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LOW-ENERGY PROTON AND ELECTRON EXPERIMENT FOR THE ORBITING GEOPHYSICAL OBSERVATORIES B AND E*

by

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ABSTRACT

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The instrumentation and calibrations of the University of Iowa low-energy proton and electron experiment for the Orbiting Geophysical Laboratories (OGO) B and E are described. The experiment utilizes cylindrical curved-plate electrostatic analyzers to provide measurements of the differential energy spectrums of protons and electrons within and in the vicinity of the earth's magnetosphere. Continuous channel multipliers (Bendix 'Channeltrons') are used to count individual charged particles accepted by the analyzers and provide the instrument with a dynamic range in proton and electron intensities extending from 10^4 to 10^{10} $(cm^2\text{-sec-sr})^{-1}$ in a given energy bandpass of the electrostatic analyzer. The widths of the energy bandpasses of the electrostatic analyzers are sufficiently wide to cover the entire energy range extending from 90 eV to 70,000 eV (protons and electrons separately) in 14 voltage steps on the curved plates. The four electrostatic analyzers (two analyzers each for protons and electrons covering the above energy range) complete with signal conditioner, high-voltage power supplies, and thermal shell require an average power of 2 watts and an instrumental weight of 6.3 pounds.

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I. INTRODUCTION

Previous descriptions of the Low-Energy Proton and Electron Differential Energy Analyzer (abbreviation: LEPEDEA) in its earlier stages of development are as follows:

> "SUI Experiment for the Interplanetary Monitoring Platforms (IMP F and G)" by L. A. Frank, dated 4 August 1964.
>
> "SUI Experiment for the Eccentric Orbiting Geophysical Observatory OGO-E (Experiment No. 7)" by L. A. Frank, dated 8 August 1964.
>
> "Further Information Concerning the SUI Experiments for IMP's F and G and OGO-E" by L. A. Frank, dated 4 September 1964.

The present report concerns the instrumentation and calibration of the OGO B LEPEDEA experiment.

The OGO B and E LEPEDEA experiments are designed to measure the differential energy spectrums of protons and electrons over the energy range 50 eV to 70,000 eV within and in the vicinity of the earth's magnetosphere. The instrumentation employs cylindrical curved-plate electrostatic analyzers to identify the energy and the species* (protons

*All charged particles with a given E/Q where E is the energy and Q is the charge of the particle will be equally accepted by the analyzer. For practically all applications of this instrument for magnetospheric measurements the charged particles will be electrons (Q = -1) and protons (Q = +1).

and/or electrons) of a beam of charged particles and Bendix continuous channel multipliers as particle detectors. The dynamic range of the instrument extends from 10^4 to 10^{10} particles $(cm^2\text{-sec-sr})^{-1}$ within a given energy band-pass ($\Delta E/E \simeq 0.45$) and the minimum time for resolving temporal variations in the intensity of charged particles of given energy is ~ 100 milliseconds. The rapid spectrum scan mode (the instrument has two modes of operation) which is accomplished by means of sweep voltages on the analyzer plates covers the energy range 50 eV to 70,000 eV in a period ~ 25 seconds with a repetition rate of once each 300 seconds; this operation mode is followed by a stepped band-pass mode of 14 voltage steps on the electrostatic analyzer plates which fully scans the energy range 90 eV to 70,000 eV. In order to provide a coarse angular distribution with the non-spinning spacecraft, two sets of electrostatic analyzers, each set composed of one analyzer each for electrons and for protons with the above energy ranges, are mounted such that the axes of their fields of view are orthogonal (approximately along the +Y and +Z spacecraft body axes).

Investigative areas of interest include surveys of protons and electrons in the magnetopause-transition region on the sunward side of the magnetosphere, a search for ringcurrent protons, measurements of the electron and proton spectrums and morphologies in the outer radiation zone as a function of radial distance, an investigation of low-energy protons and electrons in the inner radiation zone, and an analysis of charged particle intensities and spectrums in the neutral sheet and in the 'spikes' of electron and proton intensities in the local-night hemisphere of the magnetosphere. Detailed researches of specific phenomena and correlation with the results of other OGO B and E experiments and of ground-based observations should provide an almost inexhaustible source of investigative opportunities.

Although the present discussion concerns the OGO B and E LEPEDEA experiments similar instrumentation with modifications according to the attitude control, orbit, and mission of the specific satellite is planned for IMP's F and G and Injun V.

II. DESCRIPTION OF THE INSTRUMENTATION

The basic components of the OGO B LEPEDEA instrumentation, neglecting the signal conditioner and the timing pulse generator, are shown in the block diagram of Figure 1. The experiment consists of two sets of the components shown in Figure 1 with a common low-voltage power supply and signal conditioner. The pulse of electrons initiated by a primary proton or electron (according to the appropriate electrostatic analyzer channel) incident on the aperture of the corresponding continuous channel multiplier, a Bendix "Channeltron", is collected by a small collector plate which provides the input to a voltage-sensitive amplifier followed by a discriminator; the discriminator output is suitable for subcommutation and accumulation in the experiment signal conditioner. In order to extend the dynamic range of the instrument and to remain within the storage capacity of the signal conditioner accumulator (32,767 counts with a maximum accumulation period of $\sim$ 1 second at the 1 kb $(sec)^{-1}$ spacecraft telemetry rate) the discriminators have been provided with rate-limiting electronics which produce a non-linear response curve beginning at $\sim$ 10,000 counts $(sec)^{-1}$ and allow detector counting rates up to 150,000 counts $(sec)^{-1}$ to be processed by the signal conditioner with reasonable counting rate resolution. In order to suppress a variability in the overall response of the LEPEDEA due to a secular change in the gain of the continuous channel multipliers, the pulse amplitude threshold of the amplifier has been set as low as possible without introducing a significant background (< 0.01 count $(\mathrm{sec})^{-1}$) due to high-voltage power supply and spacecraft noises. This pulse amplitude threshold is ~ 3 mV and since the typical pulse amplitude from the continuous channel multiplier is ~ 150 mV a severe gain decrease of the multiplier by a factor of 20, for example, will decrease the overall sensitivity of the LEPEDEA by ~ 20%. Laboratory operation of the LEPEDEA at a pressure of 10^{-5} mm Hg for ~ 100 hours showed that a drift in its efficiency for counting charged particles was indetectable to within the measurement error of ~ 3%. Stimulation of the continuous channel multipliers in the LEPEDEA with a Co^{60} source provides a more sensitive measure of the multiplier gain drifts since the ~ 1 MeV γ-rays produce secondary electrons along the entire length of the multiplier and provides a distribution of output pulses extending from 0 to ~ 150 mV which are in turn fed into the amplifier with a fixed threshold of 3 mV. The drift in the absolute gain of the four multipliers mounted in the OGO B LEPEDEA as deduced with the Co^{60} γ-ray measurements was $\lesssim 30\%$ at a pressure of 10^{-5} mm Hg (a relatively poor vacuum in comparison with pressures at satellite altitudes) for a duration of ~ 100 hours. Extensive investigation has been performed and is continuing in this laboratory concerning the gain degradation of the continuous channel multiplier at a variety of pressures and with different amplifier-discriminator circuits both individually (with pulse-height analyzers) and in LEPEDEA assemblies. All results so far indicate that the present LEPEDEA assembly and electronics combination should have an operating lifetime of at least one year with regard to secular changes of multiplier gain. Periodic calibrations of the OGO B LEPEDEA have been performed since its final assembly on 1 March 1965 to the period of this report (July, 1965) during various environmental tests at S.U.I. and G.S.F.C. and will continue until launch. After launch the gain drift of the multipliers will be determined by monitoring the galactic cosmic ray response for the high energy channels at appropriate satellite apogee positions; such positions will be selected on the basis of the unshielded 213 G.M. tube ($E_e > 40$ keV, $E_p > 500$ keV) responses. Since the amplifier threshold is ~ 3 mV and corona discharges may produce voltage 'spikes' with voltage amplitudes up to ~ 3 kV at the amplifier input during unrealistic environmental tests (pressure > 10^{-4} mm Hg, for example) protection circuits antecede the amplifier input which are sufficient to eliminate the possibility of amplifier gain degradation due to repetitive 3 kV pulses.

The high-voltage power supply for the electrostatic analyzer provides a known and variable voltage over the range 5 V to 6,000 V. The control deck shown in Figure 1 provides a known sequence of reference voltages to a differential amplifier which modulates the amplitude of the chopped voltage waveform on the primary side of a step-up transformer and slaves the high-voltage supply output by utilizing the reference voltage from a resistive divider across the end of the multiplier string to circuit ground. The electrostatic analyzer voltage is monitored by feeding the voltage on the primary side of the transformer to a voltage-controlled oscillator which is periodically sampled by the signal conditioner. The control deck provides a programmed sequence of 16 reference voltages corresponding to 16 electrostatic analyzer curved-plate voltages. The reference voltage is stepped to a higher voltage once each 19 seconds by means of an internally generated timing pulse until the highest voltage is attained and the reference voltage is returned to 0 V and another cycle is initiated. The decay of the plate voltage at the beginning of each cycle (6,000 V to 5 V in ~ 25 seconds and hence requires two adjacent 0 V reference voltages) provides a relatively rapid scan of the proton and electron energy spectrums over the energy range 70,000 eV to 50 eV whereas the 14 stepped voltages fully covering the energy range 90 eV to 70,000 eV allow studies of the temporal variations of electron and proton intensities in a given energy range and increase the sensitivity of the instrument by virtue of the ability of the signal conditioner to obtain up to 130 samples and the longer accumulation time, respectively, during a given voltage step.

