ARC AND GLOW DISCHARGES IN AN ELONGATED GLASS TUBE SURROUNDED BY A GROUNDED SHIELD

by

RAIMO BAKIS

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INTRODUCTION

The characteristics of various types of discharges in rare gases and rare gas-mercury mixtures have been studied, both experimentally and theoretically by several investigators. Penning (1928) measured the glow breakdown voltages between electrodes separated by 1 cm, using gas pressures of approximately 20 mm Hg. He worked with neon, argon, and neon-argon mixtures, as well as with mixtures of both gases with mercury. Penning found that the addition of a small amount of mercury to argon produced a significant lowering of the breakdown voltage. This is the well-known "Penning effect." Penning's work was done with currents less than 10^{-6} amperes.

Higher currents were used by Headrick and Duffendack (1931). They measured the potential gradient in the positive column of a glow discharge operated at 40 ma dc in a tube of 40 mm diameter. They found that the addition of 6 microns of mercury vapor to argon at a pressure of 14 mm Hg caused the potential gradient to increase. This they attributed to the loss of metastable argon atoms used to excite but not ionize mercury atoms.

The relationship between the current and potential gradient in the positive column of dc arcs in inert gases has been investigated by Lompe and Seeliger (1932). They used currents from 20 to 350 ma and gas pressures of 1 to 29 mm Hg. They found that increasing currents resulted in decreasing potential gradients. Lompe and Seeliger did not, however, use mixtures of gases.

The positive column of the low-pressure argon-mercury arc has been analyzed both theoretically and experimentally by Kenty (1950) and by Waymouth and Bitter (1956). The dynamic characteristics of the argon-mercury arc have been studied by Barnes (1952). These studies indicate that, at the current densities used in the arc (approximately 0.05 amp/cm^2), the primary process of ion production is the ionization of metastable mercury atoms by electron collision.

The starting characteristics of long enclosed ac arcs in argon-mercury mixtures were studied by McFarland (1951). He found that the glow discharge between the electrodes was preceded by a brush discharge from one electrode to the tube wall. When the potential distribution on the outside surface of the tube was such as to prevent the brush discharge from occuring, abnormally high voltages were required to start an arc.

The internal parameters effective in determing the starting voltages of long ac arcs have, however, not been extensively studied in the past. Preliminary work dealing with such parameters has been described by Bell (1955). It is the purpose of this paper to present experimental data on glow and arc striking potentials in argon, neon, krypton, zenon, and mixtures of these gases with mercury under conditions where the influence of external electric fields was controlled.

APPARATUS AND PROCEDURE

Two discharge tubes were used, one containing a small amount of liquid mercury, the other being kept free of mercury by a trap cooled with liquid nitrogen. The tubes were made of pyrex glass with an inner diameter of 38 mm. One electrode (A) in each tube was attached to a movable glass cylinder in the tube. This cylinder contained an iron slug and could thus be moved with a magnet from the outside of the tube. The connection to this movable electrode was made by means of a nichrome wire helix. The resistance of the nichrome wire in the tube with mercury was 40 ohms, and in the tube without

The starting characteristics of the discharge were described by four voltages E_1, E_2, GSV, and ASV. These voltages, each measured across the tube only, were observed in the order listed as the voltage applied across the tube and the inductance in series with it was increased. These voltages are defined as follows:

(1) E_1 is the rms voltage at which a brush discharge carrying a few microamperes between the movable electrode A and the grounded water jacket first appeared.

(2) E_2 is the rms voltage at which a current of about 5×10^{-6} amperes flowed from electrode A to electrode B. This is the lowest voltage at which the discharge between A and the water jacket fills the tube as far as electrode B.

(3) GSV is the glow starting voltage and is the maximum voltage reached prior to a glow discharge carrying a current of 2×10^{-3} amperes between the two electrodes.

(4) ASV is the arc starting voltage and is observed just prior to the drop in voltage and increase in current due to the onset of an arc discharge between the electrodes.

In addition to these voltages associated with the starting of the arc, the operating voltage of the arc, AOV, at a current of 0.4 amperes rms, was also measured.

The electrical circuit used is shown in Plate I in the appendix. A variable ac voltage was obtained from an autotransformer followed by a 1:10 step-up transformer. The variable autotransformer was driven by means of a constant-speed motor at such a rate that the voltage across the secondary of the step-up transformer increased at 25 v/sec.

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The magnitude of the current flowing to the fixed electrode was indicated by means of an Ne-2 lamp which was actuated by an amplifier followed by a 1N34 rectifier and a filter working into the grid of a 6SJ7, the Ne-2 being connected in the plate circuit of the 6SJ7. With no output from the amplifier, the 6SJ7 was biased beyond cutoff. The gain of the amplifier was adjusted so that with both S_1 and S_2 open, a current of 5×10^{-6} amperes through the 400 ohm resistor provided sufficient output to light the Ne-2. With S_1 closed, the sensitivity of the circuit was 2×10^{-3} amperes. Thus the circuit could be used to measure either E_2 or GSV depending on whether S_1 was closed or open.

To determine the instant at which E_1 should be measured, the current to the water jacket was observed by means of an oscilloscope. The voltage E_1 was that at which short pulses due to the brush discharge appeared as distinguished from the sinusoidal current due to capacitative effects.

The following procedure was used in making measurements. The arc was first operated for 10 minutes with a current of 0.4 amperes rms and an electrode separation d=80 cm. During this time a spectrum of the positive column was taken with a Bausch & Lomb medium quartz spectrograph. The arc was then turned off for a period of five minutes. After that, the arc was started once every minute, using the constant-speed motor to turn the variable autotransformer. GSV and ASV were recorded for each starting of the arc. Five measurements of each voltage were made at each of the following distances in the order given: 80, 70, 60, 50, 40, 30, 20, 10, 5, and 80 cm. It was normal for the 80 cm measurements at the end of the run to be lower than at the beginning. The graphs show the averages of the readings for each value of d.

E_1 was measured with the oscilloscope as described above after the final five readings at 80 cm had been obtained. The electrode separation was also 80 cm when E_1 was measured. Finally, the operating voltages were measured while the arc current was 0.4 amperes.

RESULTS

Plate II in the appendix shows the results obtained in the mercury-free tube. The curves labeled GSV and ASV represent the glow and arc starting voltages as defined above. The arc operating voltages AOV are the voltages measured across the tube, and include the voltage drop in the nichrome lead wire. The approximate voltage across the arc itself may be found by subtracting the drop in the wire from the voltages shown. At 0.4 amperes the voltage drop in the wire was 0.4x70 = 28 v.

The results of measurements in the tube containing mercury are shown in Plate III in the appendix. Since the nichrome wire in this tube had a resistance of only 40 ohms, the correction to the arc operating voltages is 0.4x40 = 16 v. Unfortunately during the collection of the data shown in Plates II and III in the appendix it was not possible to acquire all of the data desired. For example, the cathodes in neon are quickly destroyed when the pressure is at less than 6 mm Hg. Furthermore, arc striking potentials in xenon could not be adequately measured since they were considerably lower than the glow striking potentials. As a result of the latter condition, the start of the glow was followed almost immediately by the transition to the arc, so that the ASV could not be read to the accuracy desired on the voltmeter. This effect became more pronounced with increased pressure so that it was impossible to take measurements at a pressure of 8 mm.

