LOW PRESSURE STRIATIONS IN ARGON AND HELIUM GLOW DISCHARGES

by

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LOW PRESSURE STRIATIONS IN ARGON AND HELIUM GLOW DISCHARGES

Introduction

It is known that when a gradually increasing electric field is produced between two electrodes in a vessel containing a gas, a measurable flow of electricity starts before any visible signs of a discharge appear. This initial flow is called a dark discharge and exists until the applied potential exceeds a certain minimum value, termed the sparking potential. The transport of electricity, once the insulating properties of the medium have been overcome, is accompanied by a characteristic emission of radiation from the discharge tube.

If the gas is at atmospheric pressure, the discharge takes the form of a tortuous spark, which is often branched away from the positive electrode and is accompanied by sharp explosive-like sounds, or is seen to appear as sharp luminous streamers extending out from both electrodes. These are termed respectively a spark discharge and a brush discharge.

At atmospheric pressure the spark discharge is similar to the natural phenomenon of lightning, and if the gas is air the insulating properties break down at about 30,000 volts per centimeter. On reducing the pressure, the sparking potential becomes less and, at the same time, the conducting path becomes more diffuse and may ultimately occupy practically the whole of the containing vessel. This is usually referred to as a glow discharge.

When the pressure has been reduced to a few centimeters a dark layer, the Faraday dark space, can usually be observed separating a cushion of light on the cathode, the negative glow, from the positive column of light which extends to the anode. The pressure at which this is first seen and the luminosity of the positive column depend upon the nature of the gas and the distance apart of the electrodes. Particularly at the higher pressures the positive column is often almost non-luminous, and there is merely a glow representing it at the surface of the anode. The negative glow and Faraday dark space expand and move toward the anode when the pressure is further lowered, while the negative glow in turn is now seen to be separated from the cathode by the Crookes or cathode dark space. A luminosity, the cathode glow, usually persists within the latter immediately against the surface of the cathode and is, in some instances, separated from the electrode by a thin and intensely dark primary dark space. This is the normal glow discharge. The lower limit is at a pressure of about 10 microns. At this point the negative glow and the fluorescence on the walls is all the luminosity observed.

A typical glow discharge can be seen on Figure 1.

Starting from the cathode there is first a well-marked primary dark space. The region of light, the cathode glow, fades gradually into the main cathode dark space which is separated from the Faraday dark space by the negative glow. The negative glow has its maximum intensity of luminosity close to the negative boundary but fades off into the Faraday dark space. The positive column occupies all the remainder of the distance to the anode glow, the layer of light at the positive electrode.

In a glow discharge the field is not uniform but varies throughout the discharge and from one gas to another. An example of how the field varies is seen in Figure 2. If the discharge depicted were in hydrogen and if the pressure were 2.25 mm. of mercury, a plot of field against distance along the tube would look like the solid line (11, p. 512).

As is seen from this graph, practically all the potential drop takes place in the cathode dark space, and the difference in potential between the cathode and the negative glow is called the cathode fall of potential. This cathode fall is approximately independent of the current and pressure in the normal glow discharge but is found to vary with different gases and with the type of metal composing the cathode.

If the positive column presents a uniform, rather than a striated appearance, the field of the positive column is

FIGURE 1

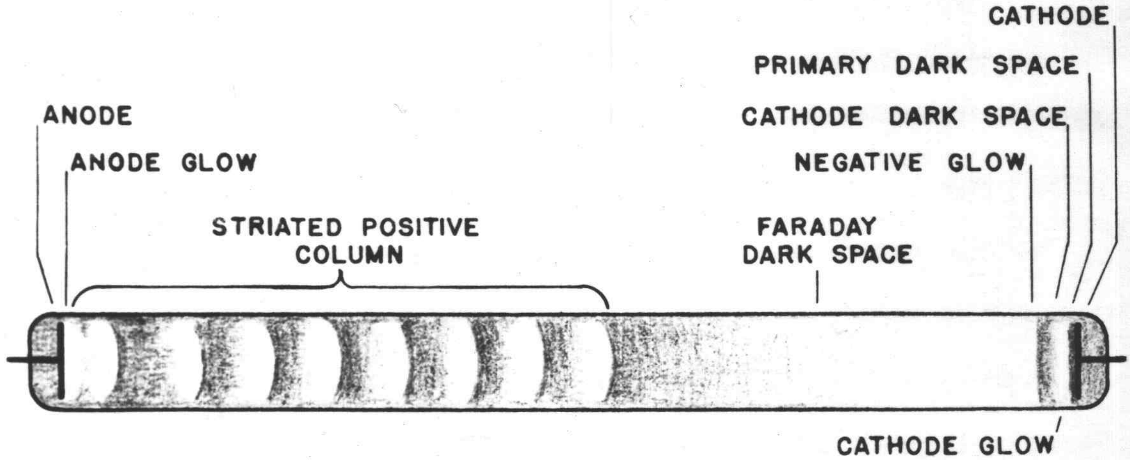
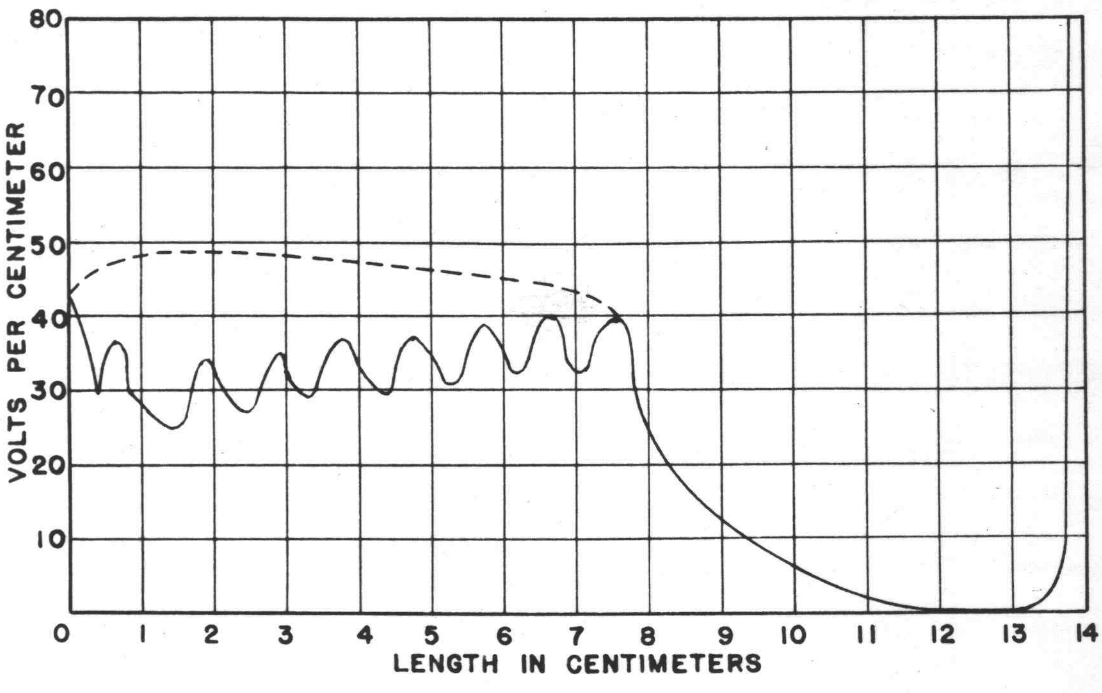


FIGURE 2



FIELD STRENGTH IN DIFFERENT REGIONS OF A NORMAL GLOW DISCHARGE of the form represented by the broken line on the graph in Figure 2 (5, p. 204).