Each of the two LEPEDEA instrumentation groups is accompanied by an EON No. 213 Geiger-Mueller tube with the axis of its collimated field of view parallel to the corresponding axis of each LEPEDEA. Electrons $E_e > 40$ keV and protons $E_p > 500$ keV penetrate the 1.2 mg $(cm)^{-2}$ windows of these G.M. tubes. The dynamic range of the G.M. tubes extends from 10^2 to 10^8 $(cm^2\text{-sec-sr})^{-1}$. The outputs of the two G.M. tubes, the two voltage-controlled oscillators monitoring the electrostatic curved-plate voltages, and the four continuous channel multipliers are subcommutated and equally time-share a 15-bit accumulator in the experiment signal conditioner.

A short summary of the temporal resolution, dynamic range, and energy resolution of the OGO B LEPEDEA is as follows:

Mode I: Scan of the proton and electron differential energy spectrums over the energy range 90 eV to 70,000 eV in two mutually orthogonal directions by stepping the analyzer plate voltages.

Energy range:	90 eV to 70,000 eV
Particle type:	protons and electrons separately
Particle direction:	measurements of both electrons and protons in the above energy range in two mutually orthogonal directions (for OGO B, along the +Y and +Z body axes)
Dimensions of fields of view:	$6^{\circ} \times 25^{\circ}$
Energy range coverage:	full coverage of energy range 90 eV to 70,000 eV in 14 analyzer voltage steps (i.e., no gaps between energy bandpasses)
Cycle time for complete spectral measurement:	300 seconds
Dynamic range:	10^{4} to 10^{10} particles $(cm^{2}\text{-sec-sr})^{-1}$ (at 1 kb $(sec)^{-1}$) 5×10^{5} to 10^{10} $(cm^{2}\text{-sec-sr})^{-1}$ (at 64 kb $(sec)^{-1}$)
Resolution for temporal variations in intensity in any energy bandpass:	$\sim$ 100 milliseconds (at 64 kb $(sec)^{-1}$)

Mode II: Rapid scan of electron and proton differential energy spectrums complementary to Mode I.

Energy range:	50 eV to 70,000 eV
Particle type:	same as Mode I

Particle direction:	same as Mode I
Cycle time for complete spectral measurement:	25 seconds
Repetition rate of Mode II:	once each 300 seconds
Dynamic range:	same as Mode I

The details of the electrostatic analyzer geometry are shown in Figure 2. Three cylindrical curved plates P_1, P_2, and P_3 form two 43° electrostatic analyzers for analysis of proton and electron differential energy spectrums separately. The two outer plates P_1 and P_3 are tied to circuit ground and the center plate P_2 is supplied with a variable positive potential ranging from 5 V to 6,000 V. Hence the outer analyzer C_2 accepts electrons of appropriate energy and the inner analyzer C_1 performs analyses of positive ion differential energy spectrums. This geometry was chosen primarily because of its mechanical simplicity (i.e., only one curved plate with high voltage is required for two electrostatic analyzers), large energy bandpass width, and large geometric factor. The radii of curvature of plates P_1, P_2, and P_3 are 11.6 cm, 12.8 cm, and 13.9 cm, respectively. In order to suppress the ultraviolet (primarily Lα) and electron scattering along the analyzer plates into the continuous channel multipliers

(A and B are the entrance apertures) the concave surfaces of plates P_2 and P_3 were machined with sawtooth serrations of 1 mm depth facing the entrance apertures of the electrostatic analyzers. An elaborate collimator with knife-edged light baffles was also added to reduce this scattering and to define a rectangular field of view with dimensions 6° and 25° in the plane of and in the plane perpendicular to Figure 2, respectively. All interior surfaces of the electrostatic analyzer and of the collimator were platinum-blackened to further suppress the contamination of the analyzer response to solar $L\alpha$. Direct calibrations of this instrument's response to ultraviolet light will soon be performed but magnetospheric charged particle measurements are the primary mission of this experiment and do not require the detector to directly view the sun. Data acquired while the analyzers view the sun can be identified from the known attitude of the spacecraft and will be processed separately.

A simplified diagram of the mounting of the continuous channel multipliers is also shown in Figure 2. The multipliers are positioned such that the normals to the surface of their entrance apertures form approximately a 30° angle with the normals to the exit apertures of the respective electrostatic analyzers. This feature forces all primary charged particles incident on the aperture of the multiplier to produce secondary electrons near the front end (as compared with normal incidence where a primary particle could penetrate more deeply into the multiplier before striking the capillary wall) thus utilizing the full gain of the detector without a large sacrifice in projected area. The entrance apertures of the continuous channel multipliers are biased at 150 V (A) and -3,000 V (B) for post-acceleration of electrons and protons, respectively. Electron pulses arriving at the exit apertures C and D of the multipliers are accelerated into charge-collecting cups Y and X by a potential difference of +50 V. The cup Y for the electron channel is at a potential of 3,000 V and is coupled into an amplifier by means of a capacitor (50-100 pf).

Three views of the OGO B LEPEDEA instrumentation are given by Figures 3, 4, and 5. The low-voltage power supply is shown in Figure 3 (center) with the two control decks for the analyzers at the extreme left and right of the structure. Figure 4 displays a control deck on the extreme left, the 213 G.M. tube housing (tube at top) and four high-voltage power supplies: +700 V for the 213 G.M. tube, -3,000 V and +3,000 V for the continuous channel multipliers, and the 5 V to 6,000 V power supply for the analyzer plate. A similar set of electronics for the second analyzer is on the opposite side of the unit. The thermal shell and collimators of the completely assembled instrument are shown in Figure 5. The dimensions of the right parallelepiped portion of the structure are 7.1 in. (height), 7.1 in. (width), and 6.9 in. (depth). Average power supplied to the instrument is 2 watts and the weight including thermal cover and collimators is 6.3 pounds.

III. CALIBRATIONS WITH CHARGED PARTICLE BEAMS

The absolute efficiencies of the continuous channel multipliers for counting singly ionized lithium ions (Li^+) and electrons over the energy range 50 eV to 25,000 eV were obtained with a laboratory electron-ion gun which provided a stable and homogeneous beam of $\sim 10^{-13}$ amp $(cm^2)^{-1}$ over the above energy range. A curve of the absolute efficiency (i.e., counts (numbers of ions incident on the aperture area of 8×10^{-3} $cm^2)^{-1}$) of a selected multiplier for counting Li^+ ions as a function of ion energy is given in Figure 6. The entrance aperture of the continuous channel multiplier was grounded and the bias voltage at the exit aperture was +2750 V; hence there is no post-acceleration of the incident Li^+ ions. Amplifier-discriminator electronics identical to those installed in the LEPEDEA instrument were used. The efficiency of the continuous channel multiplier for counting Li^+ ions rises from $\leq 4 \times 10^{-5}$ count $(ion)^{-1}$ at 70 eV to a peak efficiency of 0.5 ($\pm$ 20%) count $(ion)^{-1}$ at 3,000 eV and then monotonically decreases with increasing ion energy to 0.3 count $(ion)^{-1}$ at 30,000 eV. Direct calibrations of the multiplier with protons will soon be undertaken but the absolute efficiency for counting protons E $\gtrsim$ 3,000 eV should not largely differ from the Li^+ curve of Figure 6 (compare the extreme cases of Li^+ and electron efficiencies for energies exceeding 3,000 eV of Figures 6 and 7, respectively). Since the post-acceleration potential is -3,000 V for the positive ion detector of the LEPEDEA (refer to Figure 2) only that portion of the efficiency curve of Figure 6 for ion energies $\geq$ 3,000 eV is pertinent to this instrument. The absolute efficiency of the multiplier (again no post-acceleration voltage and with the LEPEDEA amplifier-discriminator electronics) for counting electrons as a function of energy is shown in Figure 7. At 30 eV the efficiency is 4×10^{-4} counts $(\text{electron})^{-1}$, rises to a peak value of 0.5 ($\pm$ 30%) counts $(\text{electron})^{-1}$ at 400 eV and then monotonically decreases to 0.07 counts $(\text{electron})^{-1}$ at 25,000 eV. Reference to Figure 2 shows that the post-acceleration voltage for the electron detectors of the LEPEDEA instrument is + 150 V; hence all electrons arriving at the detector will have energies $\geq$ 150 eV and will be efficiently counted (refer to Figure 7).

