubes and manifolds, the vacuum pump and the support structure.

Figure 2 - Change in response of the SEQ with HV.

Figure 3 - Variation of response of SEQ with position of beam.

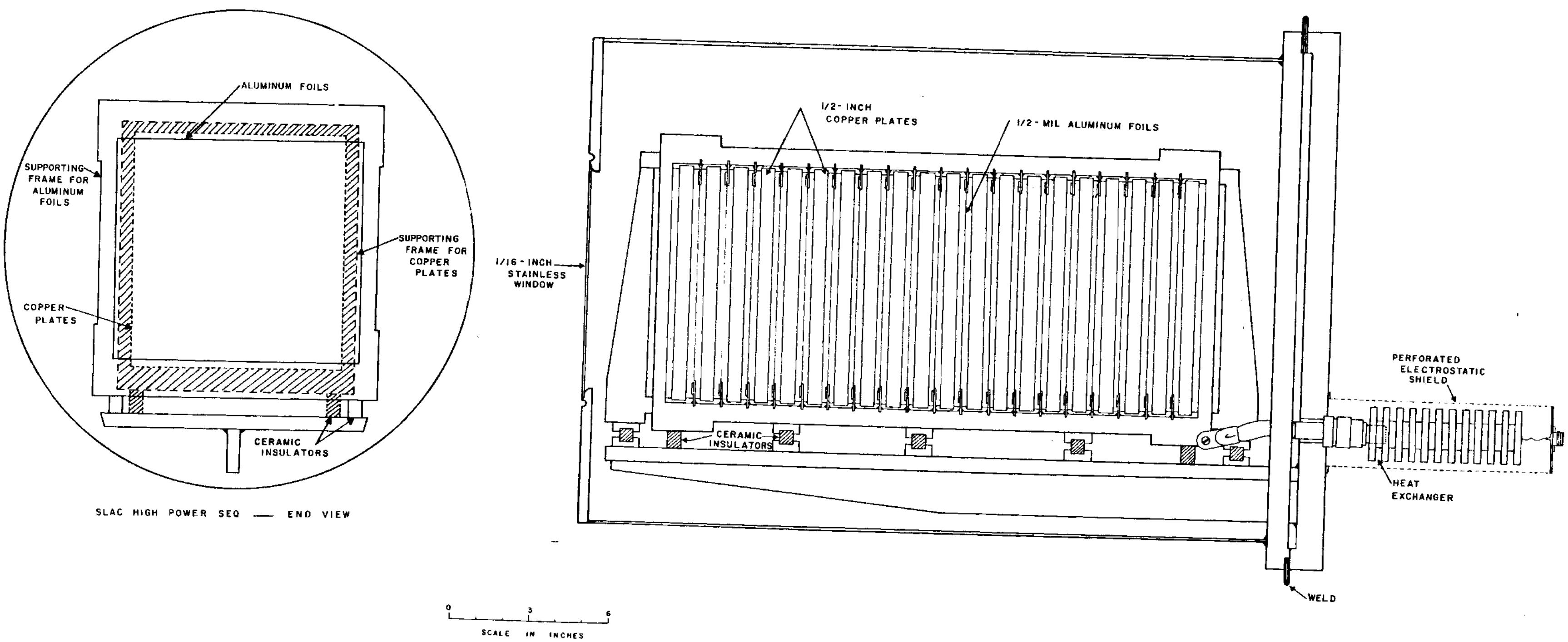

ALUMINUM FOILS
SUPPORTING FRAME FOR ALUMINUM FOILS
SUPPORTING FRAME FOR COPPER PLATES
COPPER PLATES
CERAMIC INSULATORS
SLAC HIGH POWER SEQ — END VIEW
1/2- INCH COPPER PLATES
1/2- MIL ALUMINUM FOILS
1/16 - INCH STAINLESS WINDOW
CERAMIC INSULATORS
PERFORATED ELECTROSTATIC SHIELD
HEAT EXCHANGER
WELD
0
3
6
SCALE IN INCHES