The positive column is separated from the walls by a positive ion sheath across which there is a fall in potential that suffices to maintain a net zero current of ions and electrons between the ionized gas and the insulated walls. In the case of the striated column, where conditions vary between striations, the sheath on the walls suffers concomitant changes. In some cases there is a dark space between the anode glow and a uniform positive column.

In a pure monatomic gas it is thought that stationary striations occur over a limited range of pressures and current densities. With increasing contamination by other gases, the striations become more evident, and it is, therefore, not quite certain that they can be obtained at all with absolutely pure inert gases. In polyatomic gases the appearance of stationary striations is easier to produce, but again the range of conditions under which they can be formed is more restricted the greater the degree of purity. The appearance presented by striations is variable and often complicated.

In wide tubes several centimeters or more in diameter, or in a large spherical enclosure, the positive column is usually invisible. In this case the discharge diffuses over the whole volume, and the density of the excited atoms becomes too low to observe any light. This condition does not hold in some electro-negative gases, such as water vapor. In the case of wide tubes where the effect of the walls is negligible, the gradient is approximately proportional to the pressure.

The electric fields in narrow tubes, unlike those in larger containing vessels, depend upon the current density and the diameter of the tube, as well as upon the nature and pressure of the gas. This is due mainly to the presence of the insulating walls. These walls now disturb practically the whole of the ionized column when they draw the zero current from it, instead of merely affecting the periphery as they do in the case of wide tubes. This current occurs because the electrons, with their high thermal energy, diffuse to and collect on the walls. Unless the walls are quite conducting, however, there will be little flow of electrons through the glass and down the walls. This charges the walls to a negative potential, which is able to repel all but the faster electrons in the distribution. This at once sets up a positive radial potential gradient outward from the axis of the tube to the walls. As a result the equipotential surfaces in the positive column (which, in the absence of the wall potential, would be planes normal to the axis of the column) become curved surfaces of revolution about the axes whose cross section contours are ellipsoidal.

Due to this field produced by the electron diffusion to the walls and the consequent attraction and neutralization of positive ions, charges are being removed from the positive column and must be replenished by ionization. This migration of charge to the walls is known as ambipolar current or ambipolar diffusion (6, p. 561).

The current passing through the positive column is determined by conditions in other parts of the tube and in the external circuit, as well as by those in the column. The electric field in the column has to be sufficient to pass this current under the conditions prevailing locally. From the spectrum of the positive column it is known that little recombination of positive ions and electrons occurs within it; thus, the main function of the longitudinal field is to generate new ions and electrons at the rate at which they disappear toward anode, cathode, and walls.

On this basis, with the additional assumption that the positive and negative space-charges are equal at all points, a theory was developed for the uniform positive column which was in fair accord with experimental evidence. This theory held only for the special case of the uniform positive column.

The study of the uniformly striated positive column has led only to a qualitative explanation, for the data are not consistent enough to formulate a rigorous theory.

The primary factor in the production of striations has been ascribed to the effect of an inelastic collision upon the speed of an electron. Electrons describe tortuous paths under the conditions that are being considered and have a drift velocity that is superposed due to the effect of the electric field and diffusion upon a random thermal motion. The greater the thermal motion, the less is the drift velocity, percentagewise, imparted by a given electric field. Electrons of small temperature will, therefore, contribute more to the drift current but less to the negative space-charge than electrons of higher temperature. Electron temperature is the temperature in degrees Kelvin which would give an electron the same energy it would have when in thermal equilibrium at this temperature. When the kinetic energy of the electron is equated to the product of three-halves Boltzmann's constant and the temperature in degrees Kelvin, the electron temperature may be found in units of degrees Kelvin. The contribution of positive ions to drift and random currents is small compared with that of electrons.

The concept to which this leads is one of slow electrons starting with a large velocity of drift from the bright part of one striation, moving toward the anode. If the field is assumed to be almost uniform, they acquire on the way an increased temperature but a decreased drift motion. At a certain stage their thermal energies become so great that collisions with the gas molecules cease to be elastic. At this point they give rise to the formation of excited atoms or ionize the atoms, either directly or by a cumulative process. The electrons now have a greatly reduced velocity, for those which have suffered inelastic collisions have lost energy in the act. Those electrons which have been formed in the collisions are naturally slow, so they all move away with a relatively rapid drift motion until they again make inelastic collisions at a point nearer the anode. Layers in which there are great concentrations of excited atoms and ions thus result and are the bright parts of the striations. Immediately before the electrons make inelastic collisions they have their maximum temperature and minimum drift velocity so there is a local negative space-charge, the corresponding positive space-charge being spread over most of the region between the bright parts. A further effect of the negative space-charge is to concentrate the direct electric field there and so stabilize conditions by augmenting the ionization and excitation in this region.

Two other conditions must be satisfied in order for striations to form. The first is that the initial production of excited atoms should occur within a limited region. If not, a spatially diffuse general emission of radiation will occur as the atoms return to their normal states with a consequent disappearance of the striations. The restriction of production of excited atoms to a limited region is taken care of both by the effect of the concentration of the field at the heads[1] of the striations and by the fact that the excitation function usually falls off rapidly above an excitation potential (9, p. 442). The continuous luminous background, upon which striations are sometimes seen to be superposed, may be partly due to excitation by electrons which have passed the heads without undergoing inelastic collisions.

The second condition is that large numbers of atoms in excited, particularly metastable states, must be suppressed except at the heads of the striations. The average life of a metastable atom may be quite high, and if these metastable atoms were not localized at the heads of the striations, the positive column would be only a diffuse bright region since a collision of the second kind could occur at any part of the positive column. A collision of the second kind is a collision in which internal energy of an atom is transferred to an electron (7, p. 75).

The last major division of types of positive columns, and the type which is under investigation in this paper, is the positive column with moving striations.