Plate IV in the appendix shows the values of E_2 and GSV obtained at various times in the mercury-free tube. All measurements were made with 10 mm Hg of neon. The curves for GSV are labeled A, B, and C according to the chronological order of the measurements. The corresponding curves for E_2 are indicated by B' and C'. The mercury-free tube developed increasing amounts of deposits on the wall from electrode sputtering during the life of the tube. When the results of the curve A were obtained, the tube wall was almost free of these deposits, while curve C represents the results with a large amount of material deposited at irregular intervals along the tube wall.

Plate V in the appendix shows E_1, E_2, GSV, and ASV for argon without mercury at 4 mm Hg. Plate VI in the appendix shows E_1, E_2, GSV, and ASV in argon and mercury at 4 mm Hg. The curves for ASV are labeled according to the chronological order of the measurement. These curves represent the work of many weeks and a large number of intervening measurements. For GSV the range of values is indicated with the curve drawn through the averages. Plate VII in the appendix shows E_1, E_2, GSV, and ASV for Ne Hg at 10 mm Hg.

The currents immediately prior to the starting of the arc were measured in argon-mercury mixtures at various values of p and d. The results are shown in Table 1. The values for other gases are presented in Table 2 along with values for argon given for comparison. Differences in the values for argon given in Tables 1 and 2 are probably due to the fact that different tubes were used for the two series of measurements. The values shown in Table 2 were obtained with an electrode separation of 15 cm.

The current to the water-jacket was measured in the tube containing mercury and argon at 4 mm Hg. With 300 volts rms applied to the movable electrode, and the other electrode disconnected, a current of 0.3 amperes rms was found.

Table 1. Current immediately preceding the start of the arc as a function of pressure and electrode separation in Argon Mercury.

d	p		
cm	2mm	4mm	8mm
80	44ma	31	26
70	44	31	26
60	43	31	26
50	43	31	26
40	43	30	26
30	42	31	27
20	42	31	26
10	42	30	26
5	42	30	26

Table 2. Current immediately preceding the start of the arc for inert gases mixed with mercury at a total pressure of 6 mm Hg.

Gas	Arc starting current
Ne Hg	130
A Hg	41
Kr Hg	27
Xe Hg	16

The spectrum from the region near the cathode exhibited lines of both mercury and the major gas in all mixtures with inert gases.

The spectrum of the positive column showed strong mercury lines in all mixtures containing mercury. In the case of neon and mercury, several neon lines appeared weakly in the region between 5700 and 7000 A. These may, however, have been due to scattered light from the regions near the electrodes, since the red neon lines were emitted with great intensity from those regions.

In the case of argon and mercury, argon lines were barely discernable on the plates with 8-minute exposures. In krypton and mercury, four krypton lines, 5871, 5570, 4320 and 4274, A, of médium intensity were found. These lines were, nevertheless, at least a factor of 10 weaker than mercury lines in the same region of the spectrum. In xenon and mercury, xenon lines appeared at 4624 and 4671 A. The mercury lines were weaker in xenon than in the other gases used. The 3126, 3132, 3341, 3663, 4078, 5770 and 5791 A Hg lines were of intensity comparable to the two Xe lines. In the pure gases, all lines found could be identified as belonging to the gas used, thus showing no evidence of impurities. In the mixtures with mercury, no impurities were found, except in neon and mercury. In the latter case, weak bands appeared at 3880 A during part of the work. These bands probably were caused by the CN molecule.

With the apparatus used, only the region between 2900 and 7000 A was accessible to observation, limited above by the range of the spectrograph, and below by absorption in the pyrex glass.

DISCUSSION

The voltage designated as E_2 may be regarded as the voltage at which the discharge between the movable electrode and the tube wall extended the length of the entire tube, but had not yet been modified appreciably by the presence of the other electrode. It is clear that the longitudinal current cannot be uniform at all points along the length of the tube in a discharge of this type, since current flows between the tube wall and the ungrounded electrode. Furthermore, this type of discharge can never exist in an equilibrium condition in the sense that a dc arc can be in equilibrium, since direct current can not pass through the wall of the tube. Therefore, a theoretical treatment of this type of discharge would require a consideration of at least three independent variables: time, distance along the tube, and radial distance from the axis of the tube. The resulting differential equations have not at this time yielded to analytical methods of solution and must, therefore, be treated by numerical methods. Complete computations of this nature have not been carried out, and therefore, the interpretation of E_2 in terms of fundamental processes must be somewhat uncertain. However, comparison of Plates IV and VII, as well as V and VI shows that the addition of mercury to either neon or argon decreases E_1 and E_2. This suggests that the Penning effect plays a role in initiating and extending the wall discharge in argon-mercury and neon-mercury mixtures. This is to be expected, since the current densities in portions of the discharge must be quite low.

Because of the shielding effect of the grounded water jacket, the potential gradients near the grounded electrode were small as long as the wall discharge had not reached the grounded electrode. Thus, it appears likely that a discharge between the electrodes could not have started at voltages lower than that required to extend the wall discharge over the entire length of the tube. On the other hand, it may be possible that the wall discharge can cover the distance between the electrodes at a lower voltage than is required to operate a glow between the electrodes. Therefore, the glow starting voltages, GSV, should either correspond to the operating voltage of glow at 2 ma or should equal E_2. It appears from Plates III and IV that the latter condition occurred at short electrode separations. The operating voltage for a glow discharge would be expected to be a linear function of the electrode separation, since the potential gradient in the positive column should be uniform when the wall current is negligible. This expectation is confirmed by Plates IV and V, where it is evident that GSV was a linear function of d at those values of d where $GSV>E_2$.

The dependence of E_2 on the condition of the tube wall is illustrated by Plate IV. A theoretical explanation of the phenomenon is not possible at the present time, but it may be surmised that the coating on the tube wall was slightly conducting, thus tending to reduce longitudinal potential gradients. This would be expected to increase the voltage required to extend the glow across the tube.

In gases where the Penning effect cannot occur, the following two processes are important: ionization of gas atoms from the ground state by electron collision, and ionization of metastable atoms by electron collision. If the metastable atoms involved in the second process are produced by collision of atoms in the ground state with electrons, then the number of metastable atoms may be expected to be proportional to the concentration of electrons. The rate of ion production should be proportional to the product of the electron concentration and the metastable atom concentration. The ion production from this two-stage process should, therefore, be proportional to the square of the current density. The ion production from the single-stage process, however, may be expected to be directly proportional to the current density. At low current densities, therefore, the single-stage process may predominate, while at higher current densities the two-stage process may be more important, since it does not require as high electron energies as the direct ionization from the ground state.

The effects observed in each gas will now be discussed separately.

Neon

Compared to the other pure gases, neon had the lowest glow starting voltages. The reason for this is not known. It may be noted, however, that the ratio of ionization potential to excitation potential is lower in neon than in any of the other gases used. Also, the collision cross section of neon is smaller than for the other gases. If the single-stage process is responsible for ionization at currents of the order of 2 ma, then the number of electrons with energies above the ionization potential of the gas should be a significant factor in determining the starting characteristics of the discharge. It has been shown by Barbiere (1951) that the maximum energy of electrons in a gas is limited largely by the first excitation potential of the gas, with only a small fraction of electrons possessing energies appreciably above this excitation potential. Therefore, the ratio of ionization potential to excitation potential may be expected to bear some relationship to the potential gradients required for starting a glow.