Calibrations of several proton and electron channels of the OGO B LEPEDEA are shown in Figures 8, 9, 10, and 11. Since the OGO B unit has 14 channels (voltage steps) X 2 species (electrons and protons) X 2 analyzer sets (two directions) = 56 individual channels, only several representative bandpasses are discussed here. Figure 8 displays the counting rate of a LEPEDEA proton channel (curved-plate voltage, 106 V) as a function of incident ion energy and with the angle between the normal to the entrance aperture of the electrostatic analyzer and the direction of the ion beam, Θ, as a parameter. The angle Θ lies in the plane of Figure 2. For each angle of incidence $\Theta = 2°$, $5°$, and $9°$ and fixed curved-plate voltage V_p, the particle energy was varied with a constant beam intensity. For a given angle of incidence Θ the energy bandpasses of Figure 8 are well defined with a notable absence of scattering 'ghosts' or 'tails' at the high energy cutoffs. Two characteristics of the bandpasses are immediately noticed, the ion energy corresponding to the center of the bandpass, E_c, and the width $\Delta E/E_c$ of the bandpass increases with increasing angle of incidence Θ. Hence the width $\Delta E/E$ of the bandpass is determined to a large extent by the collimator angles shown in Figure 2. This dispersion of the bandpass energies over a small angle of $\sim 6°$ will be unimportant for most magnetospheric applications; highly directional beams can be measured when the instrument is in its scan mode of operation (i.e., continuously varying curved-plate voltage). The energy bandpass shown in Figure 8 extends from 625 eV to 950 eV or a width $\Delta E/E_c = 0.43$. A higher energy positive ion channel is shown in Figure 9 for a curved-plate voltage $V_p = 1710$ V. The general characteristics of the energy bandpass as a function of energy and angle of incidence θ are similar to those of a lower energy channel (refer to Figure 8). The energy bandpass displayed in Figure 9 extends from 11 keV to 18 keV with a width $\Delta E/E_c = 0.48$. Electron channels also share similar bandpass characteristics as shown in Figure 10. With 2600 V supplied to the curved plate the energy bandpass (15 keV to 26 keV) has a width of $\Delta E/E_c = 0.54$. The coverage of the electron energy decade 1 keV to 10 keV provided by five consecutive channels is displayed in Figure 11. A beam of electrons of constant intensity (5×10^5 electrons $(cm^2\text{-}sec)^{-1}$), angle of incidence $\theta = 5°$ and variable energy was used to scan the five adjacent channels. Corresponding curved-plate voltages are given in the legend of Figure 11. The bandpasses are well-defined with background rates due to electron scattering smaller than the peak channel response by a factor ≥ 500. The gaps between the energy bandpasses are filled by the dispersion of the bandpasses as a function of incidence angle θ (for example, refer to Figure 10) so that the energy range 1 keV to 10 keV is fully covered by the five channels, or voltage steps, 7 through 11. After the experimental determination of the characteristics of the LEPEDEA bandpasses as demonstrated above the curved-plate voltages were trimmed so that the 14 discrete steps fully covered the energy range 90 eV to 70,000 eV. The approximate energy bandpasses are as follows:

90 eV	to	145 eV,	
145 eV	to	230 eV,	
230 eV	to	370 eV,	
370 eV	to	600 eV,	
600 eV	to	950 eV,	
950 eV	to	1500 eV,	
1500 eV	to	2400 eV,	
2400 eV	to	3800 eV,	
3800 eV	to	6200 eV,	
6200 eV	to	9800 eV,	
9800 eV	to	16000 eV,	
16000 eV	to	26000 eV,	
26000 eV	to	42000 eV,	and
42000 eV	to	67000 eV	

for protons and electrons separately. The scanning mode of the instrument with a continuously variable voltage on the plates complements the above stepping mode. The positions of the energy bandpasses vary for different analyzers by $\sim 10\%$ depending primarily on the performance of the high voltage supplies and positioning of the curved plates and are determined by direct calibrations with charged particle beams and by measurements of the curved-plate voltages.

Future improvements of the instrument will be directed toward extending the energy range, increasing the temporal resolution for measuring charged particle spectrums and increasing the intensity dynamic range.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the many personnel of the U. of Iowa laboratory who unselfishly donated their efforts toward the development, construction, and calibration of the LEPEDEA instrument. Prominent among these were Dr. J. A. Van Allen for his support and encouragement, Messrs. D. C. Enemark, R. Carlson, R. Randall, and D. Hyde for the electrical design, Messrs. N. Henderson, W. Stanley, and R. Gabel for supervising construction, satellite integration, and field testing, and Messrs. M. McLaughlin and S. Robinson for the mechanical design.

FIGURE CAPTIONS

Figure 1. Block diagram of major components of the electrostatic analyzer and its accompanying 213 Geiger-Mueller tube.

Figure 2. Geometry of the mechanical assembly of the curved plates, collimator, and light baffles, and continuous channel multipliers.

Figure 3. Photograph of the OGO B LEPEDEA instrument with the low-voltage power supply shown in center.

Figure 4. Photograph of the OGO B LEPEDEA instrument with one of the two high voltage sections (+700 V, +3,000 V, -3,000 V and 5 to 6,000 V) on the right, tubular 213 G.M. tube housing (upper left) and control deck on the left.

Figure 5. Another photograph showing assembled thermal cover and collimators. The upper and lower slits inside the collimator are the electron and proton channels, respectively, of one of the two analyzers.

Figure 6. Absolute efficiency of a continuous channel multiplier for counting Li^+ ions as a function of ion energy without post-acceleration at the multiplier. A post-acceleration potential of -3,000 V is used in the LEPEDEA.

Figure 7. Absolute efficiency of a continuous channel multiplier for counting electrons as a function of electron energy without post-acceleration. A post acceleration potential of +150 V is used in the flight instrumentation.

Figure 8. The response of one of the positive ion channels to a Li^+ beam of intensity 5×10^4 $(cm^2\text{-sec})^{-1}$ as a function of ion energy and angle of incidence θ.

Figure 9. A continuation of Figure 8 for a higher energy positive ion channel.

Figure 10. The response of one of the electron channels to an electron beam of intensity 3×10^5 $(cm^2\text{-sec})^{-1}$ as a function of electron energy and angle of incidence θ.

Figure 11. A composite of the responses of five electron channels to an electron beam of intensity 5×10^5 $(cm^2\text{-sec})^{-1}$ over the energy range 1 to 10 keV and directed at a fixed incidence angle $\theta = 5°$. The dispersion of the energy bandpasses as a function of θ will allow these five channels to fully cover the energy range 1 to 10 keV.

