

Seventh Annual

GASEOUS ELECTRONICS CONFERENCE

**PROGRAM
AND
ABSTRACTS OF PAPERS**

New York, N. Y.

OCTOBER 14-16, 1954

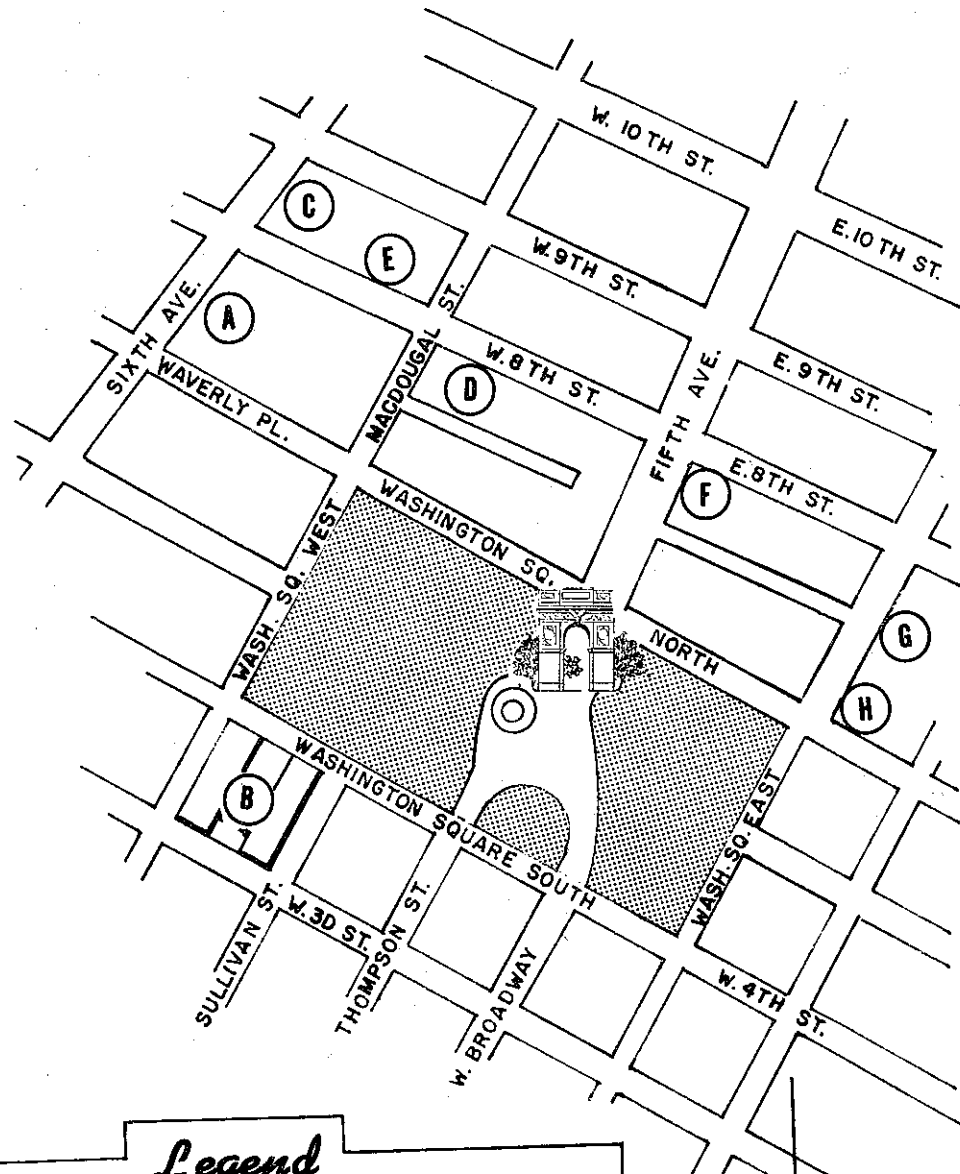
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Washington Square & Vicinity

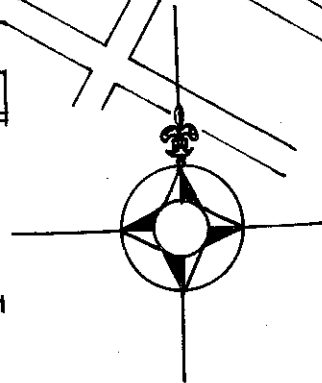


Legend

- A - 6th and 8th Avenue Independent Subways
- B - Vanderbilt Hall

RESTAURANTS

- | | |
|---------------------|---------------------------------|
| C - Captain's Table | F - No. 1 Fifth Avenue Hotel |
| D - Jumble Shop | G - Mother Hubbard's Restaurant |
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SEVENTH ANNUAL CONFERENCE ON GASEOUS ELECTRONICS

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Thursday, October 14

9:30 A. M.

SESSION A

INELASTIC IMPACTS, DIFFUSION, AFTERGLOW

Chairman, R. Geballe

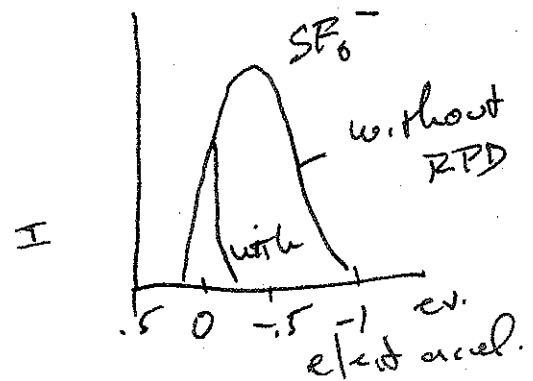
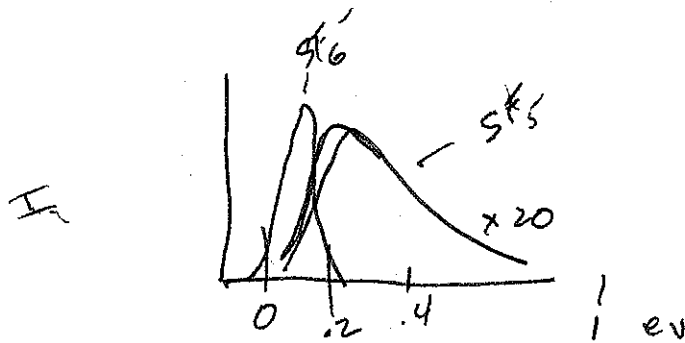
University of Washington

NEGATIVE ION FORMATION
USING MONOENERGETIC ELECTRONS

A-1

W. M. Hickam and R. E. Fox
Westinghouse Research Laboratories
East Pittsburgh, Pennsylvania

Ion formation involving electron attachment at low energies was investigated with monoenergetic electrons as obtained by the retarding potential difference (RPD) method.¹ Initial studies with this method reveal that electron attachment in some cases may occur only over an extremely narrow energy range. For such cases it becomes increasingly important that monoenergetic electrons be used in order to obtain the true excitation curve. For example, in the case of the formation of SF_6^- , the large cross section is found to occur only for electrons whose energy is less than 0.1 ev. The dissociative attachment process which yields SF_5^- also has a maximum cross section for electron energies of less than 0.1 ev. In this case, however, the negative ion formation as a function of electron energy decreases more slowly, going to zero at about 2 ev. The use of monoenergetic electrons can account for the wide differences between these results and those previously obtained² for SF_6^- . It will be demonstrated how the extremely narrow capture process can yield information concerning the behavior of the electron beam at these low energies.



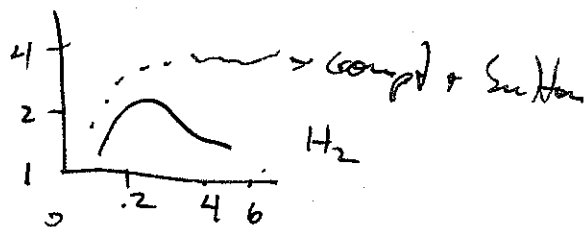
To obtain electron dist.
electron current $\frac{dI_e}{dE}$
0.1 elect accel v.
same as SF_6^- curve, but displaced by 0.3 ev. in 0.3 ev. is excitation

1. R. E. Fox, W. M. Hickam, T. Kjeldaa, and D. J. Grove, Phys. Rev. 84, 859 (1951).
2. A. G. Ahearn and N. B. Hannay, J. Chem. Phys. 21, 119 (1953).

E. Gerjuoy and S. Stein
 University of Pittsburgh and Westinghouse Research Laboratories
 Pittsburgh, Pennsylvania

Theoretical cross sections have been developed for the rotational excitation of homonuclear molecules by slow electrons,¹ and the results applied to calculation of the fractional energy loss per collision λ . In N_2 , at energies below the vibrational threshold, theoretical losses are approximately twice experimental² but many times larger than $2m/M$. In H_2 the theoretical losses are not more than 2.5 ($2m/M$), and, except at the lowest energies studied ($\sim .1$ ev), are significantly smaller than observed.²

It would be desirable to have more direct experimental evidence of rotational excitation. For this reason we have calculated λ at 77°K in pure para-hydrogen and in the equilibrium mixture of ortho- and para-hydrogen. At electron energies $\sim .075$ ev, the two λ 's should differ by about 50 per cent. Similarly, because of the altered rotational distribution, λ for deuterium differs from λ for H_2 . Such differences, if observed, could hardly be accounted for on any other basis than rotational excitation.