The addition of mercury to neon did lower the GSV and ASV, although the effect was not as great as in the case of argon. This may be attributed partly to the fact that the glow starting voltages in pure neon were already low compared to the GSV in pure argon.

As can be seen from Plates II and III, the addition of mercury did not have any appreciable effect on the AOV.

Argon

The lowering of glow starting voltages by the addition of mercury was very large in the case of argon. This may probably be attributed to the Penning effect, i.e. the ionization of mercury by collisions between ground-state mercury atoms and metastable argon atoms. It will also be noted that for argon-mercury mixtures, the GSV curves were straight lines, whereas they deviated considerably from linearity for pure argon. This suggests that in pure argon the glow started as soon as the wall discharge had bridged the gap between the electrodes, while in the A-Hg mixture the wall discharge crossed the tube at a sufficiently low voltage so that GSV corresponded to the operating voltage of a glow of 2 ma.

The slopes of the ASV curves are reduced slightly by the addition of mercury. The points at which these curves cross the d=0 axis, however, are not appreciably affected by the presence of mercury.

The arc operating voltages were, as in the case of neon, not affected by the presence of mercury.

Krypton

In the case of krypton, it is evident that although the glow and arc starting voltages in mixtures with Hg were somewhat lower than without mercury, the effect was not as pronounced as in the case of argon. It also appears that even when mercury was added, the GSV curves were not linear. This means that the addition of mercury did not lower the voltage required for the wall discharge to cross the tube to a value below the operating voltage of a 2 ma glow discharge. This can probably be attributed to the fact that one of the metastable levels of krypton is below the ionization potential of mercury although the other metastable level is slightly above. (Plate VIII in the appendix).

The arc operating voltages, again, were not affected by the presence of mercury.

Xenon

In xenon, the glow starting voltages were not affected appreciably by the admixture of mercury. This is probably due to the fact that xenon does not have any metastable levels above the ionization potential of mercury. It is again evident that the GSV curves do not follow straight lines.

General Characteristics

It appears that the GSV curves are linear only in gas mixtures where the Penning effect can occur, although pure neon may be an exception.

The arc operating voltages in general did not appear to be affected by the presence or absence of mercury. In the case of argon and neon, this may have been only fortuitous. The results of Kenty, as well as those of Waymouth and Bitter indicate that in argon-mercury arcs only the mercury contributed significantly to the ionization in the positive column, while in pure argon, the ions must necessarily be argon ions. Thus the similarity of the arc operating voltages in the pure gases and mercury mixtures could be attributed to the fact that at the current densities used in the arc, two-stage ionization in the pure gases contributed sufficiently to the ionization to lower the potential gradients to values comparable to those in mercury mixtures. In krypton and xenon, however, the arc operating voltages would be expected to depend to a lesser degree on the presence of mercury for the same reasons that the glow starting voltages were only slightly affected by its presence. It should be remembered that the actual voltage drop across the arc was about 16 volts less than shown on the graphs for mercury mixtures, and about 28 volts less than shown for the pure gases.

Since the ASV and AOV, as shown in Plate III, are linear functions of d, they can be expressed as

$$ASV = A_s + B_s d$$

and

$$AOV = A_o + B_o d$$

where d is the electrode separation in cm. The values of A_s, A_o, B_s, and B_o are listed in the table below, together with the arc starting currents from Table 2 and the atomic weights and atomic numbers of the gases.

Table 3.

Gas	At.No	At.Wt.	arc starting current ma	A_s volt	B_s v/cm	A_o volt	B_o v/cm
Ne	10	20	130	330	1.4	44	1.4
A	18	40	41	235	1.5	19	1.0
Kr	36	84	27	275	1.7	14	0.6
Xe	54	131	16	335	2.1	10	0.5

The data shown in Table 3 refers to mixtures of the given gases with mercury, at a total pressure of p=6mm Hg.

It may be noted from Table 3 that the arc operating voltage constants, A_o and B_o, decreased in the order of increasing atomic number—they were highest for neon and lowest for xenon. This can be attributed to the lower ionization potentials of the heavier gases and to their larger collision cross sections.

The currents immediately prior to the starting of the arc, listed in Table 1, were independent of the electrode separation within experimental error. This can be explained by assuming that the transition to the arc is caused by conditions at the cathode, and that conditions at points separated by several tube diameters from the cathode can not influence the condition at the cathode. Thus, if the electrode separation is more than approximately 10 cm, the position of the anode would not be expected to exert any influence on the starting current of the arc. The arc starting voltages should therefore correspond to the operating voltages of a glow of sufficient current to condition the electrodes for transition to the arc. The operating voltage of a glow discharge of constant current would be expected to be a linear function of the electrode separation. Hence, the ASV curves should all fall on straight lines.

Table 3 shows that the arc starting currents decreased as the atomic mass of the gas increased. On the other hand, the potential drops at the electrodes, A_s, obtained by extrapolating the ASV curves to zero electrode separation, are seen to increase as the atomic mass increases. This suggests that the power, or perhaps the momentum transfer per unit area required to condition the electrodes for transition to the arc may be approximately constant for all gases. The present information is not sufficient to verify this, since the size of the cathode spot covered by the arc was not measured due to the difficulty involved in defining it.

CONCLUSIONS

The following conclusions can be drawn concerning electric discharges in long, shielded discharge tubes under conditions comparable to those described above:

(1) The initial discharge observed is a brush discharge between the ungrounded electrode and the grounded lamp wall. Since the gap involved is

quite short, the properties of this discharge should be predictable on the basis of the work of Paschen (1889), Townsend, Penning, and others who have measured the onset of small discharge currents across short gaps.

(2) A glow discharge occurs in an elongated tube only after the discharge has been extended along the tube wall until it bridges the gap between the two electrodes, and the applied voltage has been raised to a point that it will support a stable discharge without significant contributions to ionization from wall current. The necessary voltage depends on:

(a) External and internal lamp wall conductivity.

(b) Type of gas. Mixtures in which mercury atoms could be ionized by collisions of the second kind with metastable atoms of the major constituent of the gas, showed much lower starting voltages than other gases or mixtures. Neon appears to be an exception, giving low starting voltages in the pure gas without mercury.

(3) The arc starts in such a tube when the glow operating current becomes sufficient to condition the electrodes to emit the larger arc currents. This current depends on the gas, being smaller for heavier gases, but is not affected significantly by addition of mercury except possibly in the case of argon. The operating voltage of the glow just before the start of the arc was a linear function of the electrode separation in all cases where it could be accurately measured. The electrode drop, obtained by extrapolating the ASV to zero electrode separation, depended only on the major gas present, while the slope of the ASV curves was lowered somewhat by the admixture of mercury in neon and argon.

(4) Both the slope and intercept of the arc operating voltage curves were lower for the heavier gases than for the lighter ones. The AOV's were not affected significantly by the admixture of mercury.

One may apply the above four conclusions to an elongated gaseous discharge tube in the following manner:

The choice of gas for such a tube depends on its specific use. If low operating voltages are of primary importance, xenon or xenon-mercury mixtures would be suitable. These, however would require high voltages for starting. On the other hand, low glow starting voltages could be obtained with neon or neon-mercury mixtures. Neon-mercury mixtures, however, may be unsuited for fluorescent lighting because of the characteristic red glow which appears near the electrodes, although the positive column emits only the mercury spectrum. At extremely low temperatures neon may be easier to start than Argon - Hg, since neon appears to give low starting voltages without mercury. For general use in high voltage instant starting fluorescent lighting, however, argon and mercury may be the most suitable combination.