In 1920 Aston and Kikuchi (1, p. 50) investigated the

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1. The head of the striation is the cathode side of the striation.

change of velocity of the striations in neon and helium with respect to a change of pressure. The apparatus was similar to the apparatus used in this study, which will be described later in the article.

The pressures used by Aston and Kikuchi were above a millimeter of mercury. This paper is an extension of their research into the lower pressure range of the normal glow discharge since the limits discussed here are from one millimeter down to about 30 microns, a micron being 10^{-3} mm. of mercury.

The results of Aston and Kikuchi show a relationship between the pressure and the velocity of the striations. The striations investigated were positive in nature since they traveled toward the negative electrode. In their data Aston and Kikuchi (1, p. 54) determined that the velocity of the striations in helium was roughly 50,000 cm. per second and varied inversely as the aquare root of the pressure.

Construction

To extend their data the apparatus in Figure 3 was constructed. Since only the positive column was of interest in this study, the discharge tube was so made that the positive column is restricted to a diameter of 0.75 cm. as seen in Figure 4. The Pyrex tubing is 62 cm. in length, and to a

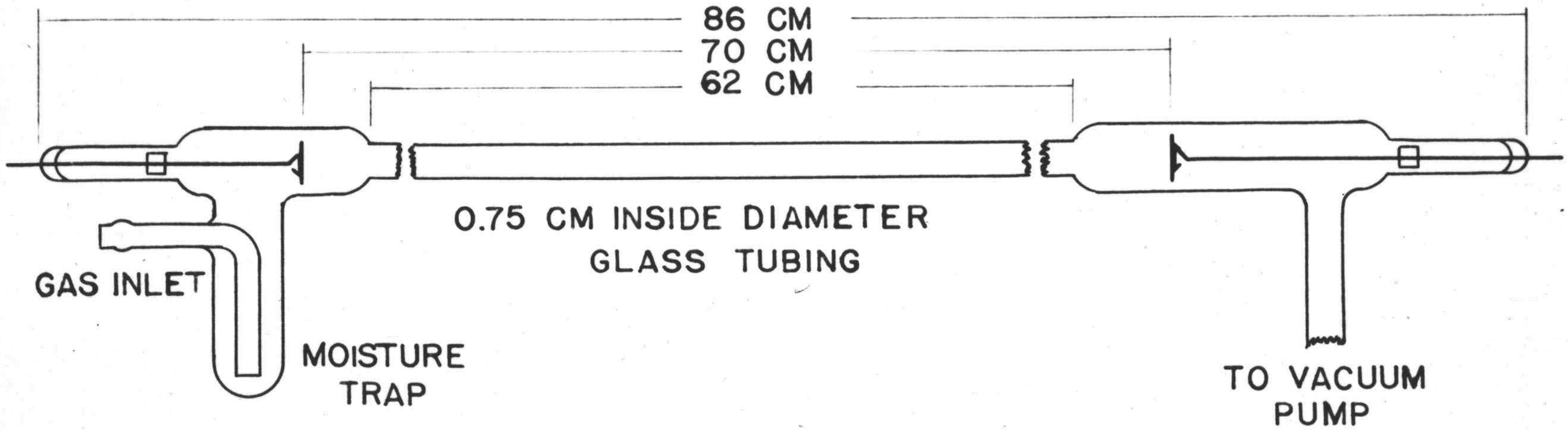
FIGURE 3

APPARATUS

The above is a front view of the apparatus. The device for measuring the angles is not included but was located directly above the mirror in a horizontal plane.

C is a mechanical counter used for counting the revolutions of the mirror at speeds below 600 revolutions per minute.

FIGURE 4



SCHEMATIC DIAGRAM OF GASEOUS DISCHARGE TUBE mirror at a distance of about half a meter the tube appears essentially a line source of light, and a moving striation appears a point source of light.

A front surfaced mirror, with effective dimensions of 3.5 by 14 cm., was affixed to a shaft with the axis of rotation parallel to the positive column. The speed of rotation of the mirror was continuously variable from about 50 r.p.m. to over 5,000 r.p.m., the speed of rotation being determined with a Strobotac[2] unit.

Immediately above the mirror, which was mounted in a horizontal plane with the discharge tube, was placed a device for measuring angles as seen in Figure 6. As shown in Figure 5, this device consisted of a straight edge placed parallel to the image of the positive column and two movable arms to be placed parallel to the image of the striations. This allowed the slopes to be measured and, knowing the time that the image was in view per revolution, the velocity of the striations could be computed.

Commercial gas was fed from the tank into the system in such fashion that the pressure could be controlled while the vacuum system was left in operation. This was necessary in order to read the pressure at any time, for the thermocouple gauge used to measure the pressure could not be included in

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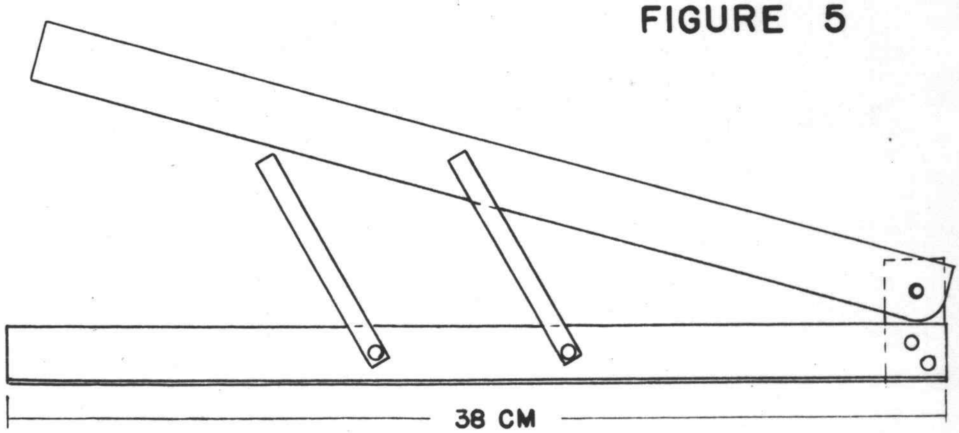
2. Trade name of stroboscopic tachometer manufactured by The General Radio Co., Cambridge, Mass.