Quad. interaction
 Born Approx.

$N_2: \frac{2m}{M} \sim .387 \times 10^{-4}$
 Obs. $\gg 6 \times 10^{-4}$; Theory $2 \times$ obs.
 $H_2: \frac{2m}{M} \sim 5.45 \times 10^{-4}$
 Obs. $\gg 25 \times 10^{-4}$; Theory \ll obs.

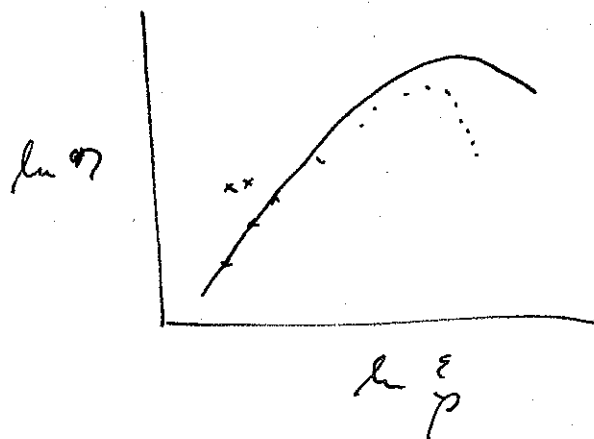
* This research was supported in part by the United States Air Force.
 1. S. Stein, E. Gerjuoy, and T. Holstein, Phys. Rev. 93, 934 (1954).
 2. R. W. Crompton and D. J. Sutton, Proc. Roy. Soc. (London) A215, 467 (1952)

REDETERMINATION OF THE IONIZATION
COEFFICIENT η FOR HYDROGEN

A-3

D. J. Rose
Bell Telephone Laboratories
Murray Hill, New Jersey

Measurements of the ionization coefficient for hydrogen have been reported by Ayers (1923) and Hale (1938). These data are inconsistent. The experiment has therefore been repeated, using the best available vacuum technique. The hydrogen was prepared either from spectroscopically pure one liter flasks, or from the decomposition of uranium hydride which was prepared in vacuum from the pure gas and reactor grade uranium. The plane parallel electrodes were 5 cm disks of molybdenum, and could be adjusted to pre-set separations within 10 microns error. Values of the ionization coefficient η were obtained in the range $20 < E/p < 1000$ volts/cm x mm Hg.



DIFFUSION OF IONS AND ELECTRONS
IN AN ELECTRIC FIELD

A-5

Robert N. Varney
Washington University
St. Louis, Missouri

The partial differential equation for diffusion has been set up to include a drift velocity term and has then been solved explicitly by standard Fourier integral procedures. The results are then applied to three ionic problems. The first is the diffusion of an ion avalanche cloud opposite to the field against an anode surface. The second is the analysis of the approach of a positive ion avalanche to a collecting cathode under the influence of both drift and diffusion. The third is the analysis of back-diffusion of electrons after escape from a cathode to the cathode surface. In all cases, a variable of controlling significance is the function vx/D , where v is the drift velocity, D the diffusion coefficient, and x a distance of travel. The function vx/D shows diffusion effects to be negligible if it is appreciably less than unity.

IONIZATION ACCOMPANYING THE LONG LIVED
NITROGEN AFTERGLOW*

W. B. Kunkel and A. L. Gardner
University of California
Berkeley, California

Extensive electron density measurements have been carried out in active nitrogen by means of the microwave method. It was found that the electron density depends strongly on the amount of contamination in the nitrogen, being highest for an admixture of 0.1% to 0.2% of oxygen and reaching a maximum at a time of the order of 100 milliseconds after the discharge excitation, in striking agreement with the emission of the visible spectrum. It is concluded that the oxygen, being totally dissociated in the discharge, does not attach electrons but serves to form nitric oxide which has a sufficiently low ionization potential to be ionized by the active particles. Since electron removal by ambipolar diffusion and recombination is rapid, two-body ionizing collisions are required to maintain the high free electron density level, ($\sim 10^9$ cm⁻³). Metastable nitrogen molecules of 9.6 eV, presumably in a singlet state, must therefore be continually formed out of the parent ground state atoms. It seems possible that the metastables are also needed as intermediate states in the afterglow reaction and that the presence of the electrons is essential for the multiplicity change required for the light emission as suggested by Nicholls.¹

* Work supported by Wright Air Development Center.

¹ R. W. Nicholls, Jour. Chem. Phys. 20, 1040 (1952).

DIFFUSION AND VOLUME LOSS
COEFFICIENTS OF HELIUM METASTABLE ATOMS
AND MOLECULES

A-7

A. V. Phelps
Westinghouse Research Laboratories
East Pittsburgh, Pennsylvania

Diffusion and volume destruction coefficients have been determined for the metastable states of the helium atom,¹ 2^1S and 2^3S , and molecule, $2^3\Sigma$, from measurements of the lifetimes of these metastables in very pure helium. The product of the diffusion coefficient and the neutral atom density for each of the metastable states is $1.53 \times 10^{19}(\text{cm}^2/\text{sec})(\text{atom}/\text{cc})$ at 300°K to within the respective experimental errors. The volume loss for the 2^1S metastables is linear with the helium pressure and suggests destruction by collision induced radiation with an average cross section of $4 \times 10^{-20} \text{ cm}^2$ at 300°K . The triplet metastable atoms are destroyed in three-body collisions¹ with a combination coefficient of $2.5 \times 10^{-34} \text{ cc}^2/\text{atom}^2\text{-sec}$ at 300°K . It has not been possible to observe a loss of molecular metastables which increases with helium pressure because of destruction in collisions with slow electrons or other metastables. These high pressure experiments show that the natural lifetime of the molecular metastables is at least 0.05 second and that the volume destruction is at least one hundred times smaller than that for the atomic metastables.

¹. A. V. Phelps and J. P. Molnar, Phys. Rev. 82, 1202 (1953).

A-8 THE EFFECT OF TEMPERATURE ON THE LIFETIME
OF METASTABLE MERCURY MOLECULES

C. G. Matland and A. O. McCoubrey
Westinghouse Research Laboratories
East Pittsburgh, Pennsylvania

The band radiation from mercury vapor in an afterglow excited by the 2537A resonance line has been accounted for in terms of metastable mercury molecules $\text{Hg}_2(^3\text{O}_u^-)$.¹ These molecules are destroyed by spontaneous radiation, three-body collisions, and upon diffusing to the walls. In the present work, the effect of temperature on these processes has been measured. The experimental method consists of measuring the decay time of the afterglow over a range of mercury vapor densities at several constant vapor temperatures. As the vapor temperature is varied from 380°K to 580°K, the results obtained are as follows: (1) the spontaneous radiation lifetime is found to decrease from 63 milliseconds to 19 milliseconds; (2) the diffusion coefficient² follows a $T^{1/2}$ variation within the experimental error (± 4 per cent); (3) the three-body collision induced radiation rate, $C = 29 \times 10^{-32} \left(\frac{\text{atoms}}{\text{cc}}\right)^{-2} \text{ sec}^{-1}$, is unchanged.

-
1. A. O. McCoubrey, Phys. Rev. 93, 1249 (1954).
 2. A. O. McCoubrey and C. G. Matland, Paper Q10, Minneapolis Meeting of the American Physical Society, June 28, 1954.

Thursday, October 14

2:00 P. M.

SESSION B

PLASMAS

Chairman, S. C. Brown

Massachusetts Institute of Technology

CONCERNING OSCILLATIONS OF A PLASMA
WITH A SKEW VELOCITY DISTRIBUTION TRANS-
VERSE TO A STATIC MAGNETIC FIELD*

B-1

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Electronic Defense Laboratory
Sylvania Electric Products Inc.
Mountain View, California

The present paper extends the analysis of Plasma Oscillations in a magnetic field developed by E. P. Gross.¹ Assuming an isotropic steady state electron velocity distribution, Gross found gaps in the spectrum of possible traveling waves at integral multiples of the cyclotron frequency for electrons. The effect of a skewed steady velocity distribution on the dispersion relation has been studied and it is found that traveling wave solutions may exist at these "gap frequencies". A condition has been derived for traveling wave solutions in terms of parameters of the distribution function. It is pointed out that a small constant transverse electric field may be included in Gross' analysis and is equivalent in first approximation to the case treated.

* Work carried out under U. S. Signal Corps Contract.
1. E. P. Gross, Phys. Rev. 82, 232 (1951).