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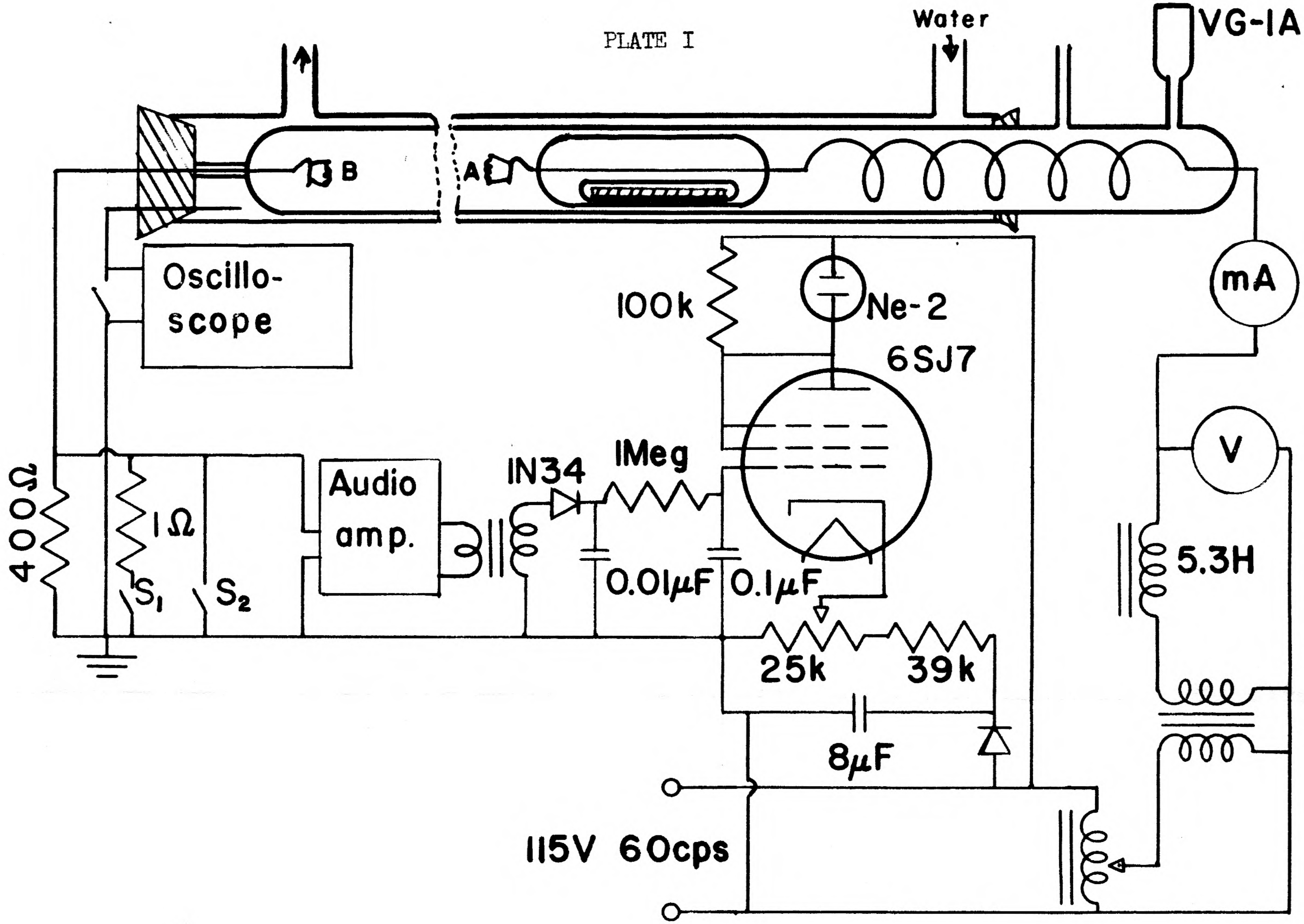
APPENDIX

EXPLANATION OF PLATE I

Diagram of the apparatus used for the measurement of glow and arc starting voltages and arc operating voltages.

PLATE I

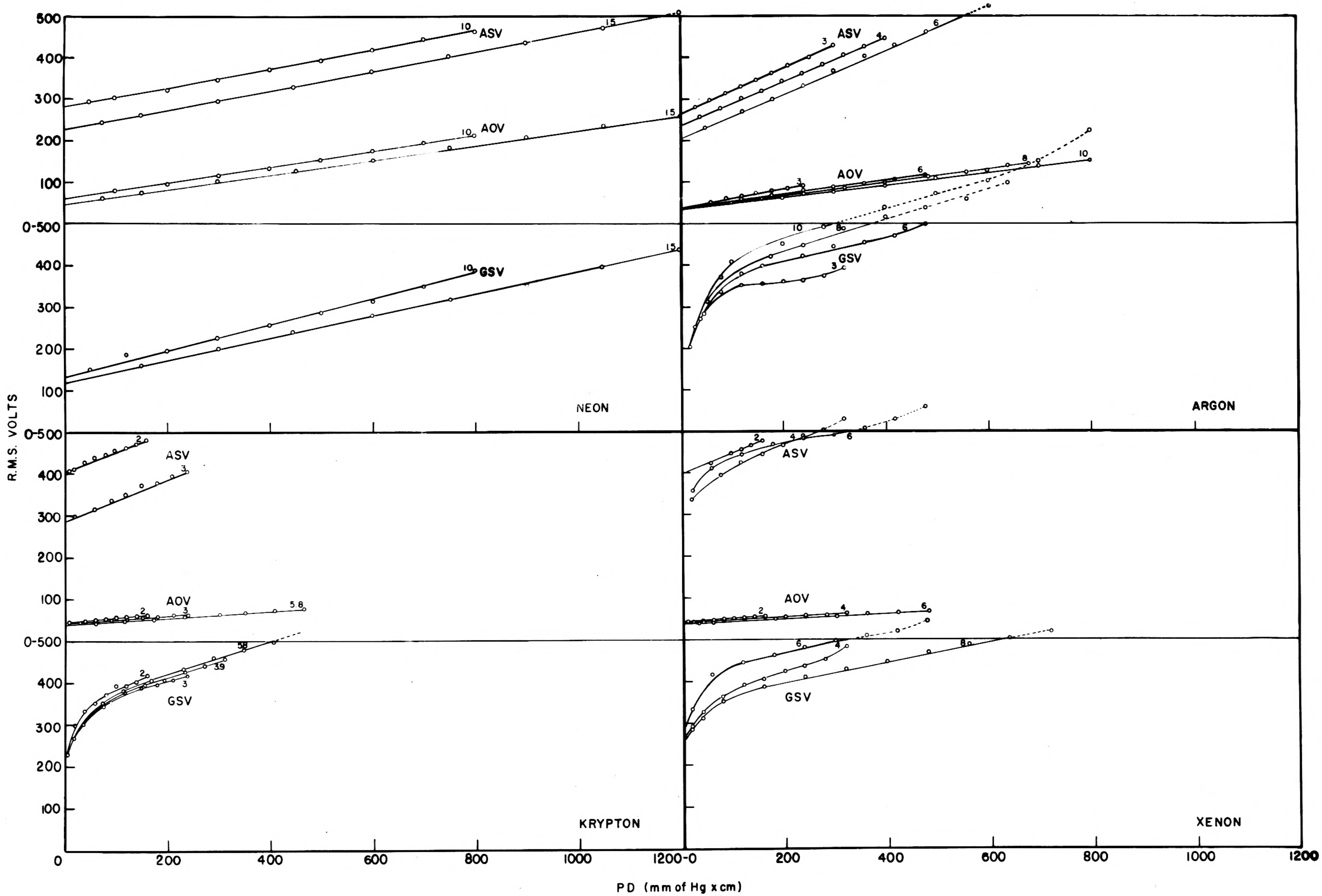


Water
VG-1A
B
A
Oscillo-
scope
100k
Ne-2
6SJ7
mA
V
400Ω
1Ω
S_1
S_2
Audio
amp.
IN34
IMeg
0.01µF
0.1µF
25k
39k
8µF
5.3H
115V 60cps