FIGURE 5



DEVICE FOR DETERMINING ANGLES

FIGURE 6

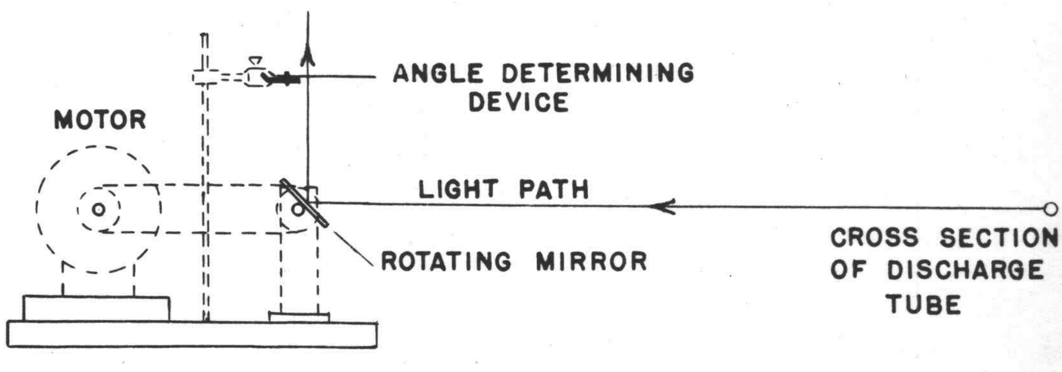


DIAGRAM OF OPTICAL SYSTEM

a static system. This type of gauge was used because it gives accurate pressure readings in the range from 1,000 microns to 10 microns. The error in reading the scale is about 5 per cent at 1,000 microns but goes down to about 2 per cent error at 30 microns.

The effective angle of the mirror (the angle through which the mirror would turn with the image in sight) was found to be 12 degrees, so the image was seen in the mirror for 1/30 revolution.

The motor speed was made continuously variable by changing the field current in the 110 volt d.c. motor. To do this a variable resistor was connected in series with the field windings. At any speed there was no observable variation of the mirror speed according to tests made with the Strobotac.

The potential difference across the tube was obtained from a direct current power supply that supplied a maximum of 5,000 volts and a maximum current of 10 milliamperes. The ripple voltage was less than 1/2 volt at under 2,000 volts with a current of 5 milliamperes. In series with the tube was placed a 150,000 ohm resistance to limit the current in order to keep the power supply from cutting out due to too large a current being drawn (there was an automatic cut-out to protect the mechanism in case the current exceeded 10 milliamperes).

The power supply was equipped with a voltage measuring instrument but since that registered the entire voltage drop in the circuit, the drop across the discharge tube was measured with a Simpson meter.

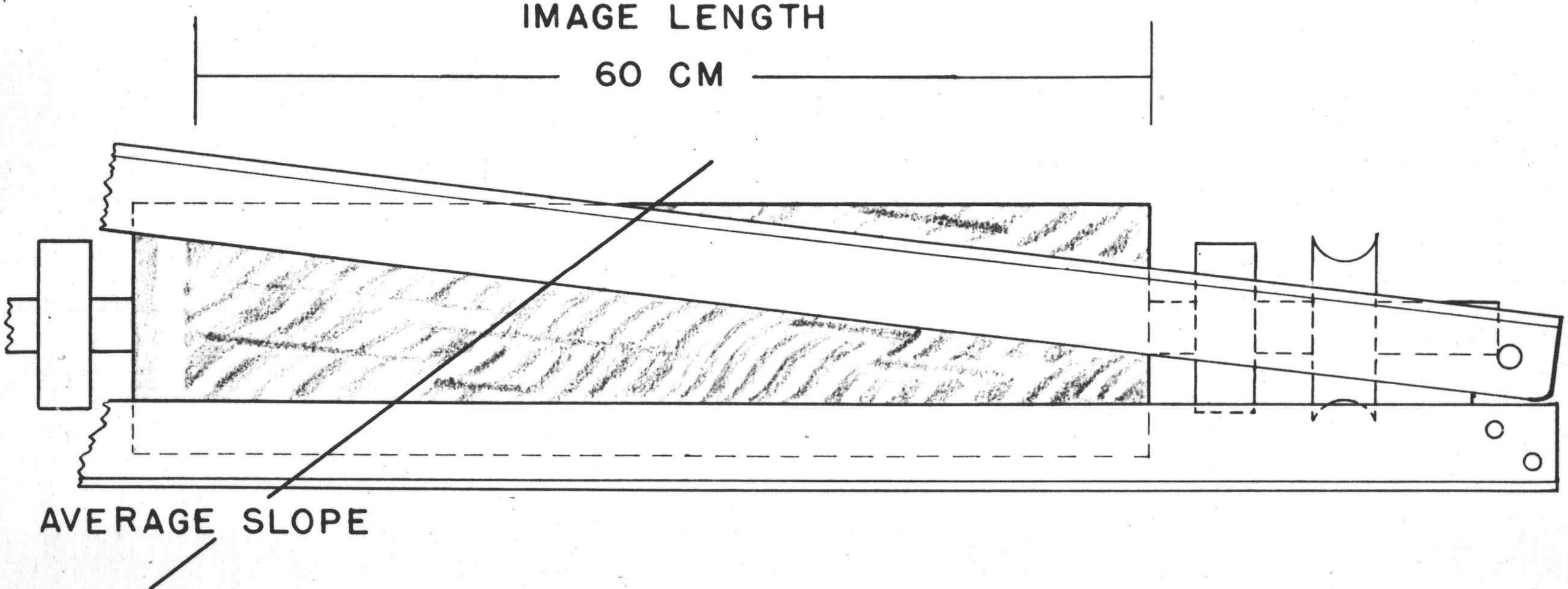
The pressure in the system was maintained by a fore-pump capable of taking the pressure in a closed system down to 10 microns. However, this degree of vacuum was not necessary, since the limit of resolution of the striations by the use of a rotating mirror is determined by the distance between the striations. In argon the striations could not be resolved below 28 microns, and in helium the lower limit was 350 microns.

The striations which are most distinct and of a positive nature, since they move toward the cathode, are here termed the principal or positive striations. The indistinct figures that appeared to move in the direction of the anode will be referred to as negative striations. These are the indistinct forms and dark lines in Figure 7 which travel in the direction of the anode.

Procedure

The system was run continuously for a period of several hours with the discharge in operation to outgas the system. This was done because it was found that a small amount of

FIGURE 7



APPEARANCE OF POSITIVE COLUMN IN ROTATING MIRROR air could change the characteristics of the discharge. To begin a data run the flow of gas into the tube was adjusted until the pressure could be read on the thermocouple gauge. If the striations could not be seen as lines on the rotating mirror, the speed of the mirror was increased until the lines could be resolved. After the lines could be distinguished one of the small angle-measuring arms was moved until the edge coincided with the slope of the striations. The speed of rotation of the mirror was then found and noted; the angle was noted as was the pressure and the voltage.

In argon there were also negative striations with a definite slope in the opposite direction to the principal striations, and this slope was also marked.