PLASMA FLUCTUATIONS IN CROSSED ELECTRIC
AND MAGNETIC FIELDS

Hugh W. Batten
Engineering Research Institute
University of Michigan
Ann Arbor, Michigan

An experimental study of the spontaneous, high-intensity electric fluctuations associated with a gas discharge in a magnetic field was undertaken. Probes were introduced into the plasma region of an especially designed gas diode, and the voltages on the probes were observed. Data were taken to cross-correlate the electric fluctuations on two neighboring probes in the discharge. These fluctuations on the two probes were similar except that those on the "downstream" probe were delayed in time with respect to those on the "upstream" probe. Interpreting this delay as the time of propagation from one probe to the other, the velocity and direction of propagation could be determined.

The results show that the fluctuations are hundreds of volts in amplitude, propagate approximately in the direction of electron drift, and have a speed somewhat less than the Lorentz drift velocity. There is experimental evidence to suggest that these fluctuations grow as they propagate.

INSTANTANEOUS PROBE MEASUREMENTS
OF TRAVELLING STRIATIONS IN AN
ARGON GLOW DISCHARGE*

B-3

N. L. Oleson
U. S. Naval Postgraduate School
Monterey, California

Further measurements have been made of the instantaneous probe currents obtained from the positive column of an Argon glow discharge in which moving striations are present. Simultaneously, the light from the neighborhood of the probe is scanned by a photomultiplier and probe current and light intensity are presented on the screen of a dual beam oscilloscope. The discharge tube has a diameter of 2 centimeters and observations have been made with pressures from one half millimeter to twelve millimeters and currents from 20 to 40 milliamperes.

The probe currents are characterized by sharp spikes where the current becomes electronic for a very short interval. The location of these spikes with respect to maximum light intensity depends upon probe position, gas pressure and current. As the probe is made more positive with respect to the anode, broader electron current peaks appear and the average current to the probe becomes electronic.

* Supported by the Office of Naval Research

B-4 NOISE MECHANISM OF ELECTRICAL DISCHARGES

M. I. Skolnik*
Radiation Laboratory
The Johns Hopkins University
Baltimore, Maryland

Many examples have been reported of electrical noise originating from gas discharges which cannot be attributed to either shot noise or thermal noise because of its large magnitude. It is suggested that such noise might be due to the discharge acting as a relaxation oscillator which produces a series of large amplitude, short duration pulses of jittered repetition rate. The jittered repetition rate gives rise to a continuous frequency spectrum, which is the noise. Experiments were conducted with low-current arc discharges at atmospheric pressure. Various combinations of electrode materials and gases were used. The amount of noise was found to depend upon the gas, the cathode material, the power supply voltage, and the external circuit configuration. The pulsed nature of the apparently continuous discharge appears to be a fundamental property of the low current, cold cathode arc which has not been considered previously.

* Now with Sylvania Electric Products, Inc., Boston, Mass.

K. S. W. Champion** and S. C. Brown
Department of Physics and Research Laboratory of Electronics
Massachusetts Institute of Technology
Cambridge, Massachusetts

The impedance (ρ) to high frequency electromagnetic waves of any region of a plasma, divided by the wavelength, (ρ/λ) is plotted as a function of $n\lambda^2$ (where n is the electron density) and $p\lambda$ (where p is the pressure). The resulting surface is of particular interest in the vicinity of plasma resonance and is important for two reasons. One is that it gives a plot of the impedance any plasma presents to the transmission of microwaves. It not only confirms the measurements of Goldstein¹ and Makinson of the microwave impedance of dc plasma, but also indicates immediately the range over which plasma resonance properties can be used as a "microwave probe" to measure electron densities. Experimentally this technique of density measurement has been used with high frequency discharges for the first time. The second reason for the importance of the impedance plot is that it enables the properties of microwave discharges to be predicted. In particular, more extensive calculations have been made which enable the appearance of any microwave discharge to be predicted quantitatively, provided its diameter exceeds four times its height.

* This work was supported in part by the Signal Corps; the Office of Scientific Research, Air Research and Development Command; and the Office of Naval Research.

** Now at Physics Department, Tufts College, Medford, Massachusetts.

1. L. Goldstein and N. L. Cohen, Elec. Commun. 28, No. 4, 305 (1951).

MICROWAVE STUDY OF POSITIVE ION COLLECTION BY PROBES

George J. Schulz* and Sanborn C. Brown
Research Laboratory of Electronics
Massachusetts Institute of Technology
Cambridge, Massachusetts

The positive ion saturation region of Langmuir probes may be a convenient tool for measuring positive ion densities in a plasma when the probe does not exhibit a sharp electron saturation (e.g., at higher pressure). The theory of the positive ion saturation region is modified to include the drift current of positive ions at the edge of the sheath, $J_d = ne\sqrt{\frac{kT}{M}}$ where J_d is the directed current density at the sheath edge, k is Boltzmann's constant, T is the electron temperature, n is the electron or positive ion density, M is the mass of the ion, and e is the electronic charge. This modification explains the large positive ion saturation currents at low pressure reported by many authors.¹

The current collected by a cylindrical probe is determined not only by J_d , but also by the collection efficiency of the probe. When no collisions occur in the sheath, ions describe orbital motions around the probe. When approximately one collision occurs on the average, most ions will lose energy and become trapped in the sheath and eventually reach the probe. The theory is equally applicable to single probes and to double probes.²

These considerations were confirmed by taking probe curves with single and double probes in a microwave gas discharge and using microwave methods for an independent measurement of electron density.

Probes collect too much + ion

Assume field penetration of sheath + \therefore directed + ion velocities

$$J_d = en \sqrt{\frac{2e}{M}(V+w)} \quad \rho = \frac{J_d}{\sqrt{\frac{2e}{M}(V+w)}} = en_0 e^{-eV/kT}$$

Bound. cond. : $\rho \gg 0, de/dx \gg 0$

$$\therefore J_d = en \sqrt{\frac{kT}{M}} \quad \text{directed current}$$

Efficiency of collection orbital motion $i \sim V^{.55} n^{.9}$
" " " $V^{.63} n^{.59}$

* Now at Westinghouse Research Laboratories, East Pittsburgh, Pennsylvania.

1. R. M. Howe, J. Appl. Phys. 24, 881 (1953).

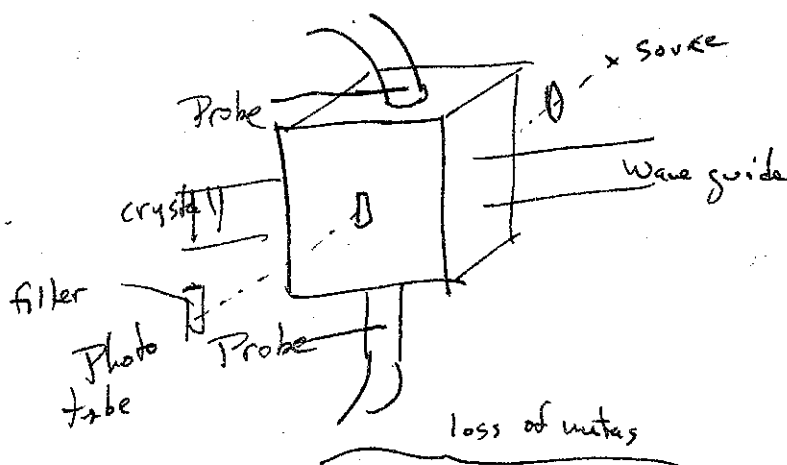
2. E. O. Johnson and L. Malter, Phys. Rev. 80, 58 (1950).

CUMULATIVE IONIZATION PROCESSES IN THE HELIUM POSITIVE COLUMN

B-7

L. S. Frost and A. V. Phelps
Westinghouse Research Laboratories
East Pittsburgh, Pennsylvania

Preliminary measurements of important parameters of a helium positive column have been made in order to investigate cumulative ionization. Electron density is measured by microwave techniques, the density of singlet and triplet He metastable atoms by optical absorption, and the axial electric field and the average electron energy by fine wire probes. The total ionization rate is calculated by the diffusion loss equation. The rate of direct ionization of normal He atoms by high energy electrons is calculated from published microwave breakdown data for He,¹ assuming negligible electron-electron interaction. The difference between the rates of total and direct ionization is the rate of cumulative ionization. This is compared with the ionization rate due to ionizing collisions between pairs of triplet metastable atoms,² calculated using the cross section obtained from afterglow studies. Results of this comparison together with evidence on the relative importance of other possible cumulative ionization processes will be presented.



$$2M n = -D_M \nabla^2 M + Z \alpha M^2 + \beta M n$$

Direct exc. of Metas
Diff.
Meta-Meta coll.
electron-Meta
(β unknown at present)

1. F. H. Reeder and S. C. Brown, Phys. Rev. 95, 885 (1954).
2. M. A. Biondi, Phys. Rev. 88, 660 (1953).

STUDIES OF THE LOW VOLTAGE ARC*

E. O. Johnson
Radio Corporation of America
RCA Laboratories
Princeton, New Jersey

This paper describes an analytical and experimental study of the "Low Voltage Arc". The explanation usually advanced for this discharge involves cumulative ionization in a virtual anode. A new model is proposed. It is based upon a virtual anode and also upon the observation that the electrons have a maxwellian energy distribution over a fairly wide range of discharge conditions. By using particle flow and continuity relations, along with the ion generation arising from electrons in the tail of the distribution, all important discharge parameters can be computed in a systematic manner. There is no dependence upon cumulative processes and, furthermore, the usual difficulty in accounting for the flow of electrons out of the virtual anode is automatically taken care of.