EXPLANATION OF PLATE II

Glow starting voltages, GSV, are starting voltages, ASV, and are operating voltages at 0.6 amp, AOV in rare gases without mercury. The AOV include a drop of 28 volt across the lead wire, which should be subtracted from the values shown to obtain voltage drop across the arc.

PLATE II

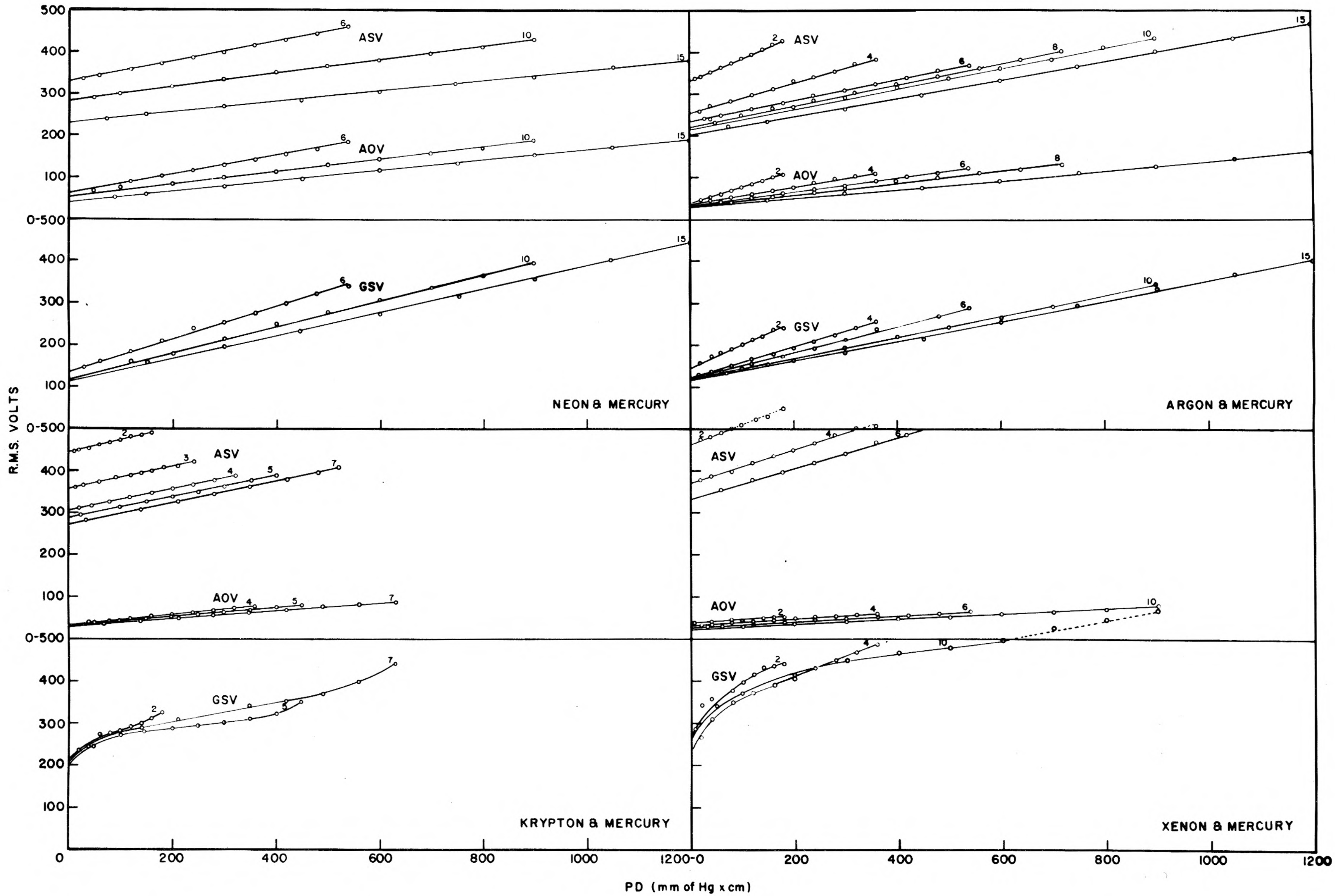


ASV
AOV
GSV
NEON
ARGON
KRYPTON
XENON
R.M.S. VOLTS
PD (mm of Hg x cm)
0
200
400
600
800
1000
1200
100
300
500

EXPLANATION OF PLATE III

Glow starting voltages GSV, arc starting voltages ASV, and arc operating voltages at 0.6 ampere AOV in rare-gas mercury mixtures. The AOV include a voltage drop of 16 volts in a lead wire, which should be subtracted from the values shown to obtain actual voltage across the arc.