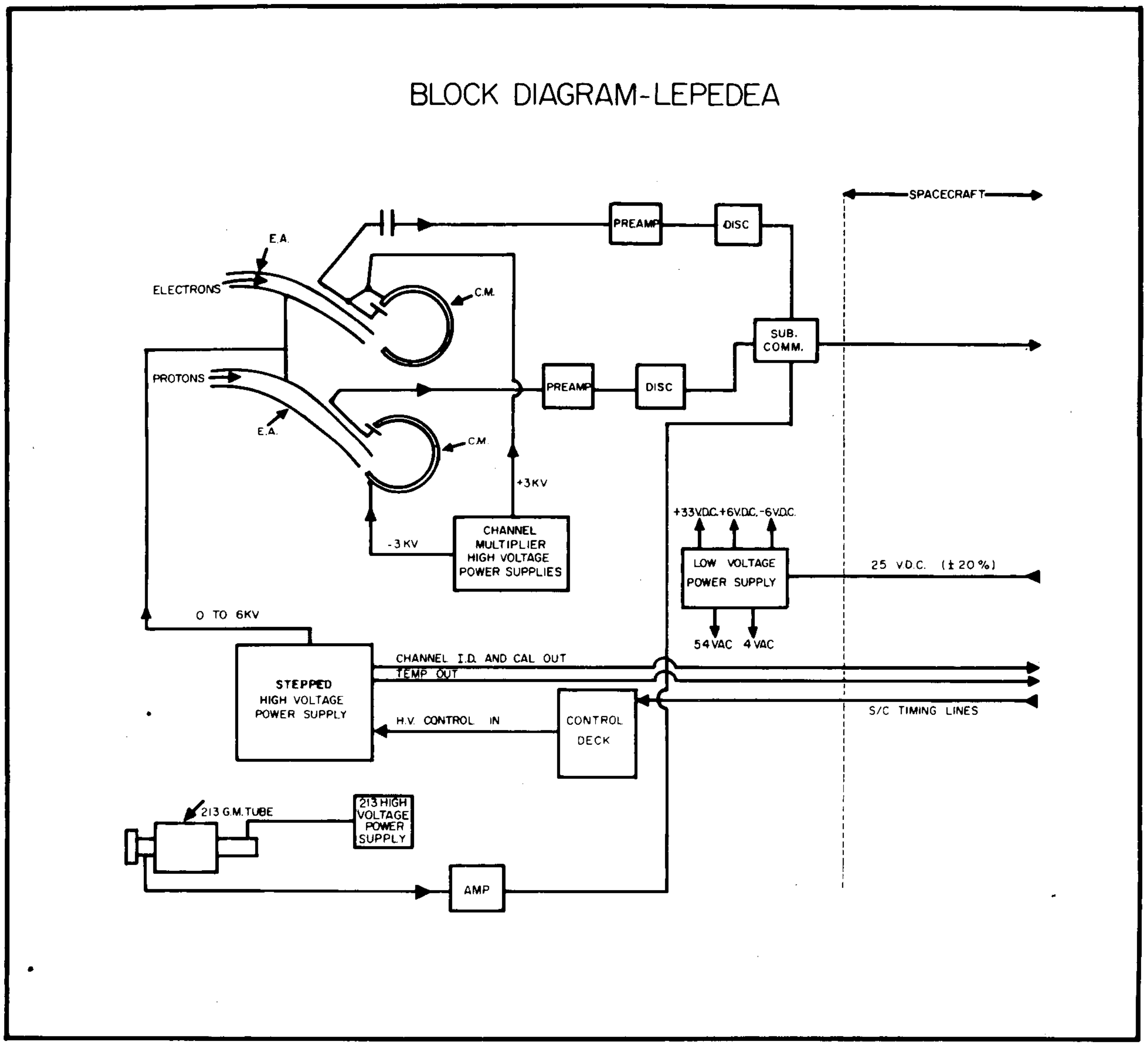
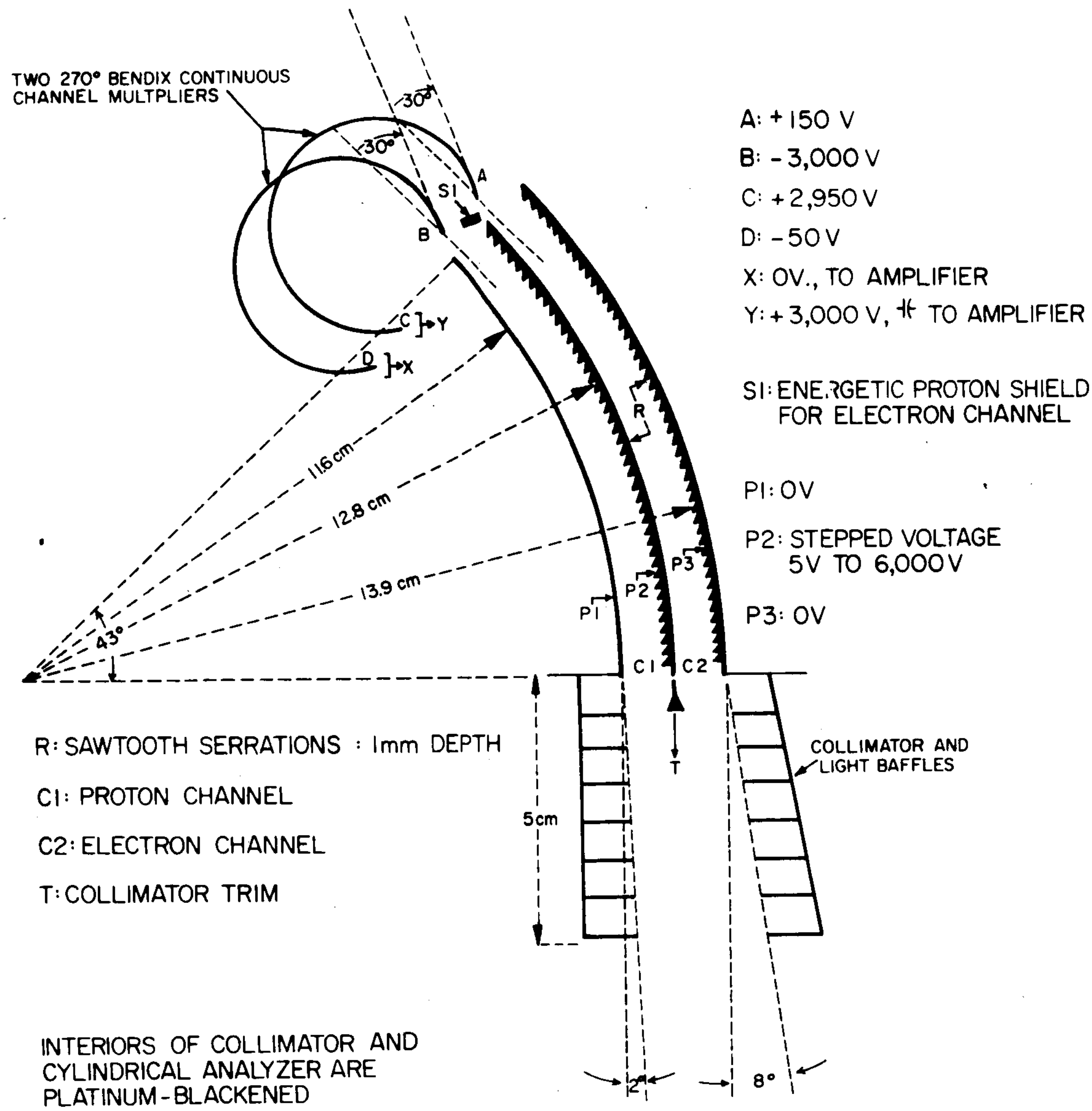

BLOCK DIAGRAM-LEPEDEA
SPACECRAFT
E.A.
ELECTRONS
C.M.
PREAMP
DISC
SUB. COMM.
PROTONS
E.A.
C.M.
PREAMP
DISC
+3KV
-3KV
CHANNEL MULTIPLIER HIGH VOLTAGE POWER SUPPLIES
+33VDC +6VDC -6VDC
LOW VOLTAGE POWER SUPPLY
25 VDC (±20%)
54VAC 4VAC
0 TO 6KV
STEPPED HIGH VOLTAGE POWER SUPPLY
CHANNEL I.D. AND CAL OUT
TEMP OUT
H.V. CONTROL IN
CONTROL DECK
S/C TIMING LINES
213 G.M. TUBE
213 HIGH VOLTAGE POWER SUPPLY
AMP