Computed values of electron temperature, ion density, total ion generation, space potential, and energy input are in quite good agreement with experiments performed over a considerable range of discharge parameters. The analysis agrees with experiment in predicting the variation of maximum plasma size with pressure. The observed onset of an anode glow and a second plasma, when the discharge path is made too long, is also accounted for. It seems quite likely that these phenomena are the basis (at least in some cases) for the concatenated series of plasmas (striations) in positive columns.

*Argon + Xenon
11-10 mm pressure*

* This work was supported in part by the U. S. Army Signal Corps.

ON ELECTRON FLOW AND MEAN FREE PATH
OF ELECTRONS IN FIRE BALL DISCHARGES

B-9

G. Medicus
Electronic Components Laboratory
Wright Air Development Center
Dayton, Ohio

In fire ball discharges the electron current flows against retarding fields. Under certain conditions the electrons have a locally well established Maxwellian distribution, together with a temperature gradient, indicating a strong coupling between the electrons, the nature of which is still unknown. In such cases one has to suspect the gradient of the electron gas pressure rather than the gradient of the electron density to be the electromotive force. Therefore the diffusion-mobility concept, usually applied to such cases, is compared to a pressure gradient-mobility concept. Evaluations of probe measurements in the saturated fire ball discharge,¹ especially for a mean free path λ_e of the electrons (with the neutral gas transparent), give practically the same results for the two concepts. λ_e (0.01 to 1 cm) is found not to be a function of the plasma density and the electron temperature only.

1. G. Medicus, J. Appl. Phys. 24, 233 (1953).

ON RETROGRADE MOTION IN GAS
DISCHARGE PLASMAS

K. G. Hernqvist and E. O. Johnson
RCA Laboratories
Princeton, New Jersey

Recently, it has been discovered that the glow region of the "ball of fire" mode in a hot cathode discharge exhibits retrograde motion like the cathode spot on a mercury pool. Since the functional dependence of the two phenomena upon gas pressure, current, and magnetic field are similar, it is quite possible that the two phenomena have a similar explanation.

In the "ball of fire" mode of discharge one plasma, the glow region, is surrounded by a dark plasma. The two plasmas are connected by a Langmuir double sheath wherein the counterflow of electron and ion currents is such as to insure an essentially zero electric field at opposite edges of the sheath. In accordance with electromagnetic laws, a magnetic field causes the density of the dark plasma on one side of the ball to increase and, on the other side, decrease. This perturbation must necessarily cause the electron and ion currents in the double sheath to become unbalanced. An elementary development, along with experimental data, will be presented to show that balance can be restored if the boundary between the two plasmas travels through the neutral gas in the retrograde direction at a constant speed whose magnitude depends upon the product of the magnetic field and the electron mobility in the dark plasma.

Friday, October 15

9:00 A. M.

SESSION C

BREAKDOWN

Chairman, R. E. Fox

Westinghouse Research Laboratories

THE EFFECT OF MEAN FREE PATH VARIATION
ON HIGH FREQUENCY BREAKDOWN

C-1

I. A. MacLennan and A. D. MacDonald
Dalhousie University
Halifax, Nova Scotia

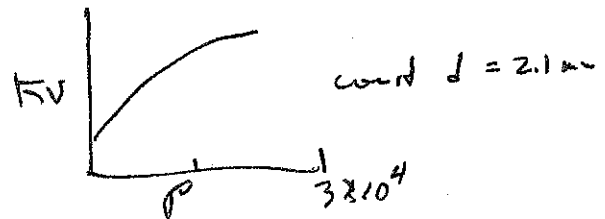
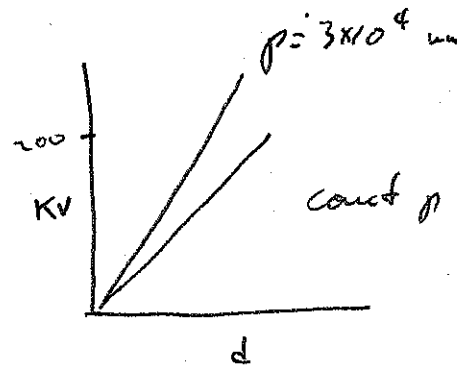
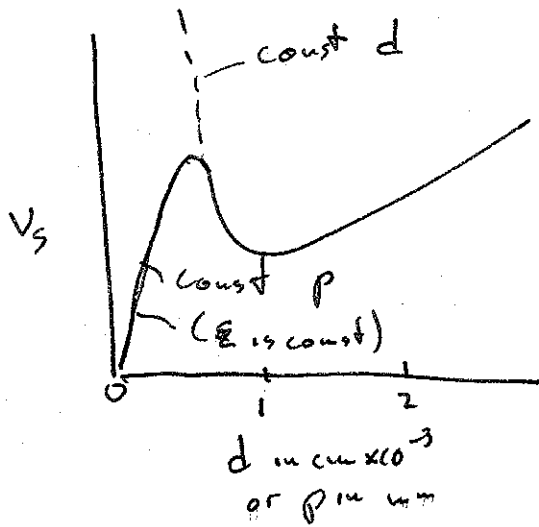
The effect of the electron mean free path on the high frequency breakdown field of gases is investigated in a Neon-Argon mixture. The mixture is predominately Neon, the Argon being added so that excited Neon atoms may collide with Argon atoms to produce ionization (Penning effect). Assuming that electrons are produced by field ionization, and lost by diffusion, the Boltzmann transport equation is solved approximately for various elastic collision cross-sections, Q . The theory shows that the variation in Q for low-energy electrons considerably changes the breakdown condition, and suggests that information about the elastic collision cross-section in some gases might be obtained from the breakdown measurements.

DEPARTURE FROM PASCHEN'S LAW
OF BREAKDOWN IN GASES

W. S. Boyle and P. Kisliuk
Bell Telephone Laboratories
Murray Hill, New Jersey

The failure of Paschen's law of electrical breakdown in gases at both high pressures and extremely small electrode separations is explained by a single breakdown mechanism. The breakdown field in these two regions is sufficiently great to draw measurable field emission currents from the cathode, which produces a relatively small number of ions. The space charge field of these ions is great enough to increase appreciably the field emission current even when the ratio of ion current to electron current is less than one per cent. As more ionic space charge is produced each ion becomes more effective in enhancing the electron current until the breakdown condition is attained.

An expression is derived for the yield of electrons per positive ion as a function of the applied field. This dependence is shown to be in agreement with experimental breakdown voltages at high pressure. It is also shown that the conditions leading to breakdowns at extremely short distances are appropriate for the same processes to take place, thus explaining breakdowns below the "minimum sparking potential".



$$J_{\text{effective}} = \frac{J_{\text{field emission}}}{J_{\text{electron}}}$$

For high pressures use
 $\alpha = 1$

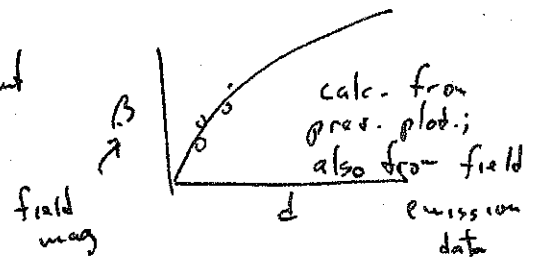
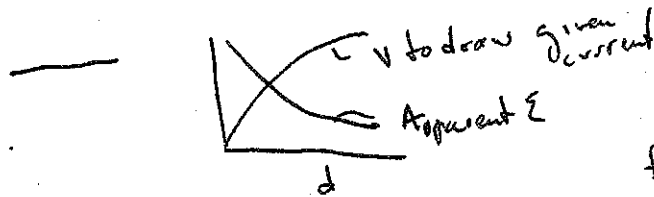
field breakdown; small d
 $J = J_{\text{oe}} \frac{1}{\alpha}$

P. Kisliuk, W. S. Boyle, and L. H. Germer
 Bell Telephone Laboratories
 Murray Hill, New Jersey

Currents preceding breakdown have been measured between closely spaced tungsten electrodes in high vacuum. It is found that field emission currents sufficient to evaporate anode metal flow before breakdown. These currents follow the Fowler-Nordheim equation when field magnification due to surface irregularities on the cathode is taken into account. The field magnification is a function of distance at electrode separations less than 4×10^{-4} cm.