After a reading was made in this manner the pressure was changed and the same procedure repeated until the lower limit of measurement had been reached. From this point the pressure was varied in the opposite direction and readings taken until the upper limit of the investigation was attained. The upper limit was a pressure of about 500 microns in argon, but in helium it was extended to 1 mm.

The distance which the striation had traveled in the length of time it appeared on the mirror was found by reading directly from a scale that was placed on the discharge tube. In the case of the negative striations in argon, the velocity was too great to use this method. The procedure used is outlined in the Appendix, page 37.

The data runs were compiled over an interval of several nights for each gas to average out the error of observations due to eyestrain and fatigue and in order to see if the data were repeatable. Eyestrain and fatigue were serious factors in the investigation, for the intensity of the light source prohibited the taking of photographic data. Thus, great care had to be taken to minimize observational errors. Also the runs were made at night in order to insure a constant line voltage.

Argon

Commercial argon with a purity of about 90 per cent was used in this investigation. It was fed into the system under a maximum pressure of about one pound per square inch, the rate of flow being controlled in order to keep the pressure in the discharge tube at the required point for that observation.

The striations in argon did not present an appearance of being continuous but seemed to be in sections with these sections moving down the tube toward the cathode, oscillating as they traveled. The slope measured was the average of the slope of the various sections as shown in Figure 7.

It was not found possible to stop the striations at any of the rotational speeds of the mirror. Thus, a measure of the wave length of the oscillation of the striations could not be found.

Knowing the time the image appeared on the mirror and the distance the striations traveled in this time, the velocity could be computed. This velocity was found to be of the order of 10,000 cm. per second for the striations moving toward the cathode. For the negative striations the speed was found to be approximately three times as much.

A representative fraction of the data obtained is listed on the data sheets following page 27. Also a graph of four data runs for each of the types of striations in argon is plotted on two graphs in order to show the consistency of the measurement and to illustrate why no one curve can be drawn due to the variation in paths.

The plot of the negative striations seems to trace its own curve, but that of the positive striations can not be said to lie on any line. This may be due to an accidental error of measurement rather than to any lack of consistency of the velocities.

The measurement of the figures that have been interpreted as negative striations was more accurate, for these striations appeared as heavy black lines. Although these lines were not of long duration in any one place on the mirror, there were so many with a persistence of about a second that the measuring device could be adjusted with a minimum of error. At a pressure of 350 microns the negative striations disappeared and no change of voltage or of mirror speed could again resolve them; only increasing the pressure above 350 microns caused them to reappear.

The upper limit of measurement of the positive striations in argon was the limit of resolving the pattern in the mirror. This was at a pressure below 500 microns. Above this pressure the pattern varied so rapidly that the probability of making consistent measurements was small.

In plotting the curves different symbols were used for each of the data runs. More points were not used since they fell within the limits of the curves which are used and would have necessitated separate graphs. The different data runs were plotted on the same scale and on the same graph in order to show that the data could be repeated by duplicating the conditions.

Helium

Essentially, the procedure for investigating the striations in helium did not differ from that for argon except in that the pressure limits were changed. Observations could not be made at pressures lower than 350 microns.

The upper limit was also changed for the striations were easily resolvable at one millimeter. At pressures below 350 microns the striations appeared to merge forming a solid glow and appearing as a uniform positive column for any speed of rotation of the mirror. This was not a gradual process but occurred in a space of only a few microns change of pressure.

The positive striations in the positive column of helium were far more distinct and appeared to form continuous lines across the rotating mirror. The negative striations were indistinct and their appearance so erratic that no measurement of their velocity could be made. It could not even be determined whether or not the traces of the negative striations were repeatable for a given pressure. On the few attempts made to measure the velocity of the negative striations, the rough approximations seemed to show their velocity to be about three times that of the positive striations.

The velocity of the positive striations in helium showed almost no variation from one data run to another. The velocities of the striations were about twice those of the striations in argon at the same pressures. It was also observed that the frequency of oscillation of the striations was more constant, but the rapidly oscillating pattern could not be stopped by varying the mirror speed. The computed pressure-velocity relationship for all the different data runs fell on the curve drawn in Figure 10. The points plotted represent only three of the runs but serve to illustrate the curve. Figure 10 shows the upper and lower extremes of the measurement. One millimeter was the highest pressure and 350 microns the lowest. At one millimeter the error in reading the thermocouple gauge was highest, and it was at this point that the largest variance in the points on the graph occurred.

It seemed that at about one millimeter of pressure the characteristics of the glow discharge in helium change. At this point the negative column loses the bright red color of the helium discharge at higher pressures and emits a blue light which was very nearly the same color as the light from the argon discharge at low pressure. The pressure at which this started to occur was slightly above one millimeter and extended to about 800 microns. No change in the pressure-velocity relationship could be observed during or after this transition that did not lie on the curve in Figure 10.

Conclusion

As a consequence of this investigation into the velocity of striations in a glow discharge at low pressures some qualitative interpretations are drawn which differ from the present generally accepted concept.

Prior to this year any mention of moving striations refers the reader to the work of Aston and Kikuchi. They measured the velocity of moving positive striations and showed that this velocity was dependent upon the pressure. The results for a glow discharge in helium give the velocity as equal to a constant multiplied by the inverse square root of the pressure. The constant was of the order of 10^5. Extrapolating their data to a pressure of 1/2 mm. gives a velocity of over 10^5 cm. per second.

This figure differs by a factor of ten from the results arrived at in the present investigation. It was here found that at a pressure of 1/2 mm. the velocity of the positive striations was approximately 10^4 cm. per second. This variance cannot be due to accidental error since in the measurements of the positive striation velocity in helium the error at this pressure was of the order of 3 per cent. An explanation of this difference might be that the pressure-velocity relationship is not constant over all ranges of pressure.

Aston and Kikuchi observed that figures were seen in their rotating mirror which could be interpreted as negative striations. No data were given on this phenomenon, however, and it was further ignored.

Donahue and Dieke (2, p. 253) have postulated negative striations in all glow discharges and have furnished data on the velocities in argon. They find the average velocity of the positive striations to be 10^4 cm. per second and that of the negative striations to be 10^5 cm. per second at 12 mm. pressure.

In the present investigation the positive striations were found to have velocities of the order of 10^4 cm. per second. The speed of the negative striations was about three times as great.

The positive striations, especially in argon, were not continuous but appeared to be only segments. However, their movement was so rapid and their number so great that the appearance very nearly presented that of uniform striations traveling through the positive column. On a coordinate system moving with the average velocity of the striations, however, the striations would appear only to be oscillating with an amplitude of from 2 to 4 millimeters.

If the striations are not continuous, any measurement made on their velocity with a moving mirror is in error since a constant average velocity was assumed.

Summary

The results of this study of moving striations in a glow discharge in helium and argon have yielded the

following:

1. There are both positive and negative striations, the negative striations having speeds several times as great as the positive striations but having intensities which are very low.