Figure 1



LEPEDEA MECHANICAL ASSEMBLY

Figure 2

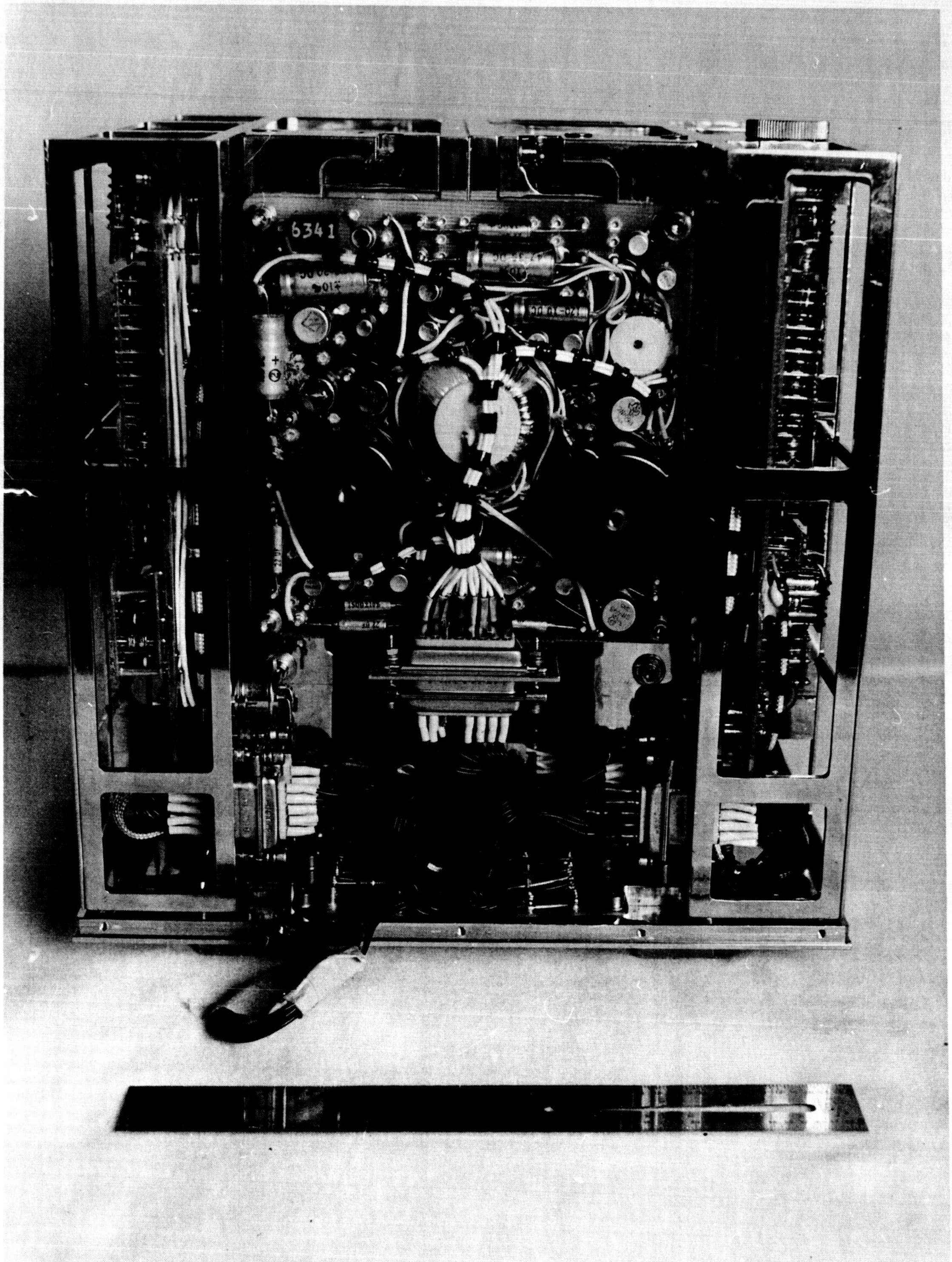


FIGURE 3

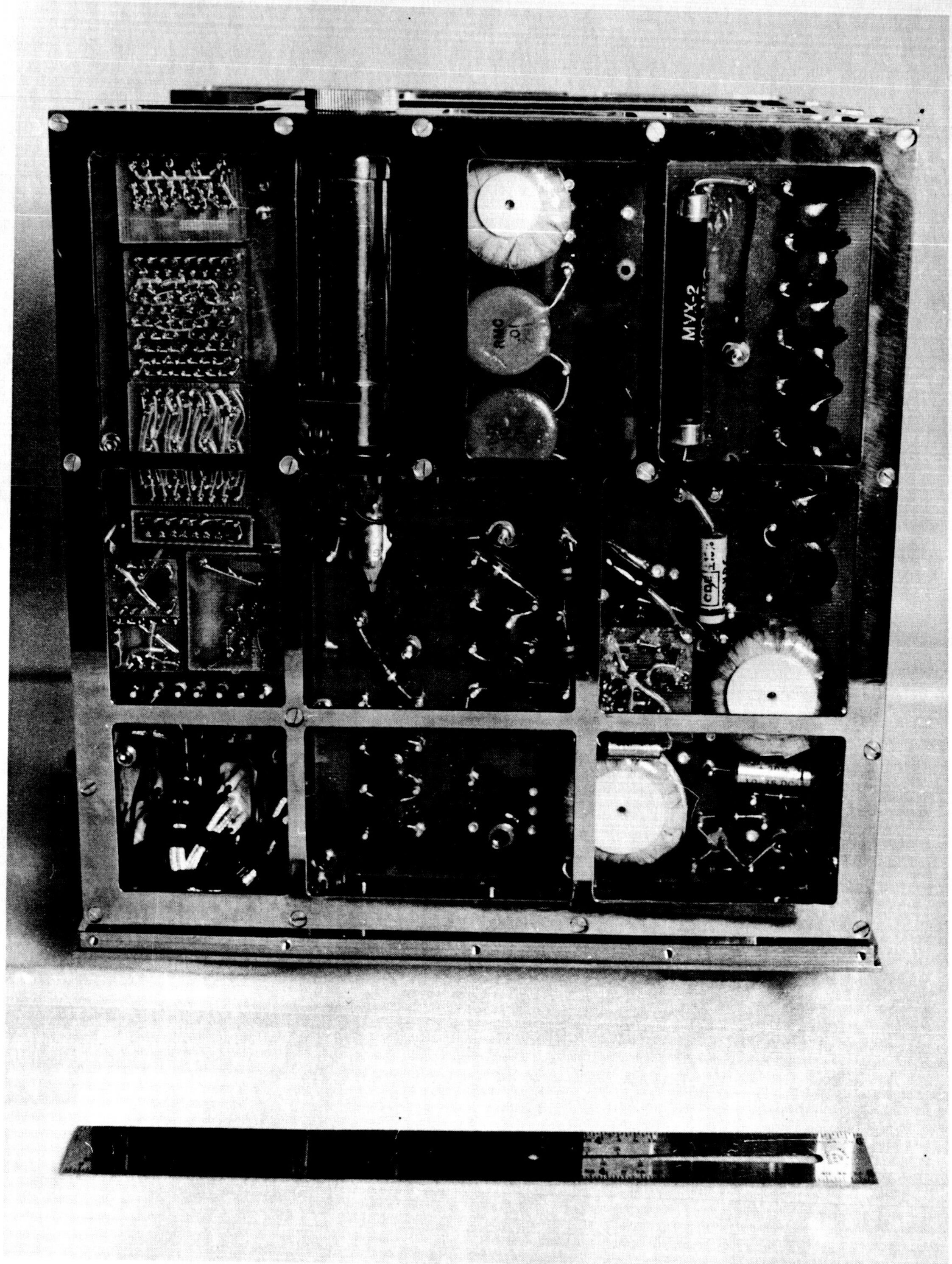


FIGURE 4