Explanation of the observed breakdown at low voltage and small spacing requires an unusually high yield of electrons at the cathode per ion formed in the gap. Furthermore there is no measurable direct enhancement of the current by ionization even at higher voltages. The high electron yield must therefore exist over the entire observed range of breakdown voltages. This high yield is satisfactorily accounted for by the increase in field emission due to the positive ion space charge, which in turn increases the positive ion current density until there is breakdown. Breakdown occurs when the field emission current is increased by only 65 per cent. This condition is reached with the ion current density much smaller than the electron current density.

$J = Ae^{-B/E}$ $E = \frac{V}{d} \beta$; β to account for irregularities
 use $d \sim 10^3 \text{ \AA}$



$J = j_0 e^{1/2} = 1.65 j_0$

True field at pt $50-60 \text{ kV/cm}$
 apparent 3×10^6

SPARKING POTENTIAL AND MOLECULAR
STRUCTURE OF HYDROCARBON GASES

R. W. Crowe and J. C. Devins
General Electric Research Laboratory
Schenectady, New York

In order to calculate the Townsend α for a gas from the energy distribution of conducting electrons, one must have information about certain physical properties of the gas molecules, such as their cross-sections for elastic scattering and energy dependence of their cross-sections for excitation and ionization. Although such information is rarely available for molecular gases, a semi-empirical expression for α may be developed by the introduction of appropriate approximations in the theoretical treatment. For example, if the total inelastic (excitation + ionization) cross-section can be approximated by $\sigma = \sigma_0 (\mathcal{E} - \mathcal{E}_e)$, where \mathcal{E}_e is the excitation threshold, then it is possible to show from the derivations of Smit¹ that α should be of the form

$$\alpha/P \approx A(E/P) \exp \left[-K(\sigma_0 \Theta)^{1/2} (\mathcal{E}_i - \mathcal{E}_e)^{3/2} (P/E) \right]$$

where Θ is the elastic cross-section of the molecule, and \mathcal{E}_i is its ionization energy.

The purpose of this investigation was to determine the influence of small variations in molecular structure upon the composite cross-section $(\sigma_0 \Theta)^{1/2}$. This was accomplished by measuring the sparking potentials of a large number of hydrocarbon gases as functions of $P\mathcal{E}$ and comparing the results with the expression derived from a combination of the above equation with the Townsend criterion for breakdown. A simple correlation between $(\sigma_0 \Theta)^{1/2}$ and the number of the various chemical bonds in the hydrocarbon molecule was found. An attempt is made to interpret such a correlation in terms of electronic structure.

$$\textcircled{1} \frac{dw}{dx} - \frac{w}{2\mathcal{E}} + \frac{G}{a\mathcal{E}^{1/2}} = 0, \mathcal{E} < \mathcal{E}_e$$

$$G = N_2 \int_{\mathcal{E}_e}^{\infty} \mathcal{E}^{1/2} \sigma w d\mathcal{E}$$

$$a = e^2 \mathcal{E}^2 \lambda / 3$$

$$w = \mathcal{E}^{1/2} \left[C_1 - (Ga/k) \log \mathcal{E} \right]$$

w is local elastic; take λ const.

$$\textcircled{2} \frac{d^2 w}{d\mathcal{E}^2} + \left(\frac{1}{4} \mathcal{E}^2 - N_2 \frac{G}{\mathcal{E}} \right) w = 0 \quad \mathcal{E} > \mathcal{E}_e$$

$$\sigma = \sigma_0 (\mathcal{E} - \mathcal{E}_e)$$

$$w = C_2 \quad ??$$

$$\Theta = n_{C-H} \Theta_{C-H} + n_{C-C} \Theta_{C-C}$$

on fitting, find $\Theta_{C-C} = 0$

1. J. A. Smit, Physica, 3, 543 (1936).

Allis says at high \mathcal{E} elastic coll losses should be important

BREAKDOWN PROCESSES IN
NITROGEN, OXYGEN, AND MIXTURES*

C-5

Elsa L. Huber
Department of Physics
University of California
Berkeley, California

Presented by: Leonard B. Loeb
University of California
Berkeley, California

The studies of corona mechanisms in coaxial cylindrical geometry with central anode using α particle triggering, initiated by Colli and Facchini and by Lauer in inert gases, have been extended to pure nitrogen, pure oxygen, and mixtures of these gases. In pure nitrogen, from 25 to 600 mm. pressure, the predominant mechanism is secondary liberation of electrons from the cathode by positive ion impact, with γ_i varying between 1.4×10^{-3} and 0.6×10^{-3} . The ion is the N_2^+ observed by Varney. Addition of the order of 1% of oxygen reduces γ_i by a factor of 1/5 and gives a weak photoelectric γ_p at the cathode, both effects resulting in part from action of oxygen on the cathode. Photoionization in the gas also appears and with 5% oxygen the self-sustaining corona consists to a large extent of Geiger counter like pulses propagating along the wire. With the use of transverse and longitudinal α particle trajectories relative to the axis, the velocity of propagation of the discharge down the wire has been measured for various pressures in air, and for constant pressure and potential as a function of oxygen concentration. Velocities ranged between 10^8 and 10^7 cm./sec. In pure oxygen above 200 mm. pressure, the absorption of photoionizing radiation is so intense that instead of spreading along the wire, the discharge propagates outward in the form of radial streamers.

* This work was supported at various stages by both the Office of Naval Research and the National Science Foundation.

MEASUREMENT OF THE CURRENT DURING THE
FORMATIVE TIME LAG OF SPARKS IN
UNIFORM FIELDS IN AIR*

H. W. Bandel
Department of Physics
University of California
Berkeley, California

Presented by: Leonard B. Loeb, Department of Physics
University of California
Berkeley, California

The current in a parallel plane gap during the long formative time lags of sparks in air has been measured from 10^{-6} amp a few μ sec after application of the voltage up to 10^{-2} amp just before breakdown, for time lags between 10 and 100 μ sec. Calculations for the increase of $e^{\int \alpha dx}$ due to field distortion by positive ions are in good agreement with an observed rapid increase of current shortly before breakdown. The Townsend discharge is shown to be spread over the whole electrode surface in contrast to the filamentary nature of the final spark. The photosensitivity of the cathode surface has been found to decrease following collection of positive ions. The conditioning of the electrodes observed by Fisher and Beder-son is believed to be due to such a decrease in γ^+ . Some gain has been made toward a theoretical solution for the buildup of the Townsend discharge. Working with an integral equation and taking due care with integration limits, has established the range of validity of the existing solution and yielded another approximate solution; from these, exact solutions for the limiting cases of only one γ^+ are obtained. There is overall agreement between theory and experiment within limits of error except for an observed delay in the initial current rise. To explain this requires the consideration of mechanisms, involving creation and transmission of active photons, which could cause a delay of the order of an electron crossing time.

* Work supported by ONR, National Science Foundation, and Research Corporation.

INVESTIGATION OF BUILDUP PROCESSES
IN AN ARGON DISCHARGE

C-7

M. Menes
Westinghouse Research Laboratories
East Pittsburgh, Pennsylvania

Formative time lag studies indicate that the spark breakdown of atmospheric pressure argon is preceded by a Townsend buildup involving a delayed photon gamma mechanism.¹ Such a delayed photon emission has been found in argon counter discharges, and has been attributed to a long lived molecular state.² The present experiment was intended to investigate further the processes active in the uniform field breakdown of argon.

The experiment consists in recording oscillographically the buildup of current and of the light emission in a gap after application of voltage to the gap. The observed current buildup is exponential except for the final stage. The results have been analyzed on the basis of a delayed photon emission as proposed by Colli; they are in fair agreement with Colli's data at atmospheric pressure, but deviate appreciably at lower pressures. The cause of this discrepancy is not known and further experimental work is in progress. The final stages of the buildup appear to be controlled by space charge field distortion, but no streamer mechanism, such as described for air, has been found in argon.

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1. Kachikas and Fisher, Phys. Rev. 91, 775, (1953).
 2. L. Colli, Phys. Rev. 95, 892, (1954).

Friday, October 15

2:00 P. M.

SESSION D

SYMPOSIUM OF INVITED PAPERS ON BREAKDOWN

Chairman, W. P. Allis

Massachusetts Institute of Technology

Invited papers

D-1 MECHANISM OF UNIFORM FIELD BREAKDOWN

F. Llewellyn Jones

University College of Swansea

Swansea, Wales

D-2 FORMATIVE TIME LAGS OF UNIFORM
FIELD BREAKDOWN

L. H. Fisher

New York University

New York, New York

D-3 SECONDARY PROCESSES AND THE MECHANISMS
OF SPARK BREAKDOWN

L. B. Loeb

University of California

Berkeley, California

Friday, October 15

4:15 P. M.