PLATE III

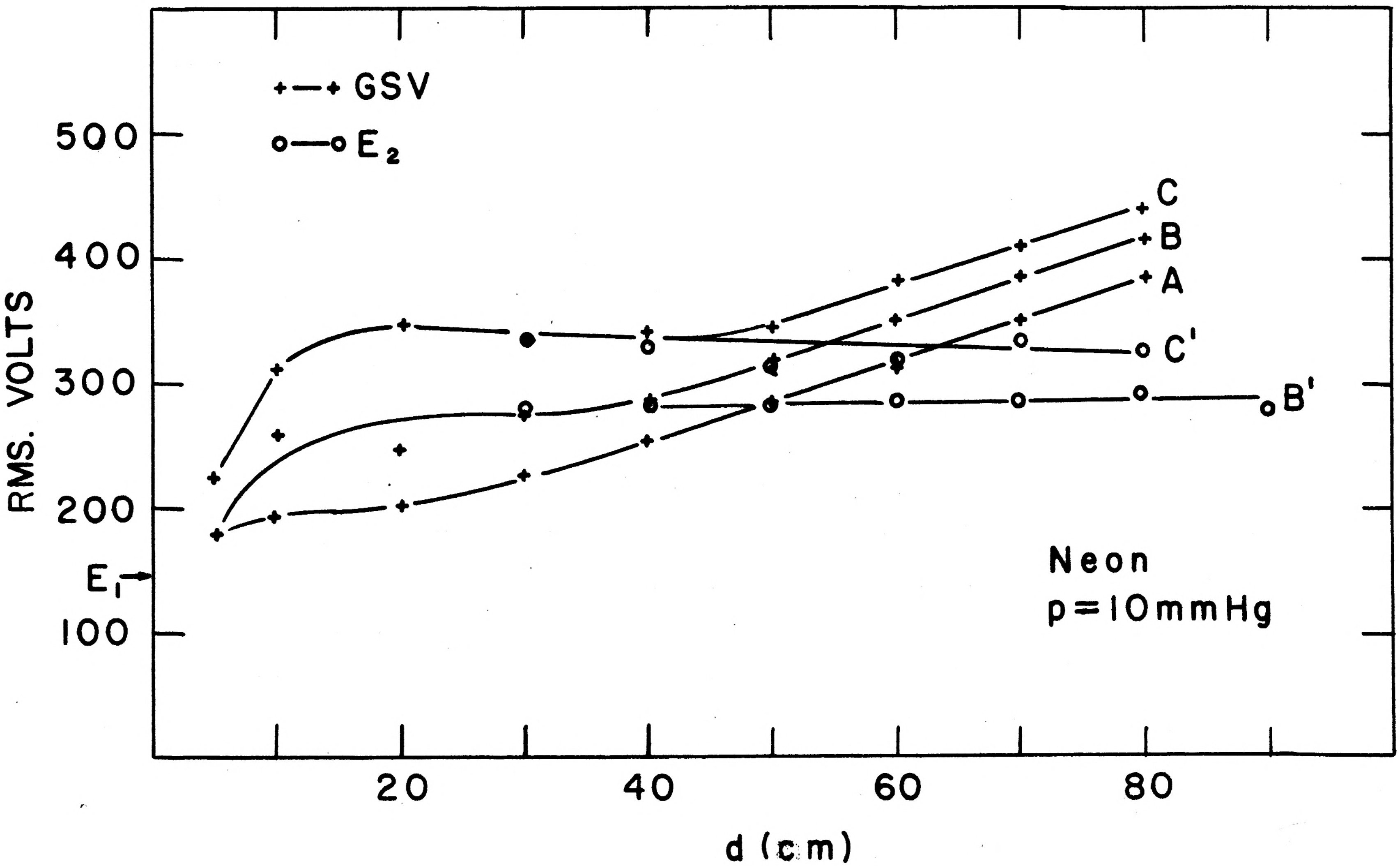

ASV
AOV
GSV
NEON & MERCURY
ARGON & MERCURY
KRYPTON & MERCURY
XENON & MERCURY
R.M.S. VOLTS
PD (mm of Hg x cm)

27

EXPLANATION OF PLATE IV

E_1, E_2, and GSV, as defined in text, for Neon without mercury at 10 mm Hg. The curves are labeled according to chronological order of measurements. The unprimed letters indicate curves for GSV, and the primed letters indicate corresponding curves for E_2.

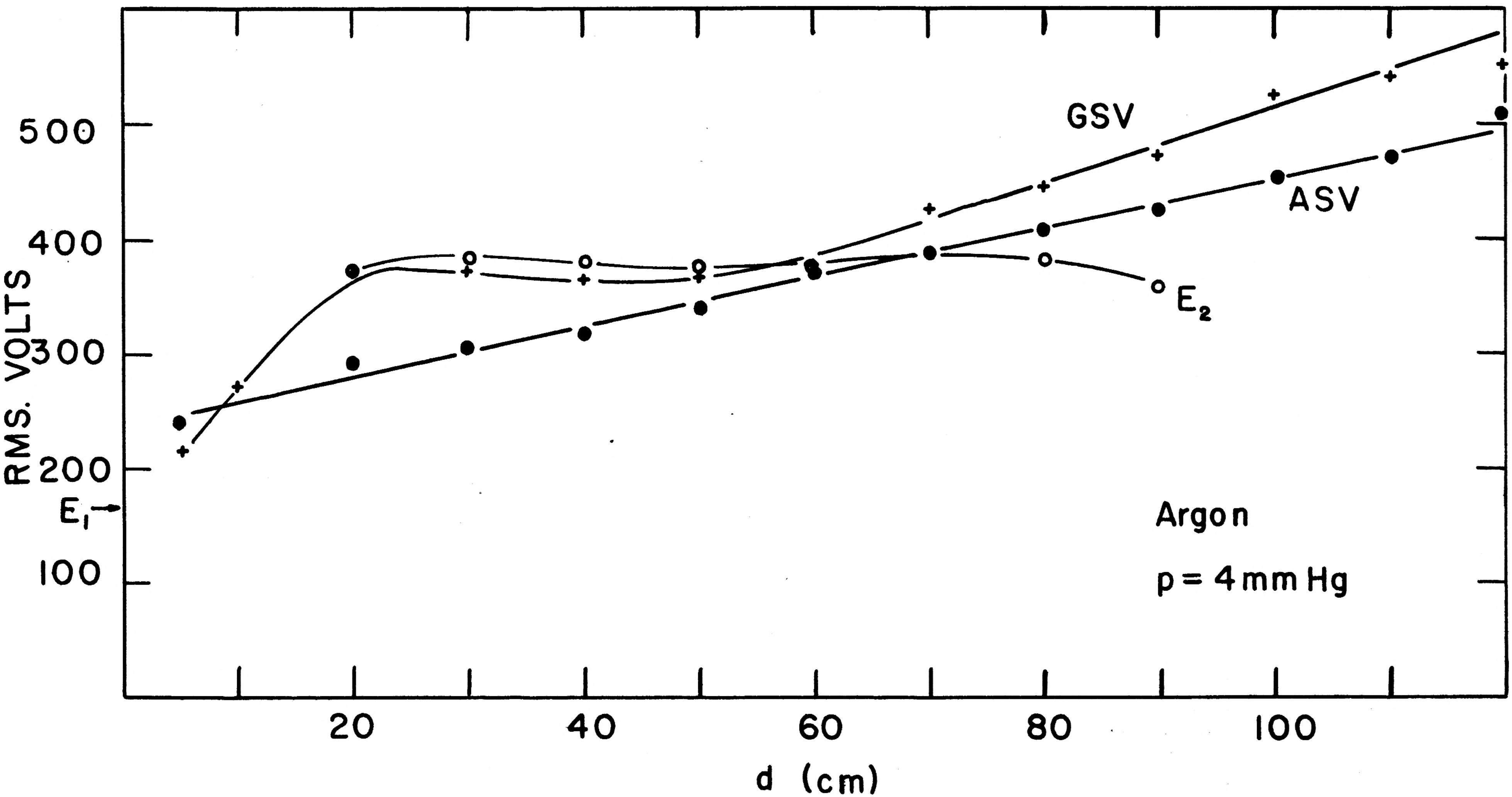
PLATE IV



GSV
E_2
C
B
A
C'
B'
RMS. VOLTS
500
400
300
200
100
E_1
20
40
60
80
d (cm)
Neon
p=10mmHg

EXPLANATION OF PLATE V

E_1, E_2, GSV, and ASV, as defined in text for argon at a pressure of 4 mm Hg.