2. The velocities of the striations vary in an inverse manner to the pressure.

3. Further investigation may show the striations to be discontinuous.

These results cannot be checked theoretically, as no quantitative explanation for moving striations in the positive column has been found. It is, however, in fair qualitative accord with the latest published material pertaining to this subject.

D A T A

POSITIVE STRIATIONS IN ARGON
1

Potential Drop volts	Pressure microns	Time sec.x 10^4	Distance cm.	Velocity (cm/sec)x 10^{-3}
600	200	18.4	20.5	11.3
600	160	18.4	21.0	11.6
600	150	18.4	21.0	11.6
600	130	18.4	21.7	12.0
650	100	18.4	23.0	12.7
700	85	18.4	24.0	13.2
750	70	18.4	26.0	14.4
750	65	18.4	26.0	14.4
1250	50	18.4	24.0	13.2
1400	40	18.4	26.0	14.4
1600	32	18.4	26.0	14.4

D A T A

POSITIVE STRIATIONS IN ARGON
2

Potential Drop volts	Pressure microns	Time sec.x 10^4	Distance cm.	Velocity (cm/sec)x 10^{-3}
600	200	18.4	20.5	11.3
600	160	18.4	21.5	11.9
600	150	18.4	21.0	11.6
600	140	18.4	21.5	11.9
650	120	18.4	21.7	12.0
650	100	18.4	22.0	12.2
700	90	18.4	23.0	12.7
750	80	18.4	24.0	13.2
800	60	18.4	24.0	13.2
1250	50	18.4	26.0	14.4
1400	40	18.4	26.0	14.4

DATA

POSITIVE STRIATIONS IN ARGON

3

Potential Drop volts	Pressure microns	Time sec. x 10^4	Distance cm.	Velocity (cm/sec) x 10^{-3}
600	160	18.4	21.5	11.9
600	150	18.4	21.5	11.9
600	130	18.4	21.7	12.0
650	100	18.4	22.0	12.2
750	80	18.4	24.0	13.2
750	70	18.4	26.0	14.4
750	60	18.4	24.0	13.2
1000	50	18.4	24.0	13.2

4

600	400	18.4	20.0	11.0
650	120	18.4	22.0	12.2
650	100	18.4	24.0	13.2
700	80	18.4	26.0	14.4

D A T A

NEGATIVE STRIATIONS IN ARGON

1

Potential Drop volts	Pressure microns	Time sec.x 10^4	Distance cm.	Velocity (cm/sec)x 10^{-4}
600	200	19.0	43	2.21
600	190	18.4	43	2.34
600	160	16.7	43	2.58
600	140	15.7	43	2.74
625	120	13.9	43	3.1
650	100	12.8	43	3.36
650	90	11.7	43	3.68

2

600	190	18.3	43	2.35
600	170	17.2	43	2.5
600	150	16.7	43	2.58
625	130	15.0	43	2.87
650	90	11.7	43	3.68

D A T A

NEGATIVE STRIATIONS IN ARGON

3

Potential Drop volts	Pressure microns	Time sec. x 10^4	Distance cm.	Velocity (cm/sec) x 10^{-4}
600	180	17.8	43	2.42
600	170	17.4	43	2.47
600	160	17.2	43	2.5
600	130	15.0	43	2.87
650	90	12.2	43	3.53