SESSION E

POSITIVE IONS ON SURFACES

Chairman, M. A. Biondi

Westinghouse Research Laboratories

EJECTION OF ELECTRONS FROM CONTAMINATED
METALS BY POSITIVE IONS

E-1

Homer D. Hagstrum
Bell Telephone Laboratories
Murray Hill, New Jersey

The studies of electron ejection by noble gas ions from metals which are either atomically clean or have a monolayer of gas upon them have been extended to contaminated metal surfaces. The ions used were He^+ and Ne^+ . The metal targets, tungsten and molybdenum, were studied in four conditions: 1. as put into the experimental tube; 2. after heating to "baking temperatures"; 3. after heating to 1330°K ; and 4. atomically clean. Measurements were made of total electron yield δ_i^* for ions of kinetic energy 10 to 1000 ev and of ejected electron energy distributions at 40 and 1000 ev. The results for the target in conditions 1 and 2 (which we call contaminated) are much the same. As judged from the electron ejection measurements, the target in condition 3 looks much like one covered with a monolayer of nitrogen. Whereas δ_i^* is always less than 0.3 and roughly independent of ion energy for a clean surface, for a contaminated surface it depends strongly on ion energy and may reach values approaching unity for 1000 ev ions. Electrons ejected from the contaminated surface are slower than those ejected from a clean surface. It is evident that ordinary baking cleans the surface of a metal very little and that much of the published work on electron ejection by ions was carried out with contaminated surfaces.

MEASUREMENTS AND COLLISION THEORY
OF HIGH VACUUM SPUTTERING

Frank Keywell
Bell Telephone Laboratories
New York, New York

A Philips Ionization Gauge discharge has served as an ion source to measure absolute sputtering ratios due to ions in the energy range 400-6100 volts for the gas-metal combinations: Ag-Kr, Ag-A, Ag-Ne, Ag-He, Cu-Kr, Cu-A, Pb-A, Pb-He. The data has been interpreted by use of classical hard collision theory as described by Seitz¹. This leads to a sputtering ratio formula which is fitted to the data by means of an absorption parameter, α , introduced to take into account the effect of recoil atoms being displaced away from the surface or being stopped before reaching the surface.

Since the phenomenon of sputtering is a process of momentum transfer, it should be possible to recognize an effect on the sputtering ratio due to ions which rebound from the surface on the first collision. The data from this experiment has been treated by an "equivalent ion shift" which displaces the various curves from their relative positions to positions which correspond to equal average momentum transfer at the first collision. This tends to merge the data but there is some scant evidence that the ion rebound effect causes the shifted curves for the light ions to be low. The effect could be given a better test by means of sputtering measurements at threshold energy or energy $\sqrt{15}$ kv on a gas-metal combination such as Cu-Kr, Cu-A, having about the same average energy transfer per collision but a metal atom of mass intermediate to the gaseous ions.

1. F. Seitz, Discussions of the Faraday Society, p. 271, (1949).

ABSORPTION OF RADIATION IN THE VACUUM
ULTRAVIOLET BY N ATOMS PRODUCED IN
A DISCHARGE PLASMA IN NITROGEN*

F-1

A. W. Ehler and G. L. Weissler
Department of Physics
University of Southern California
Los Angeles, California

Absorption of electromagnetic radiation in the vacuum ultraviolet region of the spectrum by a Phillips Ionization Gauge (PIG) type discharge plasma in N_2 was investigated. Light from a spark discharge source followed a path through the PIG plasma and was analyzed by means of a vacuum spectrograph. Two photographic plate exposures were made of the source emission spectrum: one with the PIG discharge "on" and the other with the discharge "off". With the densitometer traces of these two exposures the composite absorption cross section of the PIG plasma was determined between 800A and 400A, and found to be about $17 \times 10^{-18} \text{ cm}^2$. Then the absorption cross sections and relative concentrations of the various plasma constituents were considered in the light of available information in the literature. Evidence was presented which indicates that the significant absorbing component in these measurements was atomic nitrogen. The absorption cross section of atomic nitrogen as found by this analysis agrees well within the error limit of this experiment with the theoretical value calculated by Bates.¹

* Sponsored by the Geophysics Research Directorate of the Air Force Cambridge Research Center.

1. D. R. Bates and M. J. Seaton, Mon. Not. Roy. Astro. Soc., 109, 698 (1949).

PHOTOIONIZATION CROSS SECTIONS
OF CO₂, A, H₂ and H₂O*

N. Wainfan, W. C. Walker and G. L. Weissler
Department of Physics
University of Southern California
Los Angeles, California

The photoionization cross sections of several gases were determined in the wavelength range from 473A to 1100A.¹ Simultaneous measurements of the total absorption cross sections and ionization efficiencies were made in order to compute these ionization cross sections.

The total absorption cross sections obtained are in agreement with those reported previously.^{2,3,4} In addition, the position of the ionization onset in each case agrees with the value of the first ionization limit obtained by other methods. For CO₂, the photoionization cross sections were found to fluctuate rapidly in the region from the ionization limit to 690A. This fluctuation is presumably due to the presence of strong molecular absorption bands known to fall in this region. At wavelengths below 690A, the cross sections of CO₂ are between 30×10^{-18} and 40×10^{-18} cm². The ionization cross sections of A in the region from the ionization onset to 473A were found to be between 10×10^{-18} cm² and 25×10^{-18} cm². A value of 17×10^{-18} cm² was obtained at 770A, that is, just beyond the onset. This value is somewhat lower than the theoretical estimate for argon made by Dalgarno⁵ of 30×10^{-18} cm². A preliminary study of H₂ in the region near the ionization limit yielded ionization cross sections of the order of 8×10^{-18} cm², which verifies the estimate of the magnitude of the ionization continuum made by Lee and Weissler.³ For H₂O vapor, preliminary results give ionization cross sections ranging from about 5×10^{-18} cm² near the ionization limit to 20×10^{-18} cm² at about 650A. At present, work is in progress on these and other gases as well as on various problems associated with the mechanism of photoionization.

* The aid of the O.N.R. is gratefully acknowledged.

1. N. Wainfan, W. C. Walker, and G. L. Weissler, to be published.

2. H. Sun, Private communication, 1954.

3. Po Lee and G. L. Weissler, *Astrophysical J.*, 115, (May 1952).

4. N. Astoin, A. Johnn, and B. Vodar, *Compt. Rend.*, 237, (1953).

5. A. Dalgarno, *Proc. Phys. Soc. (London)*, 65, 392, 663-667, (1953).

PHOTODETACHMENT OF ELECTRONS
FROM NEGATIVE IONS

F-3

Lewis M. Branscomb and Stephen J. Smith
National Bureau of Standards
Washington, D. C.

The apparatus described at the 1953 Gaseous Electronics conference for measuring the cross section for photodetachment of electrons from negative ions has been substantially revised and improved. An absolute radio-meter permits reliable measurement of the very high light intensities occurring in the negative ion beam. Two mass spectrometers have been incorporated in the equipment: one a crossed-field velocity selector for isolating the desired species of ion before illumination, the second a 90° sector spectrometer with a resolution of about one in 50 for detailed analysis of the ion beam.

Measurements of the detachment cross section for H^- , using a continuous spectrum peaked at 8200 A, yield a result within 10% of the theoretical value calculated by S. Chandrasekhar. The spectral region from 4500 to 7000 A has been examined in more detail with the aid of sharp-cut glass filters.

Work now in progress on oxygen negative ions will also be reported.

$H_2O + .H_2$
1:4 gives opt. H^-

They make O^- , O_2^- in
oxygen discharge
5600 Å,

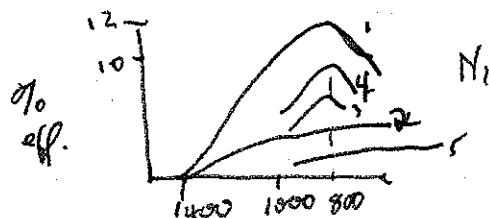
O^- beam 1 μg
 H^- 0.1 μg

FURTHER RESULTS ON THE PHOTOELECTRIC YIELDS OF METALS IN THE VACUUM ULTRAVIOLET*

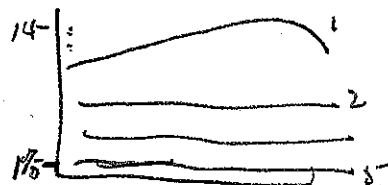
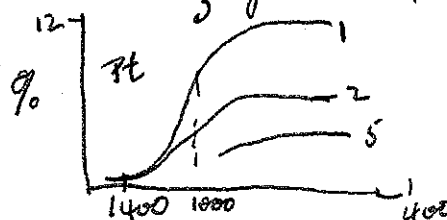
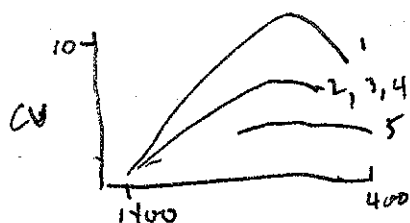
W. C. Walker, N. Wainfan and G. L. Weissler
Department of Physics
University of Southern California
Los Angeles, California

The absolute photoelectric yields of several metals subjected to various surface treatments were measured in the wavelength region from 1400 to 473A using techniques previously described.¹

Photocathodes of Ni and Cu were studied: (1) in the untreated state, (2) after being heated in vacuum, (3) after being heated in an atmosphere of oxygen at reduced pressures, (4) after being heated in H₂ and (5) while heated red hot in vacuum. Hot samples of Pt and Au were also investigated. For each metal tested, the yields from the hot sample were found to be a factor of two lower than those obtained from the same sample at room temperature and a pressure of 5×10^{-5} mm of Hg. It was also found that at wavelengths longer than about 1000A the photoyields of each of the metals decreases rapidly. In the case of Ni, oxygen treatment resulted in an increased yield due to the formation of oxides which could subsequently be removed by heating in hydrogen. The photoyields of copper were found to be insensitive to oxygen treatment and only slightly affected by moderate heating in hydrogen. Both these facts indicate that for copper the results should be considered characteristic of a copper oxide rather than a metallic copper surface. Further work is now in progress on problems concerning the energy distribution of the photoelectrons and the effect of oxide formation on the yields of some other metals.