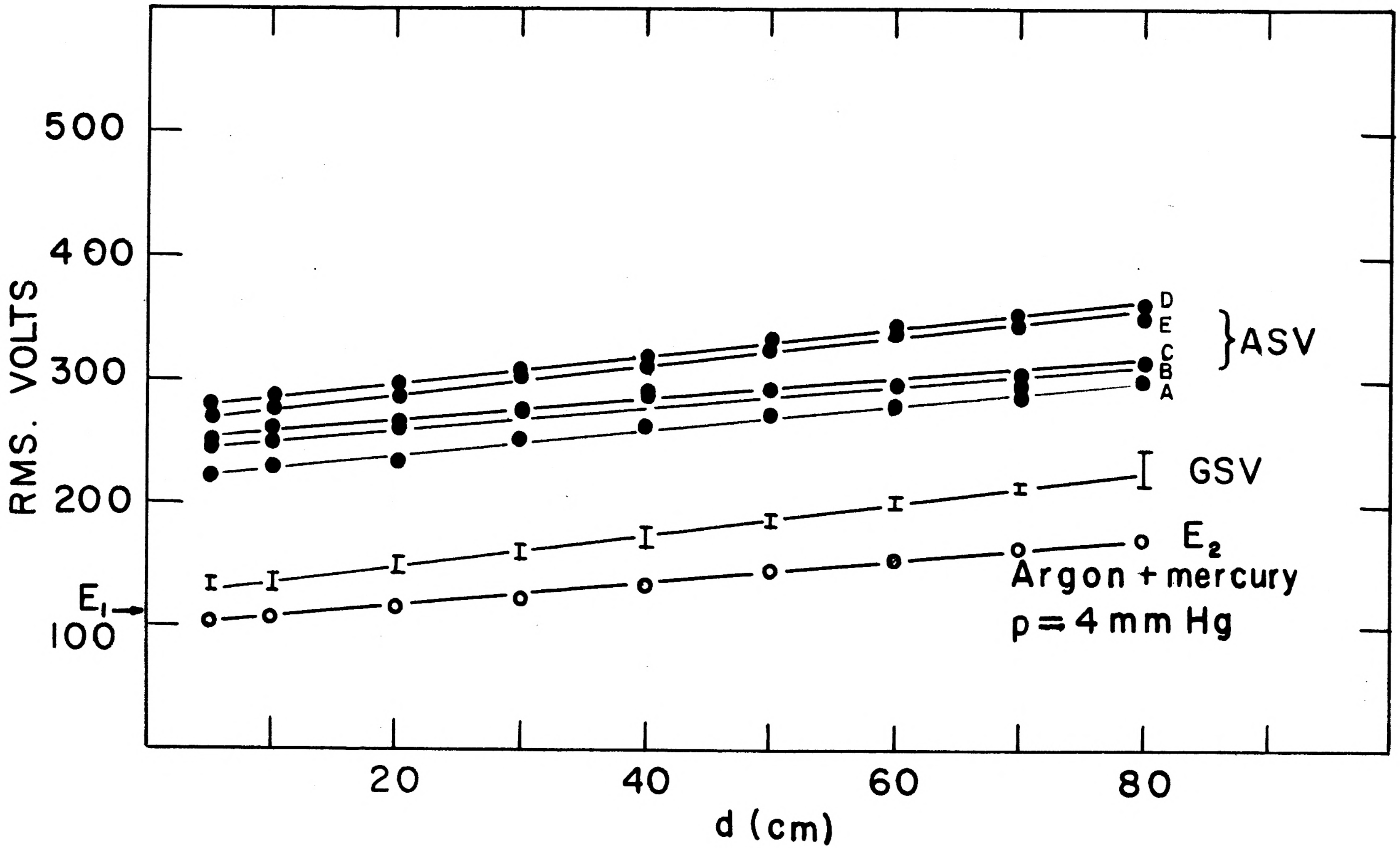


GSV
ASV
E_2
E_1
RMS. VOLTS
500
400
300
200
100
20
40
60
80
100
d (cm)
Argon
p = 4 mm Hg

EXPLANATION OF PLATE VI

E_1, E_2, GSV, and ASV, as defined in text for argon and mercury at 4 mm Hg. The curves for ASV are lebeled according to chronological order of measurements which extended over several months of time and included a large number of intervening measurements with other gases. The increase in cathode drop may be due to cathode deterioration.

PLATE VI

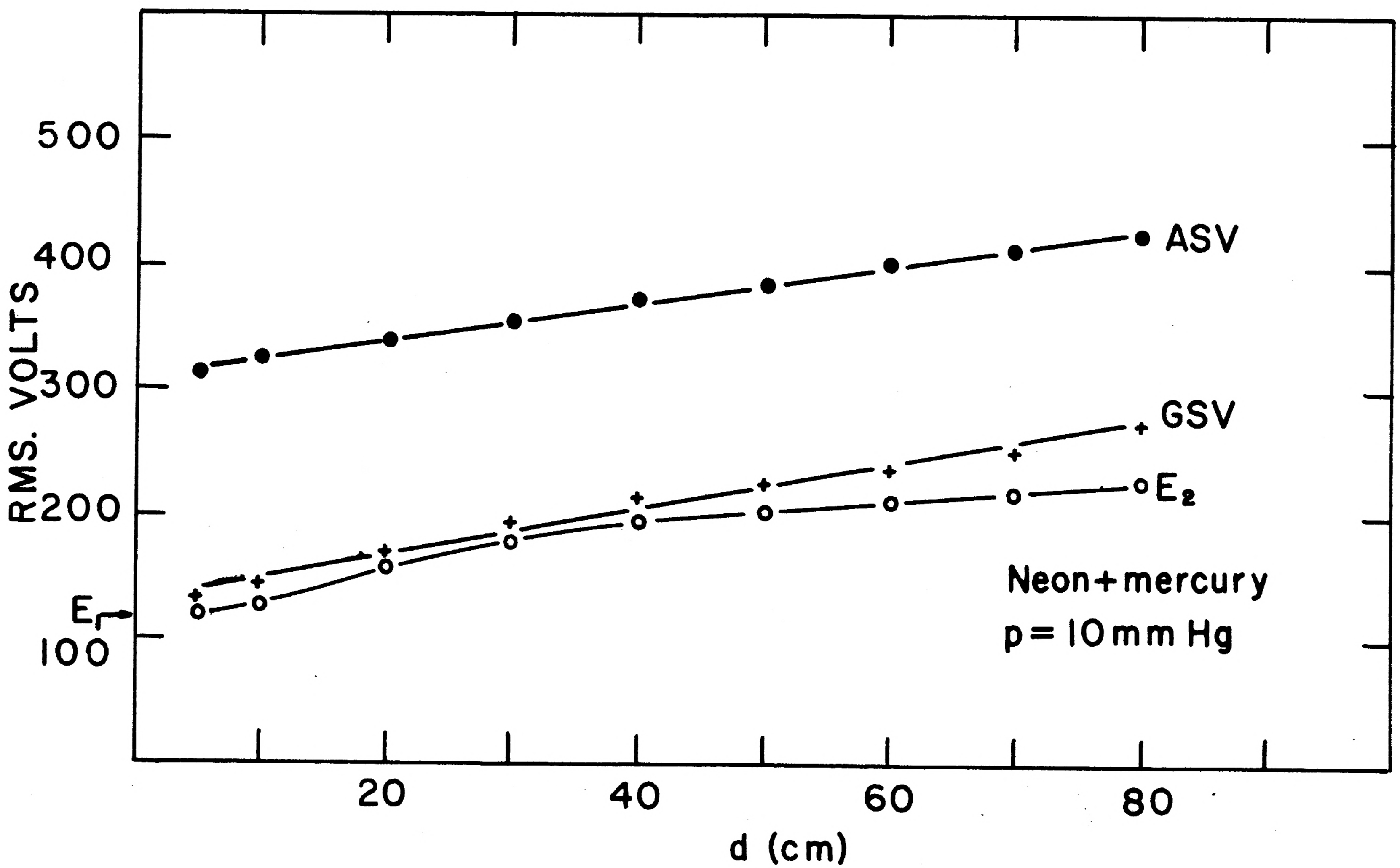


500
400
300
200
100
RMS. VOLTS
E_1
D
E
C
B
A
ASV
GSV
E_2
Argon + mercury
p = 4 mm Hg
20
40
60
80
d (cm)

EXPLANATION OF PLATE VII

E_1, E_2, GSV, and ASV, as defined in text for Neon and mercury at 10 mm Hg.