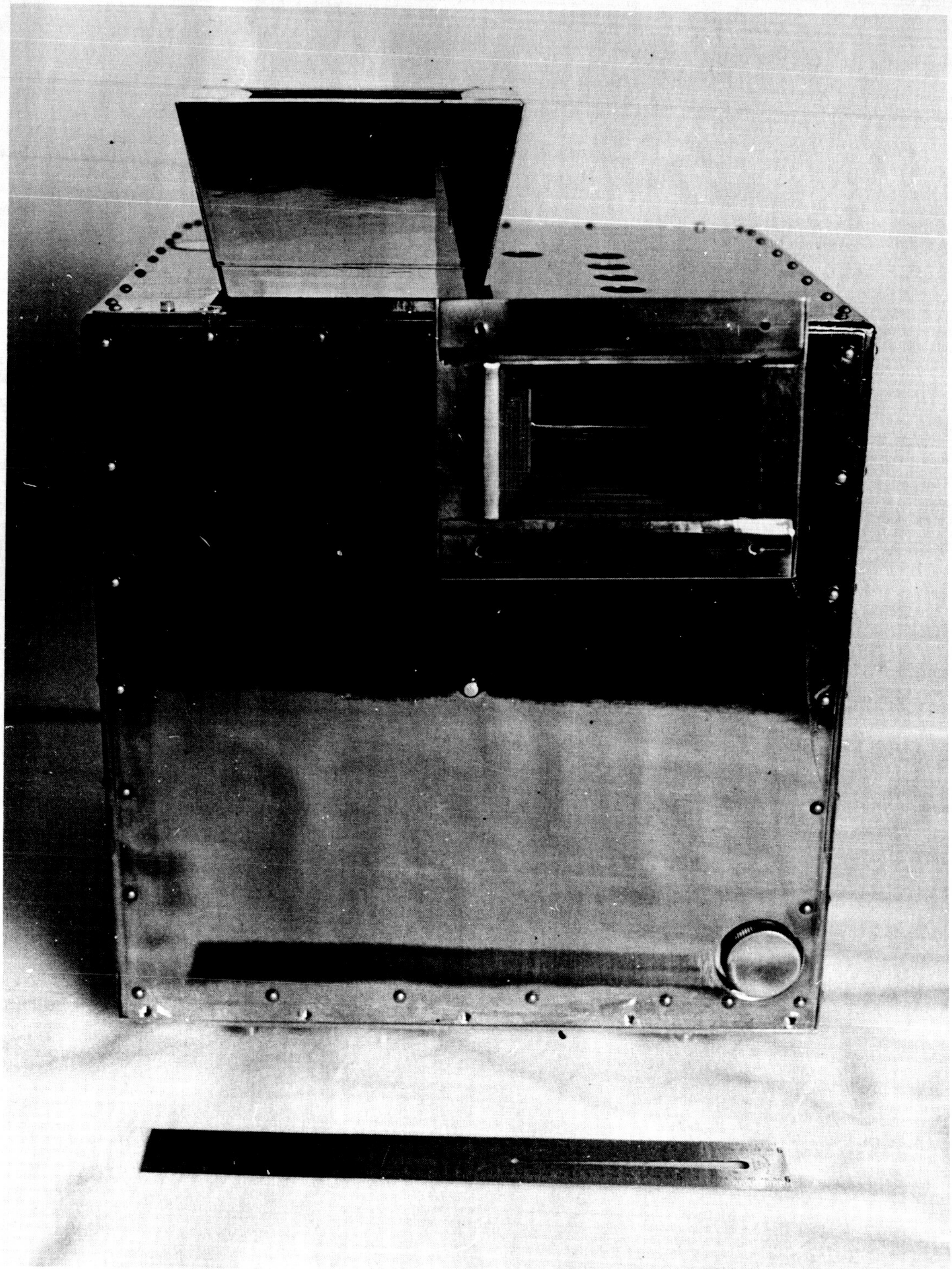


FIGURE 5

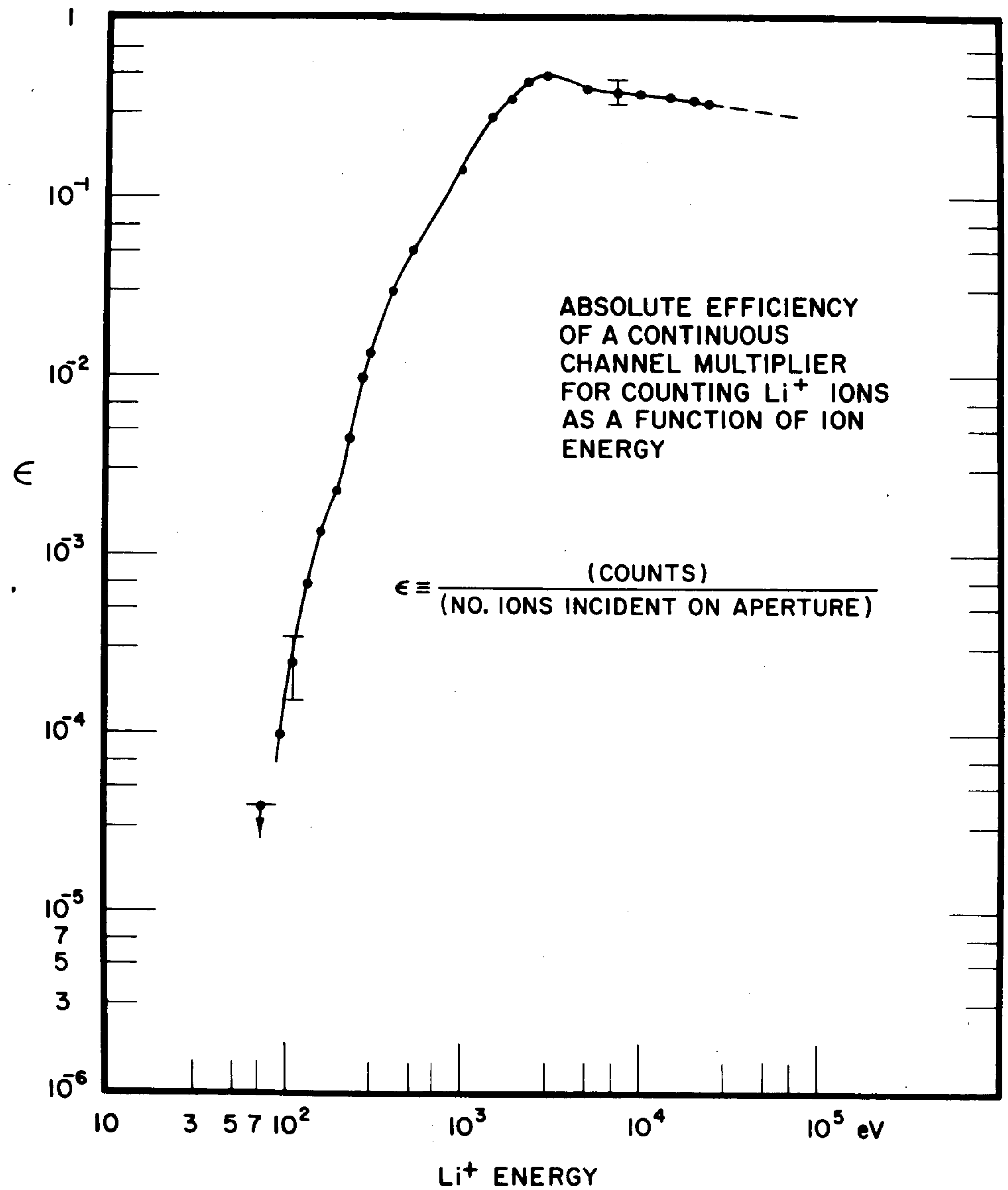
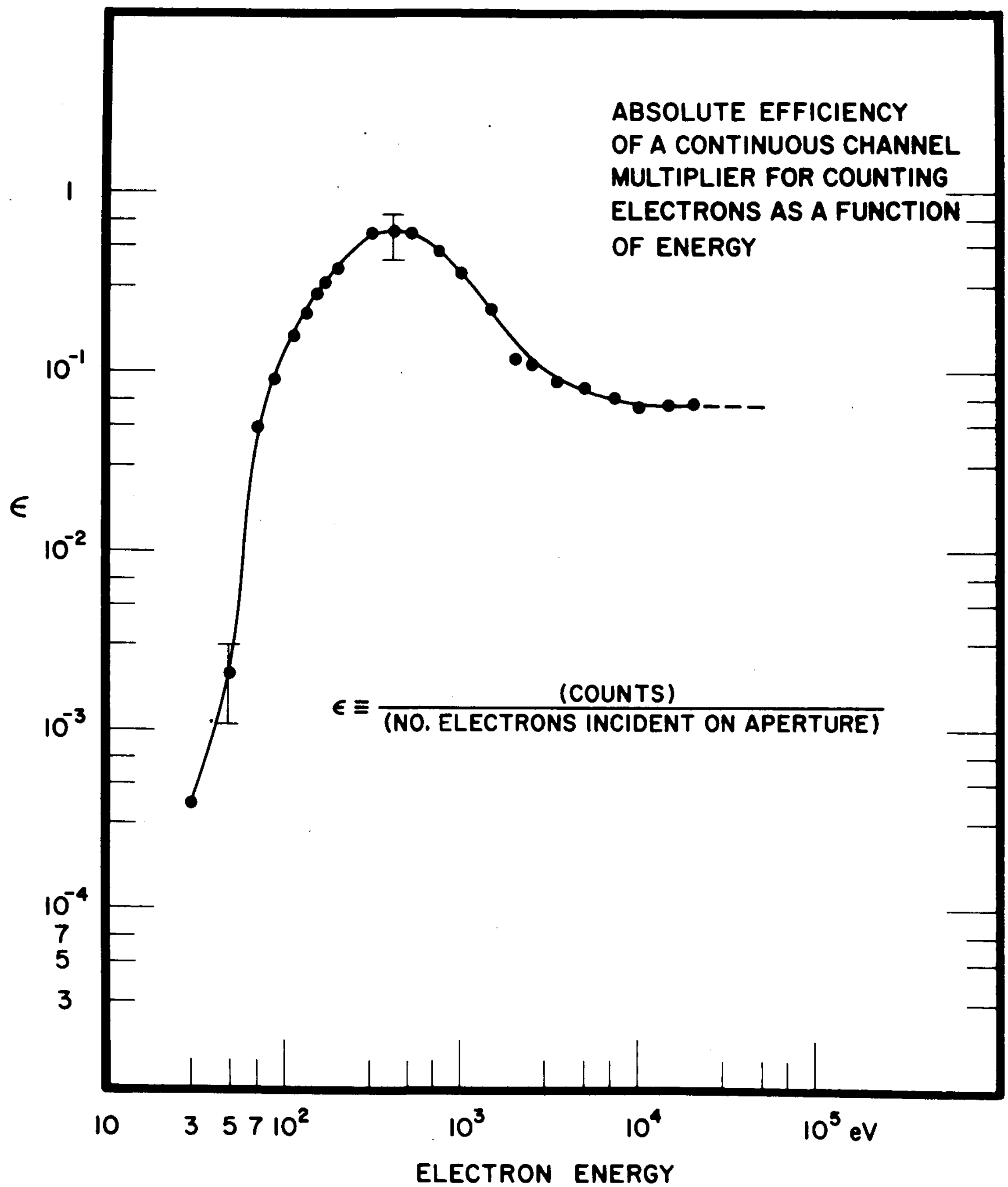
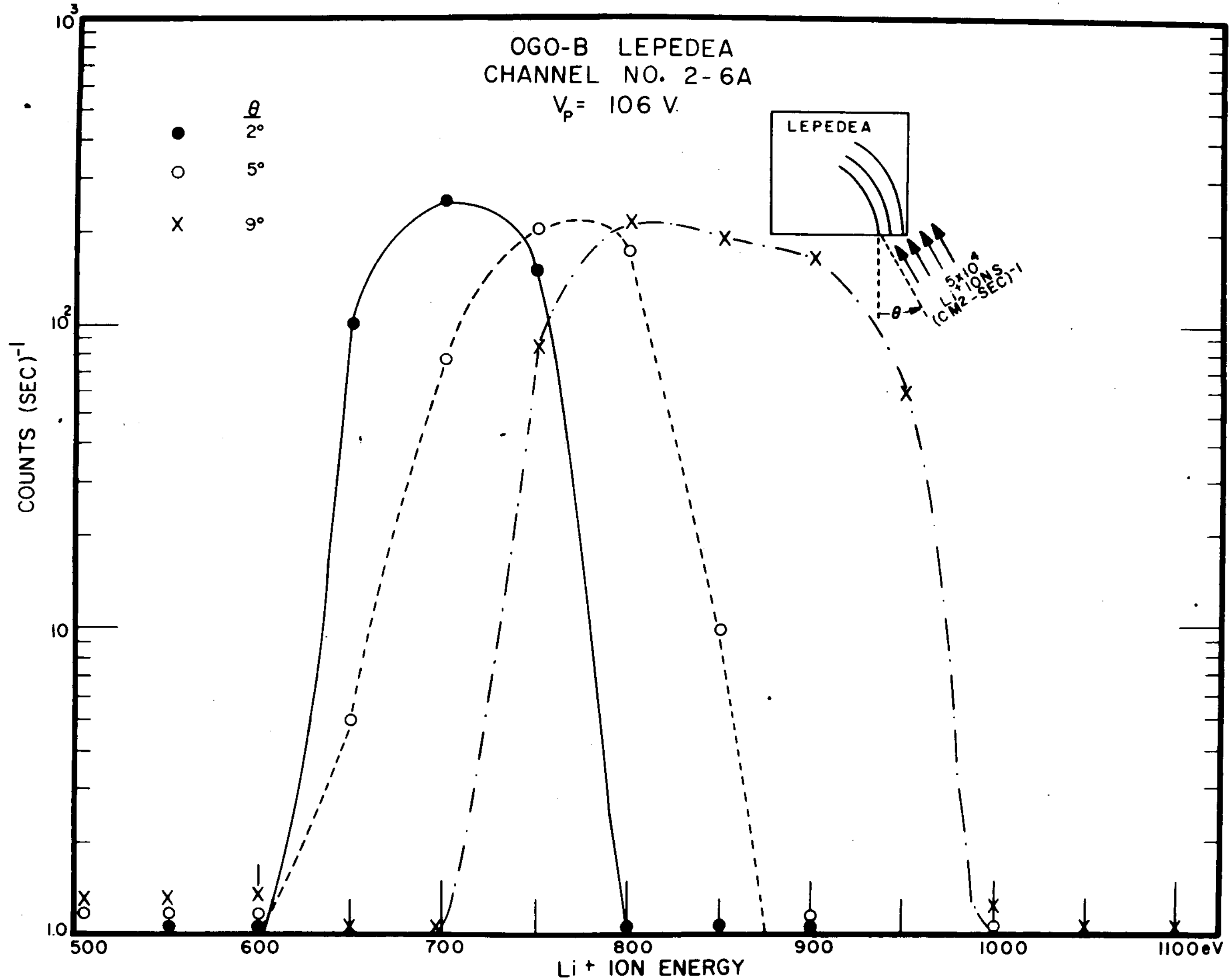