- 1 untreated
- 2 heated + cooled in vac.
- 3 O₂ admitted
- 4 Heated in O₂, visible oxide
- 5 Hot, 1900°C - may have monolayer;
change prob. due to removal of oil



* The aid of the Office of Ordnance Research, Department of the Army, is gratefully acknowledged.

1. N. Wainfan, W. C. Walker, and G. L. Weissler, J. Appl. Phys., 24, 1318-1321, (Oct. 1953).

MOTION AND SPECTRUM OF ARC CATHODE SPOT
IN A MAGNETIC FIELD

F-5

Robert St. John * and J. G. Winans
University of Wisconsin
Madison, Wisconsin

The velocity of the cathode spot of a mercury arc in a transverse magnetic field¹ has been measured for magnetic field strengths between 0 and 20,700 oersteds. The approximate doubling of retrograde velocity at about 11,000 to 15,000 oersteds was followed by an additional rapid rise of velocity at about 15,000 oersteds. Spectra of the arc showed Hg II and Hg III lines at the stronger magnetic fields. Radiation from the cathode spot showed mercury lines and a continuous spectrum which is especially intense at the lines. Some Hg lines are broadened asymmetrically and others symmetrically. The cathode spot radiation appears to come from excited gas outside the cathode surface.

An arc mechanism previously proposed¹ is extended to explain the rapid velocity rises with increasing magnetic field strength by associating them with Hg^{++} and Hg^{+++} ions.

* Now at University of Oklahoma.

¹. R. M. St. John and J. G. Winans, Phys. Rev. 94, 1097 (1954).

THE ANCHORED MERCURY ARC
CATHODE SPOTCharles G. Smith
Raytheon Manufacturing Company
Newton, Massachusetts

A mercury arc was anchored to a polished molybdenum cylinder (axis vertical, diameter 2 cm) projecting about 3 mm above the liquid. A vertical magnetic field interacted with the arc current at the molybdenum surface where the electrons came out radially. This impelled the arc spot around in the retrograde direction with a speed in these studies of about 120 meters per second. The racing spot, a horizontal line, located on the molybdenum near the mercury was observed by a probe and oscillographic method and found to be fifteen mm long, more or less. It was most intense at the leading edge, falling off exponentially to the rear. An increase in arc current compressed the spot making the length less, the head more intense and the current density decrement along the length greater. A stronger magnetic field acted similarly. The speed limiting factor for the retrograde motion is evidently at the very front edge of the elongated racing spot. The arc current density here was about four hundred amperes per sq cm.

PROPERTIES OF A D. C. ARC
IN A MAGNETIC FIELD

F-7

L. P. Winsor
Rensselaer Polytechnic Institute
Troy, New York

and
T. H. Lee
General Electric Company
Schenectady, New York

An experimental study has been made of the motion of a direct current arc between plane parallel electrodes when subjected to a perpendicular magnetic field. Arc currents up to 100 amperes in fields up to 200 gauss have been investigated.

In the lower current range, the cathode spot advances uniformly in the proper direction at the same rate as the column. The velocity increases non-linearly with an increase in either the current or the field intensity, and is essentially independent of the electrode material. Except at the lowest currents, the anode spot tends to lag behind the column and advances in discrete steps in a similar manner to that observed by others for a moving anode.

When the current is increased beyond certain limits, the cathode spot also tends to lag behind the column and advance in similar discrete steps. The average velocity is reduced appreciably from that observed for the first mode. The transition current is found to increase with an increase in field strength and to be dependent on the cathode material. The results have been correlated by photographs of the arc, the anode and cathode tracks, and cathode ray oscillograms of the arc voltage.

Anode current densities in the range between 10,000 and 100,000 amperes per square centimeter have been measured.

ELECTRIC FIELD MEASUREMENTS IN GLOW DISCHARGES BY ELECTRON BEAM PROBE TECHNIQUES*

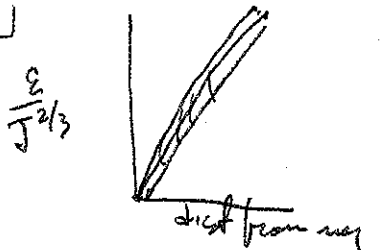
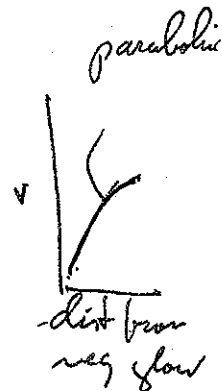
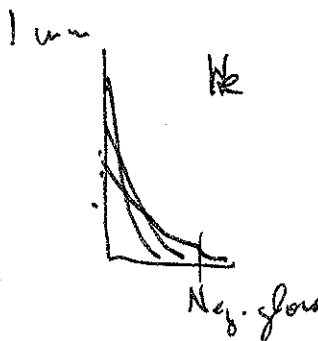
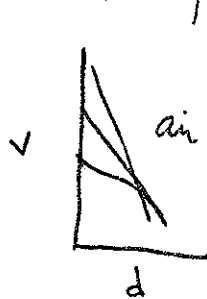
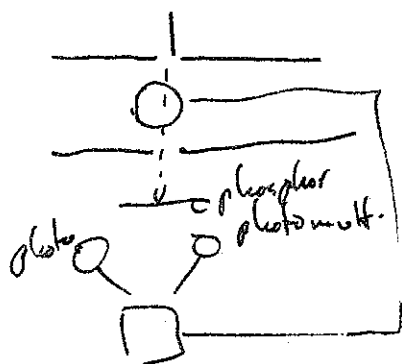
Roger W. Warren
 Department of Physics
 University of California
 Berkeley, California

Presented by: Leonard B. Loeb
 University of California
 Berkeley, California

Electric field measurements have been made in the cathode fall region of glow discharges in He, Ar, N₂, H₂, and air. In most cases, the absolute values of the fields have been determined within a few percent. The measuring technique, a null method using an electron beam or a probe, permits high accuracy, high sensitivity, and continuous measurement and recording traversing a whole discharge within minutes. Fields in the positive column and fields in striations of a few volts / cm. can also be faithfully recorded. Simultaneous recording of wall potentials and luminosity along the discharge as well as some spectroscopic studies have been made. The measurements indicate that at high pressures greater than mm Hg, the current carriers in the cathode fall region are entirely positive ions moving from the negative glow to the cathode with a velocity proportional to $(X/p)^{1/2}$. At lower pressures, complications occur.

could get 50KV beam, but only 20 sec.

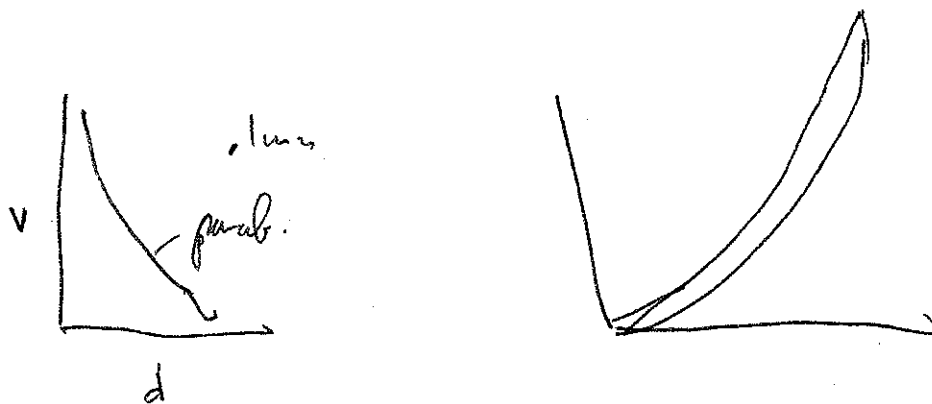
*60 cm spacing
 tank gases, ~~not~~ dried. 0.1% purity*



* This work was supported at various stages by the Office of Naval Research.