4

600	200	21.1	43	2.04
625	150	16.7	43	2.58
700	90	11.1	43	3.88

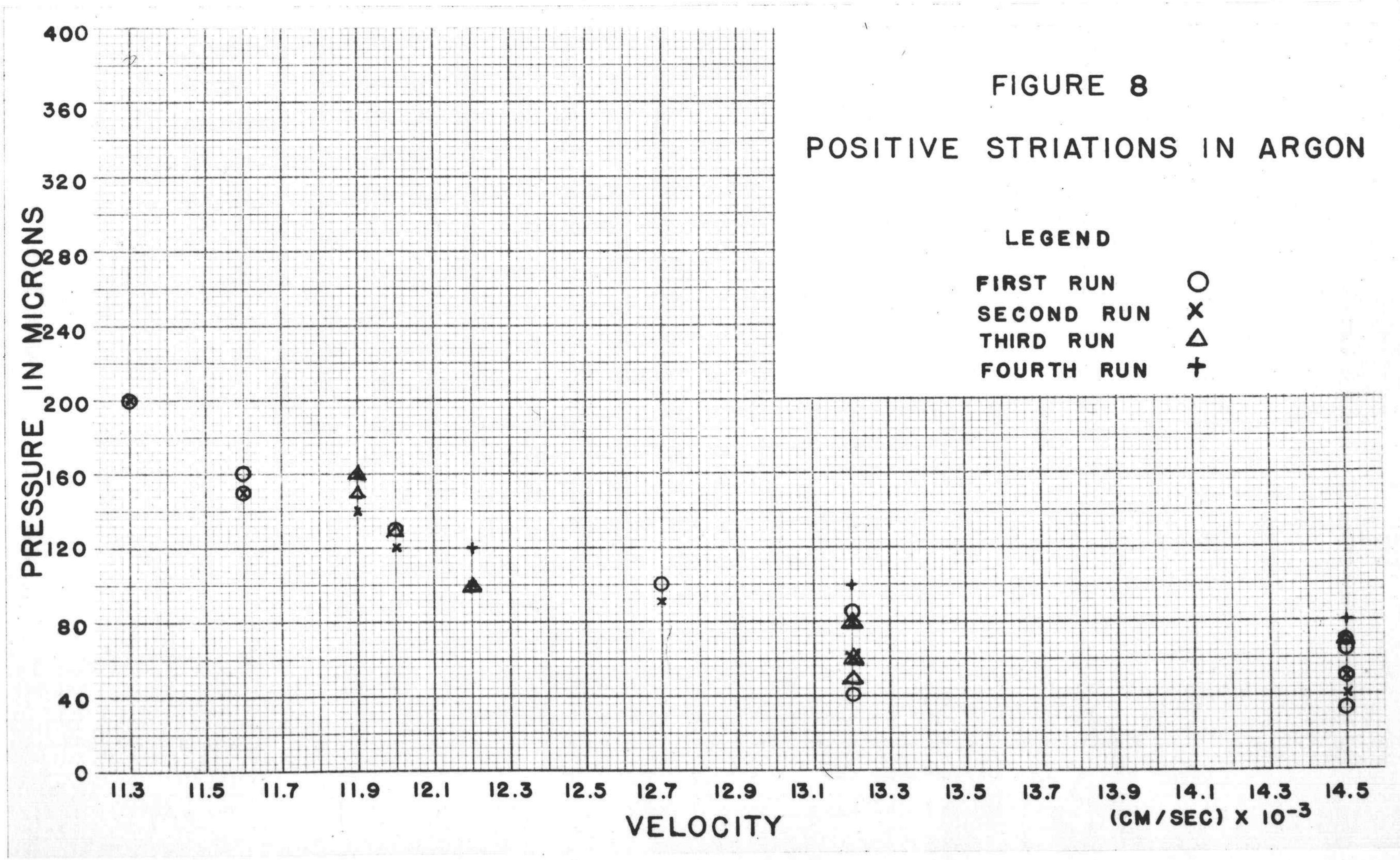


FIGURE 8
POSITIVE STRIATIONS IN ARGON
LEGEND
FIRST RUN ○
SECOND RUN ×
THIRD RUN △
FOURTH RUN +
PRESSURE IN MICRONS
400
360
320
280
240
200
160
120
80
40
0
11.3
11.5
11.7
11.9
12.1
12.3
12.5
12.7
12.9
13.1
13.3
13.5
13.7
13.9
14.1
14.3
14.5
VELOCITY
(CM/SEC) X 10^-3

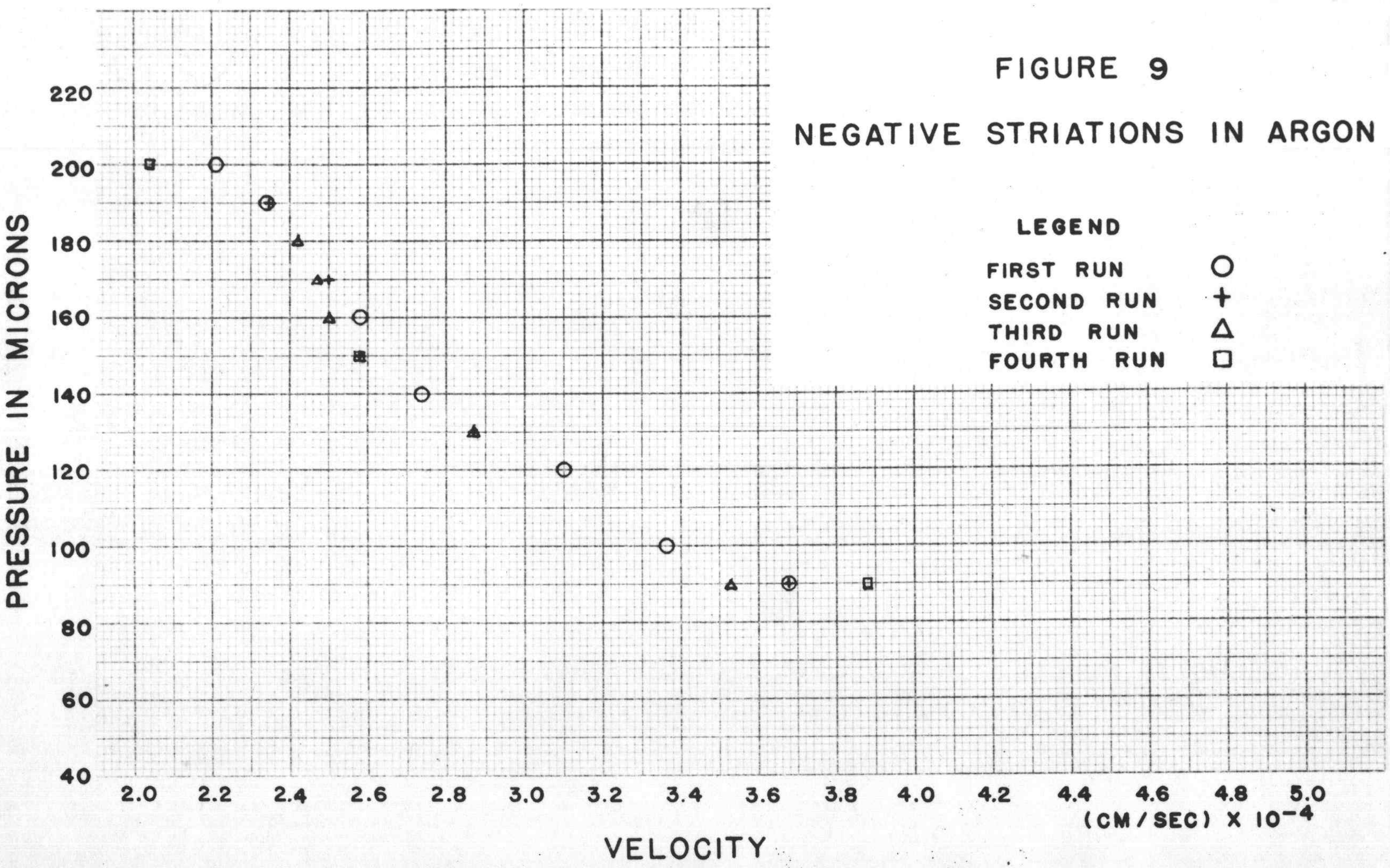


FIGURE 9

NEGATIVE STRIATIONS IN ARGON

D A T A

POSITIVE STRIATIONS IN HELIUM

1

Potential Drop volts	Pressure microns	Time sec.x 10^4	Distance cm.	Velocity (cm/sec)x 10^{-3}
1100	1000	14.2	29	20.4
1100	700	14.2	35	24.6
1100	600	14.2	38	26.7
1100	500	14.2	42	29.5

2

1100	650	11.5	29	25.2
1100	600	11.5	30	26.1
1100	400	11.5	44	38.2
1100	350	11.5	53	46.1