PLATE VII

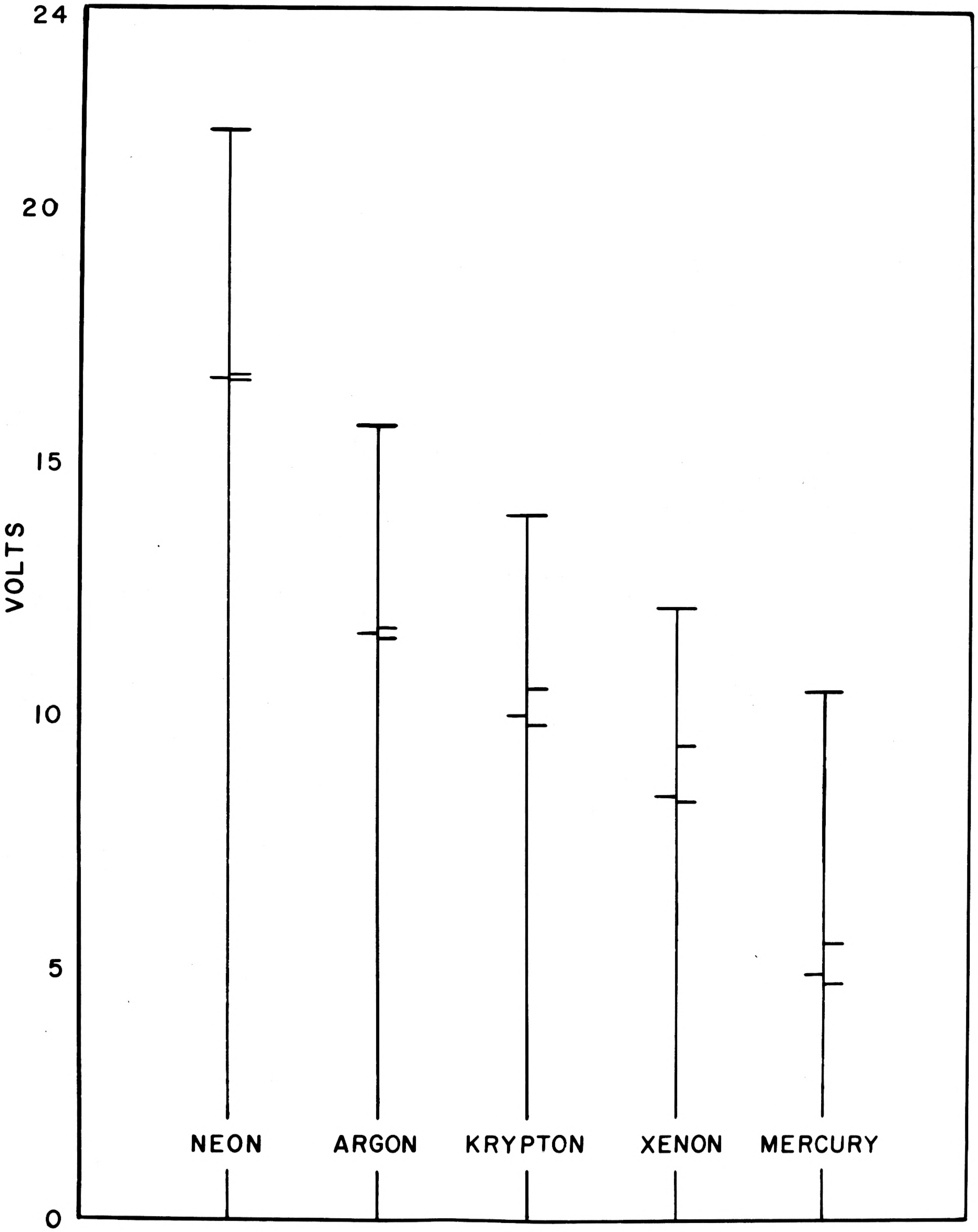


500
400
300
200
100
RMS. VOLTS
E_1
ASV
GSV
E_2
Neon+mercury
p = 10 mm Hg
20
40
60
80
d (cm)

EXPLANATION OF PLATE VIII

A diagram showing the first three excitation potentials and the ionization potentials for Ne, A, Kr, Xe, and Hg. The excitation potentials drawn to the right are metastable levels.

PLATE VIII



ARC AND GLOW DISCHARGES IN AN ELONGATED GLASS TUBE SURROUNDED BY A GROUNDED SHIELD

by

RAIMO BAKIS

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It is the purpose of this thesis to present experimental data on glow and arc striking potentials in argon, neon, krypton, xenon, and mixtures of these gases with mercury in a long discharge tube surrounded by a grounded shield.

Pyrex tubes of 38 mm inside diameter were used, in which one electrode was movable, while the other was fixed in the end of the tube. The tubes were surrounded by grounded water jackets, the temperature of which was kept at 21° C. The fixed electrode was grounded, and a gradually increasing alternating voltage was applied to the movable electrode. The starting characteristics of the discharges were described by four voltages, defined as follows:

The voltage at which a brush discharge between the movable electrode and the water jacket first appeared was designated as E_1.

The voltage at which the discharge between the movable electrode and the water jacket extended the length of the tube, as indicated by the appearance of a current of a few microamperes at the fixed electrode, was designated as E_2.

The maximum voltage prior to a glow discharge carrying a current of 2 milliamperes between the electrodes was designated as GSV.

The arc starting voltage, observed just prior to the drop in voltage and increase in current due to the onset of an arc, was designated as ASV.

The current just prior to the start of the arc was also measured. The operating voltage of the arc carrying 0.4 amperes was measured and will be designated as AOV.

It was found that in mixtures of neon and mercury, as well as argon and mercury, E_2 was approximately a linear function of the electrode separation, d.

In pure neon and pure argon, E_2 was higher than in the mixtures with mercury, and the slope of the curve of E_2 vs d decreased at increasing values of d.

In argon, the GSV was lowered considerably by the addition of mercury to argon. In neon and krypton, the addition of mercury resulted in slight lowering of GSV. In xenon, the GSV was practically unaffected by the presence of mercury. The relationship between GSV and d was linear in pure neon, but non-linear for the other pure gases. It was also linear in mixtures of argon and mercury, as well as neon and mercury, but was non-linear in mixtures of krypton and mercury, and xenon and mercury.

The ASV were linear functions of d, and they were affected by the presence of mercury to a lesser extent than were the GSV. The current just prior to the onset of the arc was independent of the electrode separation, but depended on the type of gas used, being lowest for the gases with the highest atomic numbers.

The arc operating voltages were only slightly affected by the presence of mercury, but they showed a definite dependence on the type of gas used, being highest for neon and decreasing in the order of increasing atomic number of the gas.