ABSOLUTE EFFICIENCY
OF A CONTINUOUS
CHANNEL MULTIPLIER
FOR COUNTING Li+ IONS
AS A FUNCTION OF ION
ENERGY
ε ≡ (COUNTS) / (NO. IONS INCIDENT ON APERTURE)
ε
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
7
5
3
10⁻⁶
10
3
5
7
10²
10³
10⁴
10⁵ eV
Li+ ENERGY

Figure 6



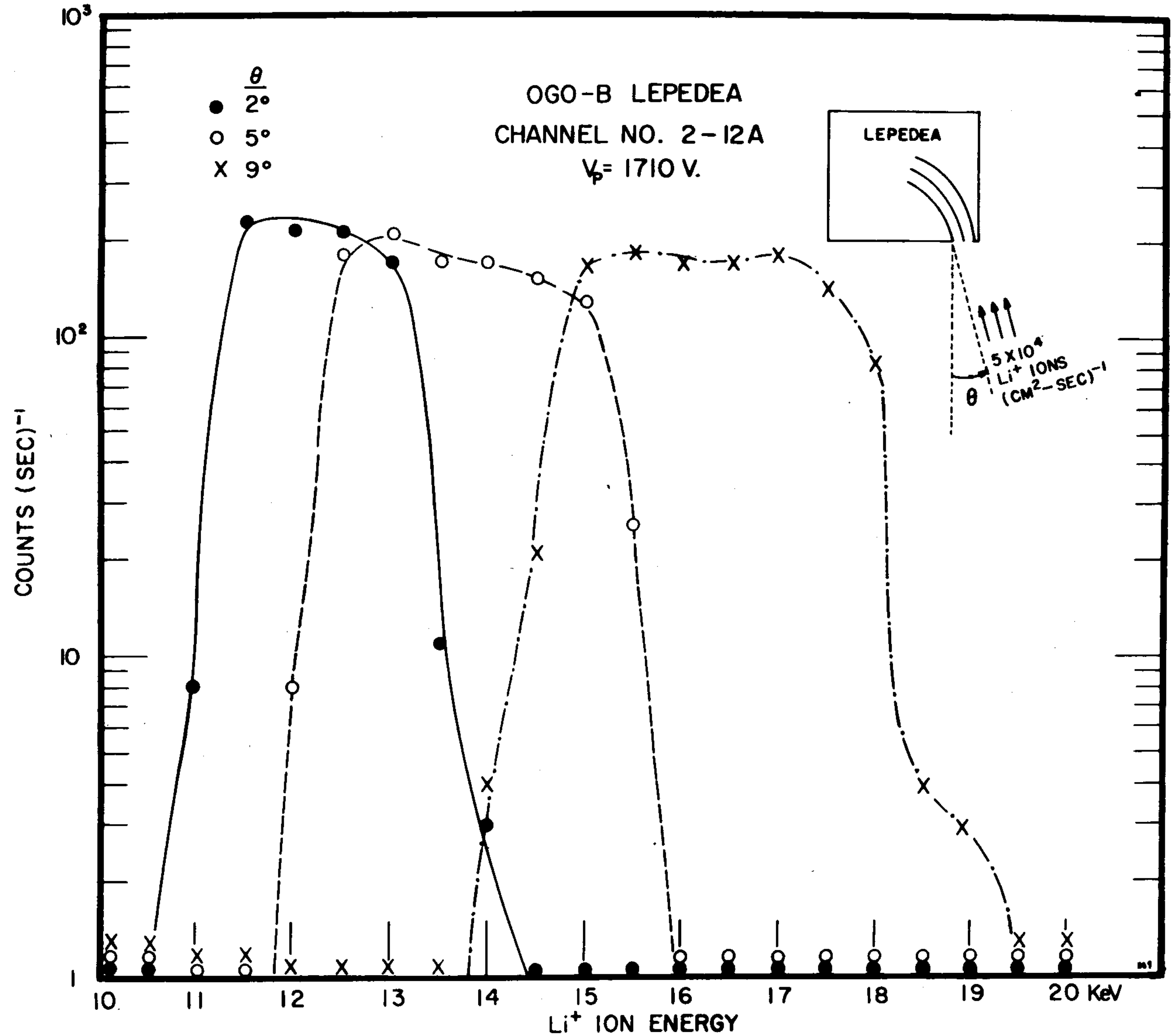
ABSOLUTE EFFICIENCY
OF A CONTINUOUS CHANNEL
MULTIPLIER FOR COUNTING
ELECTRONS AS A FUNCTION
OF ENERGY
$\epsilon \equiv \frac{\text{(COUNTS)}}{\text{(NO. ELECTRONS INCIDENT ON APERTURE)}}$
ϵ
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
7
5
3
10
3
5
7
10^{2}
10^{3}
10^{4}
10^{5} eV
ELECTRON ENERGY