3

1100	1000	14.2	30	21.1
1100	600	14.2	38	26.7
1100	500	14.2	42	29.5

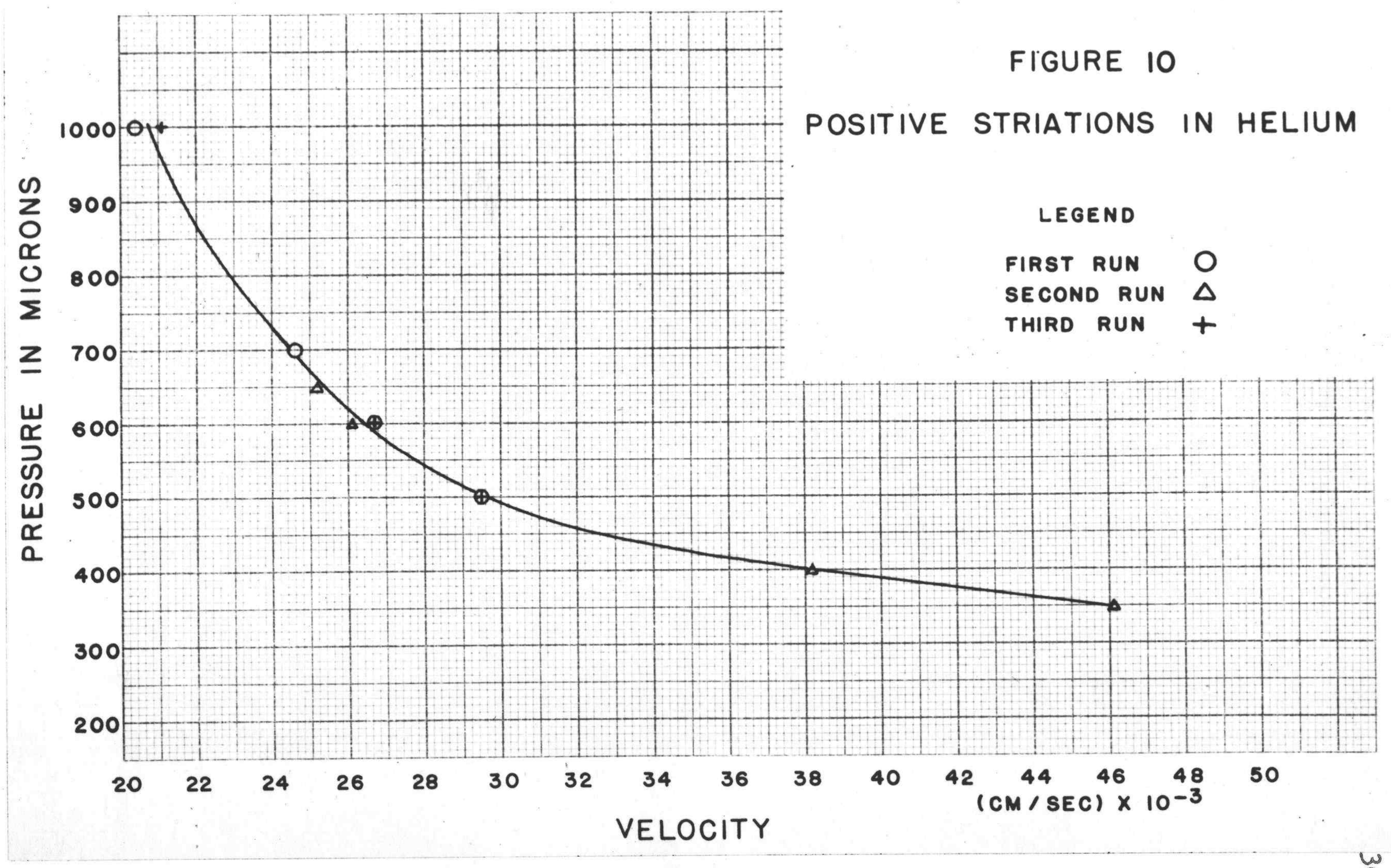
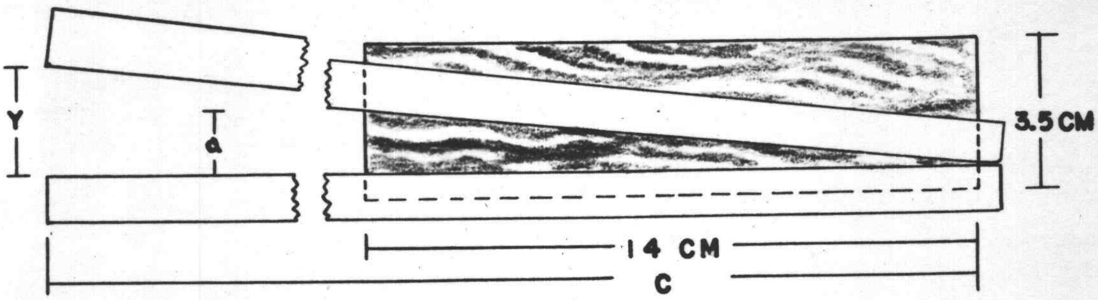


FIGURE 10
POSITIVE STRIATIONS IN HELIUM
LEGEND
FIRST RUN
SECOND RUN
THIRD RUN
PRESSURE IN MICRONS
1000
900
800
700
600
500
400
300
200
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
(CM / SEC) X 10^{-3}
VELOCITY

Appendix



If the velocity of the striation is so great that the length of the tube is traversed in less time than the mirror is effective per rotation, a measure of the time must be found in some other manner. For this the geometry of the situation is used.

The tangent of the angle measured by the adjustable angle is y/c where c is a length marked off parallel to the axis of rotation. The distance that the striation travels in time t is a length of the positive column L. If T is the time an image is on the mirror per rotation, the time t may be found and from this the velocity computed.

$$\frac{Y}{C} = \frac{a}{14} \quad \text{OR} \quad a = \frac{14\,Y}{C}$$

$$\frac{t}{T} = \frac{a}{3.5} \quad \text{OR} \quad a = \frac{3.5\,t}{T}$$

$$t = \frac{14\,Y\,T}{3.5\,C} \qquad v = \frac{L}{t} = \frac{3.5\,L\,C}{14\,Y\,T}$$

BIBLIOGRAPHY

1. Aston, F. W. and T. Kikuchi. Moving striations in neon and helium. Royal society of London proceedings A,98:50-57. 1920.

2. Donahue, T. and G. H. Dieke. Oscillatory phenomena in direct current glow discharge. Physical review 81:248-262. 1951.

3. Druyvesteyn, M. J. and F. M. Penning. The mechanism of electric discharge in gases of low pressure. Reviews of modern physics 12:87-174. 1940.

4. Emeleus, K. G. The conduction of electricity through gases. London, Methuen, 1929. 94p.

5. Holm, John H. On the distribution of electric force and the rise of temperature in the glow discharge. London, Edinburgh and Dublin philosophical magazine 11:194-221. 1931.

6. Loeb, Leonard B. Fundamental processes of electrical discharge in gases. New York, John Wiley & Sons, 1939. 655p.

7. Ruark, Arthur and Harold Urey. Atoms, molecules and quanta. New York, McGraw-Hill, 1930. 763p.

8. Stranathan, J. D. The "particles" of modern physics. Philadelphia, Blakiston, 1943. 555p.

9. Thomson, J. J. On striations in the electric discharge. London, Edinburgh and Dublin philosophical magazine 18:441-451. 1909.

10. Thomson, J. J. and G. P. Thomson. Conduction of electricity through gases. 3d ed. London, Cambridge university, 1933. 598 p. (Vol. 2)

11. Wilson, Harold A. On the variations of electric intensity and conductivity along the electric discharge in rarefied gases. London, Edinburgh and Dublin philosophical magazine 49:505-516. 1900.