Fig. 1

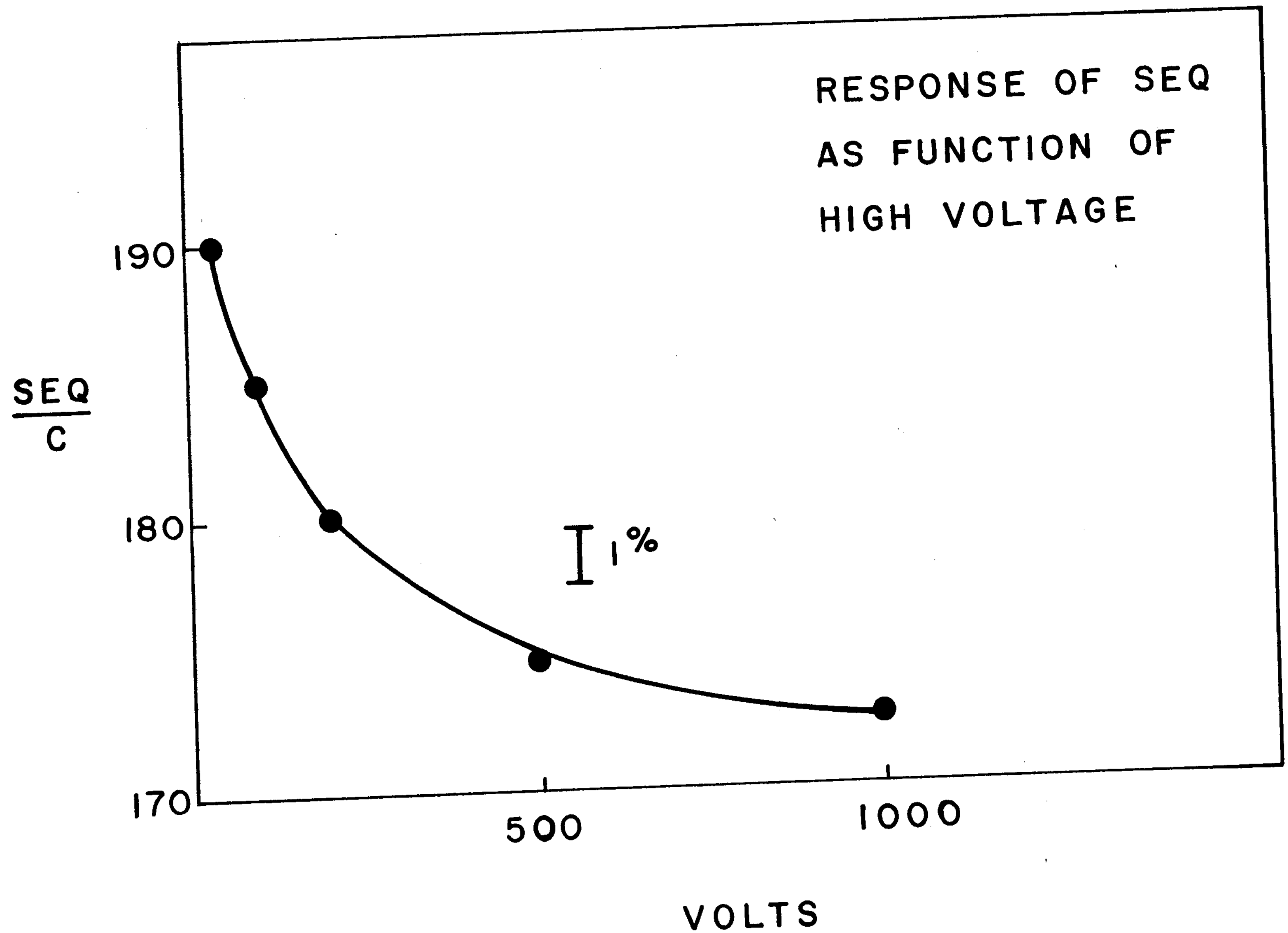
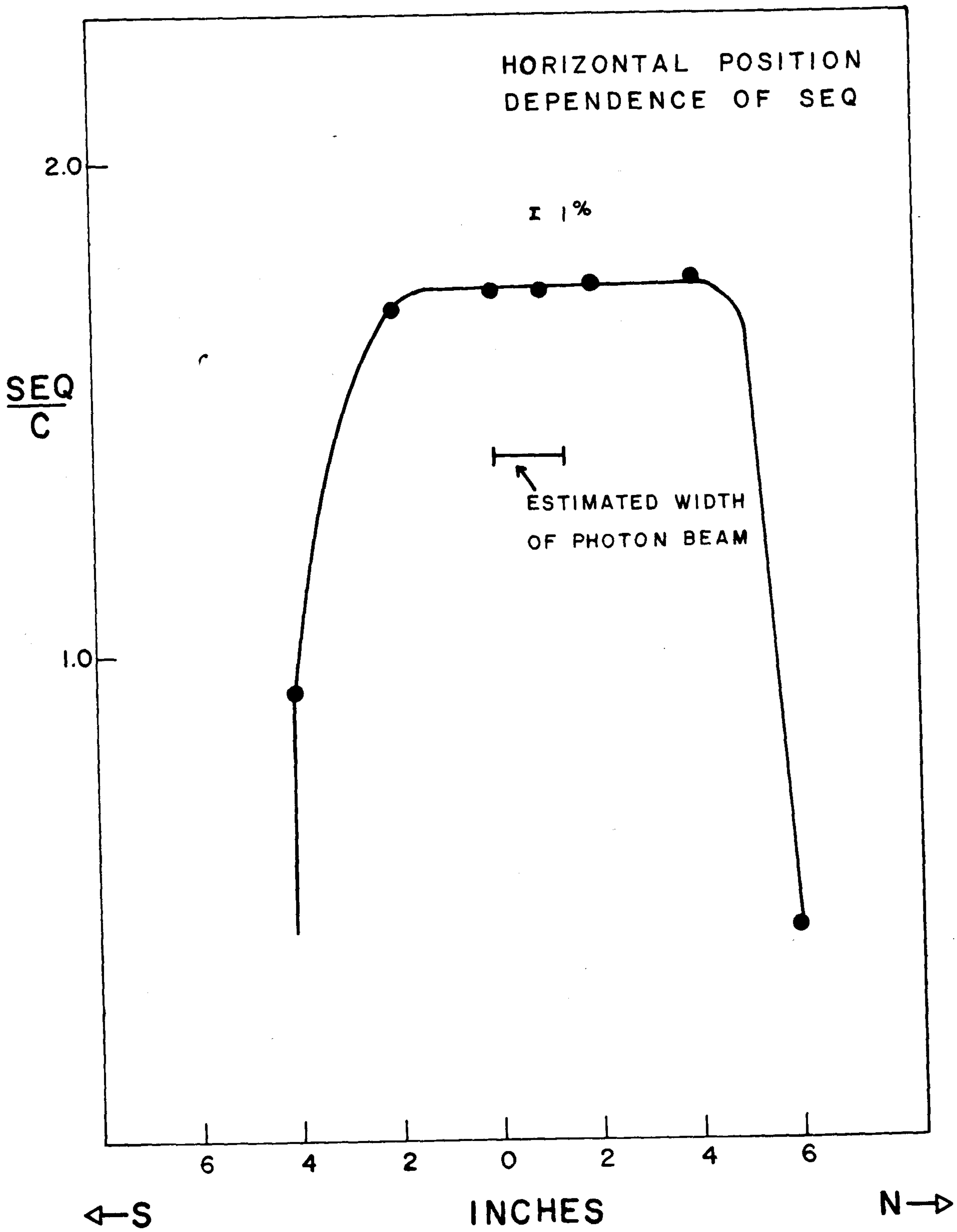

RESPONSE OF SEQ
AS FUNCTION OF
HIGH VOLTAGE
190
180
170
SEQ/C
1%
500
1000
VOLTS

Fig. 2



HORIZONTAL POSITION
DEPENDENCE OF SEQ
2.0
1%
SEQ
C
ESTIMATED WIDTH
OF PHOTON BEAM
1.0
6
4
2
0
2
4
6
S
INCHES
N

Fig. 3