Figure 7



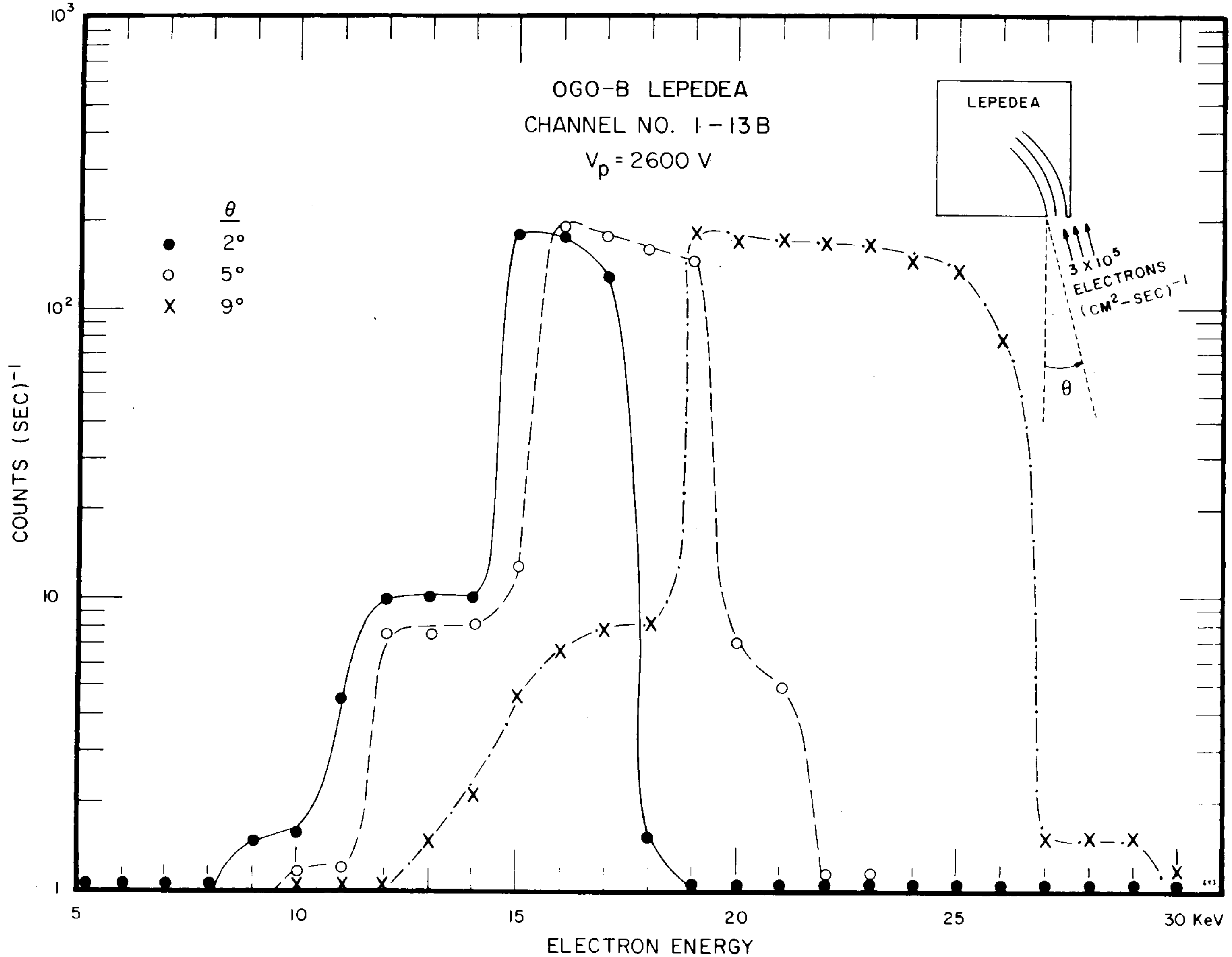
OGO-B LEPEDEA
CHANNEL NO. 2-6A
V_P = 106 V
θ
2°
5°
9°
LEPEDEA
5×10^4 Li^+ IONS $(CM^2\text{-}SEC)^{-1}$
θ
COUNTS $(SEC)^{-1}$
10^3
10^2
10
1.0
500
600
700
800
900
1000
1100eV
Li^+ ION ENERGY

Figure 8



OGO-B LEPEDEA
CHANNEL NO. 2-12A
V_p= 1710 V.
θ
2°
5°
9°
LEPEDEA
5 X 10⁴
Li⁺ IONS
(CM²-SEC)⁻¹
θ
COUNTS (SEC)⁻¹
10³
10²
10
1
10
11
12
13
14
15
16
17
18
19
20 KeV
Li⁺ ION ENERGY

Figure 9



OGO-B LEPEDEA
CHANNEL NO. 1-13B
$V_p = 2600$ V
θ
2°
5°
9°
LEPEDEA
3 X 10^5
ELECTRONS
(CM^2-SEC)^-1
θ
COUNTS (SEC)^-1
10^3
10^2
10
1
5
10
15
20
25
30 KeV
ELECTRON ENERGY

Figure 10

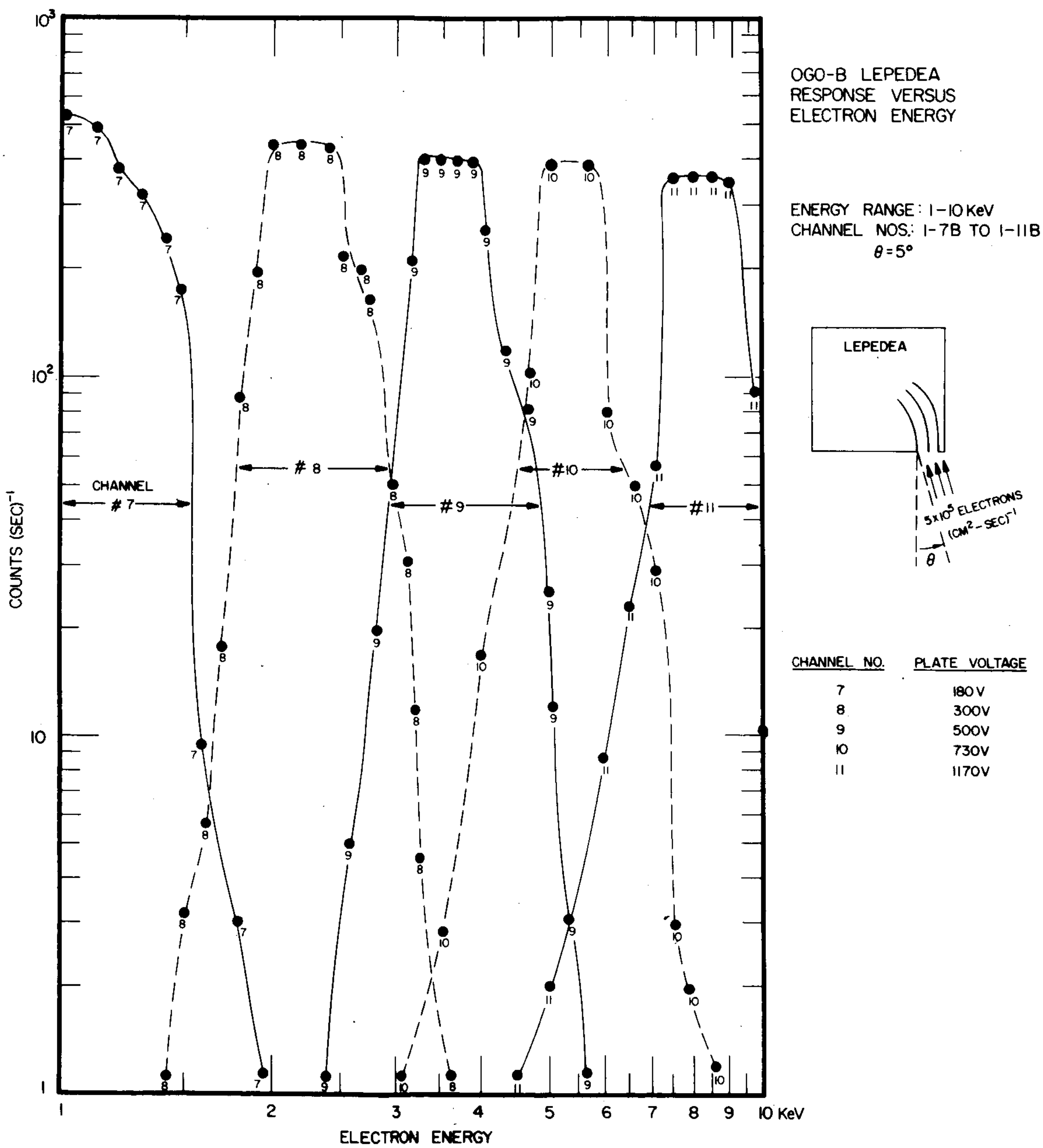

OGO-B LEPEDEA
RESPONSE VERSUS
ELECTRON ENERGY
ENERGY RANGE: 1-10 KeV
CHANNEL NOS.: 1-7B TO 1-11B
θ=5°
LEPEDEA
5x10^5 ELECTRONS (CM^2-SEC)^-1
θ
CHANNEL NO. PLATE VOLTAGE
7 180V
8 300V
9 500V
10 730V
11 1170V
CHANNEL #7
#8
#9
#10
#11
COUNTS (SEC)^-1
ELECTRON ENERGY
10^3
10^2
10
1
1 2 3 4 5 6 7 8 9 10 KeV

Figure 11

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D	
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)	
1. ORIGINATING ACTIVITY (Corporate author) University of Iowa, Department of Physics and Astronomy	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP
3. REPORT TITLE Low-Energy Proton and Electron Experiment for the Orbiting Geophysical Observatories B and E	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Progress	
5. AUTHOR(S) (Last name, first name, initial) Frank, L. A.	

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
July 1965	35	None

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b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	
10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Office of Naval Research

13. ABSTRACT

The instrumentation and calibrations of the University of Iowa low-energy proton and electron experiment for the Orbiting Geophysical Laboratories (OGO) B and E are described. The experiment utilizes cylindrical curved-plate electrostatic analyzers to provide measurements of the differential energy spectrums of protons and electrons within and in the vicinity of the earth's magnetosphere. Continuous channel multipliers (Bendix 'Channeltrons') are used to count individual charged particles accepted by the analyzers and provide the instrument with a dynamic range in proton and electron intensities extending from 10^4 to 10^{10} $(cm^2\text{-sec-sr})^{-1}$ in a given energy bandpass of the electrostatic analyzer. The widths of the energy bandpasses of the electrostatic analyzers are sufficiently wide to cover the entire energy range extending from 90 eV to 70,000 eV (protons and electrons separately) in 14 voltage steps on the curved plates. The four electrostatic analyzers (two analyzers each for protons and electrons covering the above energy range) complete with signal conditioner, high-voltage power supplies, and thermal shell require an average power of 2 watts and an instrumental weight of 6.3 pounds.

DD FORM 1 JAN 64 1473

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Low Energy Particle Detector						

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