W. Finkelburg
Siemens Schuckert Werke
Erlangen, Germany

ABSTRACT NOT AVAILABLE



Saturday, October 16

1:30 P. M.

SESSION G

INVITED PAPER AND MISCELLANEOUS

Chairman, L. W. Branscomb

National Bureau of Standards

Invited Paper

EFFECT OF ELECTRONS ON SPECTRAL LINES
EMITTED IN A DISCHARGE

G-1

H. Margenau

Yale University

New Haven, Connecticut

Exact energy - wave treatment valid
 $\lambda \ll a$ plasma, energy distributed - treat elect. as particles

$$\psi = \int c(k) e^{ikx} dx$$

$$P = \dots e^{-\frac{1}{2} k^2 / 2mkT}$$

But $|\psi|^2 = P^2$; $P = e^{-\frac{mkT}{\hbar^2} k^2}$

$$\lambda = \frac{\hbar}{\sqrt{2mkT}}$$

$\lambda \ll a^{1/3}$ leads to Fermi dist

$\lambda < a$ - atomic size; atom sees a charge about its own size. If $\lambda > a$, elect. density is too spread out.

But find $n > 10^{26}$ - works for atoms
 ($T = 6000^\circ$ sun) not for electrons.

Extended Weisskopf-Wigner theory of breadth - includes 1st order Stark

$\bar{E} = \frac{1}{2} eV$, $n = 10^{14}$ (sun) Lyman α

Universal broadening (ordinary Stark)	0.13 x normal broad.	/ α^2
Polarization, reorientation ($2p_0 \rightarrow 2p_{\pm 1}$)	.027	
Pol. induction ($2p_0 \rightarrow 2s_0$)	2.7	
Quenching	.001	/
Stark broadening by ions	80.0 - $\alpha n^{1/3}$	

at $n = 10^{17}$ they compete

\leftarrow
 $\frac{0}{a} +$

THE WIDE RANGE ELECTRONIC TUNING
OF MICROWAVE CAVITIES IN
GAS ATMOSPHERES

Frank R. Arams and Hans K. Jenny
Radio Corporation of America
Tube Division
Harrison, New Jersey

Methods for electronically tuning microwave cavities using the principles of space charge tuning and of spiral beam electronic tuning in the presence of a low pressure gas are described.

Very wide tuning ranges have been measured. One cavity was tuned over a frequency range from 3280 to 4350 Mc., and from 3280 to 2540 Mc., or ± 30 percent. These values are compared to some measurements made in vacuum.

A semi-quantitative theory for electronic tuning in gas atmospheres is presented. Limitations of the method are given. Some microwave gas breakdown measurements are described.

A DYNAMIC PROBE METHOD
FOR UNIPOLAR SPACE CHARGE FIELDS

G-3

P. Cooperman
Research Corporation
Bound Brook, New Jersey

A new method has been developed for measuring field strength and current density in the unipolar space charge fields arising from the d. c. corona discharge. The method consists essentially of firing precision ball-bearings of $3/16$ " diameter with controlled velocities through a discharge. The charge imparted to the projectile is measured by catching it in a Faraday cage connected to an electrometer. It can be shown that a graph of the reciprocal of the voltage on the cage against velocity provides information sufficient to determine field strength and current density.

The advantages of this method are: (1) minimum disturbance of the field, (2) self-checking, (3) measurement of current density as well as field strength, (4) simple mathematical calculation. The first point can be emphasized. Although $3/16$ " balls were used in these experiments, it would be possible to use balls only a fraction of a millimeter in diameter. Furthermore, there are no leads or supporting structure in the field.

Experimental results obtained using negative d. c. corona in room air will be given for two geometries (1) concentric cylinders and (2) a grating of wires between two parallel plates.

THE INFLUENCE OF SPACE CHARGE ON THE
POTENTIAL DISTRIBUTION IN MASS
SPECTROMETER ION SOURCES

W. M. Brubaker
Consolidated Engineering Corporation
Pasadena, California

The role of space charge as a factor influencing the potentials and gradients in a mass spectrometer ion source of the electron bombardment type is calculated. Planar equipotential surfaces are assumed, and the analysis then becomes that of a plane parallel positive ion diode. The "cathode" of the ion diode is either emission-limited or space-charge-limited. The analysis considers the charge of the electrons in the ionizing sheet and the charge of the positive ions in the diode.

At a critical gas pressure the influences of the positive and negative charges on the potential of the ionizing region are equal and opposite for small ionizing current. This concept leads to a pressure normalization in terms of the critical pressure. When this is done, sets of universal curves can be made for specific source geometries. Each set of curves gives the potentials and gradients in the source uniquely as a function of the normalized gas pressure and the ratio of the ionizing electron current density to the repeller voltage.

A knowledge of the potential of the ionizing region is essential in appearance potential studies. Experimental data confirm the predictions of the theory.

METALLIC FLAMES EXCITED BY ACTIVE
NITROGEN; STUDIES OF AFTERGLOWS
IN RARE GAS-N₂ MIXTURES

G-5

Carl Kenty
General Electric Company
Nela Park, Cleveland, Ohio

A Tesla spark between a flat W electrode and a W point 1-3 mm distant in .1 mm N₂ + 200 mm A produces a blue flame¹ having (a) an initial speed away from the flat electrode of 150 cm sec⁻¹ due to rebounding neutralized ions, (b) a concentration of sputtered W atoms of 2×10^{11} , cm⁻³, (c) an ion concentration of $10^7 - 5 \times 10^9$ cm⁻³, and (d) a concentration of N₂ and N metastables $> 10^{12}$ cm⁻³. The spectrum consists of low energy (mostly < 3.7 V) W arc lines and the N₂ 2d positive bands, C³ π_u ($v_0 = 11$ V) \rightarrow B³ π_g . With Ta electrodes, Ta 5212.8 (2.37V) is strong showing that N(2D=2.37V) atoms are present. N₂(C³ π_u) may be excited by a collision of N(2D) with N₂(w, about 8.6V).² The flame excites Na and (weakly) Hg but not Ba II.

A 60 cycle, 20 ma discharge in .1 mm N₂ plus 200 mm He, Ne, A or Kr produces a 5 second orange afterglow (A.G.) due mainly to v_8 (8.9V) and v_4 (8.2V) of N₂(B³ π_g), excited probably by a¹ π and/or w, and a¹(¹ Σ_u^-) of N₂ through collisions.³ The A.G. excites Na, Hg, Cd, Zn, Tl, Mg and (very strongly) Ba II 4554.0 (7.90V). With Xe + N₂ no orange A.G. is produced.^{1,4} Ba II 4550 is strongly excited showing a carrier is present of energy > 7.9 V and < 8.28 V, probably N₂a¹(¹ Σ_u^-) confirming Gaydon's placement.²

1. C. Kenty, Phys. Rev. 89, 336 (1953); 93, 651 (1954).

2. A. G. Gaydon, "Dissociation Energies", Dover Publications Inc., (1950), p. 155.

3. R. W. Nicholls, J. Chem. Phys. 20, 1040 (1952).

4. Y. Tanaka and M. Zelikoff, J.O.S.A. 44, 254 (1954);
C. Kenty, J. Chem. Phys. 22, 1466 (1954).

Herbert P. Broida
National Bureau of Standards
Washington, D. C.

Products from discharges through nitrogen have been condensed on surfaces at 4.2°K .¹ During condensation the solid material emits a yellow-green glow with occasional flashes of blue. After the supply of nitrogen is stopped and the discharge removed, a green glow continues for several minutes.

Spectra of these glows have been obtained between 3100 and 9000A with a Hilger E-2 spectrograph with glass optics and a Hilger F/4 spectrograph with quartz optics. These spectra show that the radiation is the same as that obtained from the bombardment by electrons of solid N_2 .^{2,3} It is possible that the glow is related to the formation of a solid lattice of molecular and atomic nitrogen. Evidence supporting this suggestion, obtained from discharges with other molecules, will be given.

The preliminary experiments have been made with relatively simple apparatus in which nitrogen gas from commercial cylinders has been excited in a glass with an electrodeless discharge (2450 megacycles) at pressures of a few mm. Products from the discharge are pumped rapidly and continuously from the discharge region to a vessel immersed in liquid helium.



Glow looks as much as 5 min

On warming to $\sim 30^{\circ}\text{K}$, get blue flash + it goes out

5230A from solid; continues after disch. off.

3 min. intense

line-like spectrum, but somewhat diffuse

1. H. P. Broida and J. R. Pellam, Phys. Rev. (in press).
2. L. Vegard, Nature 113, 716 (1924).
3. J. C. McClennan, H. J. C. Ireton and K. Thompson, Nature 118, 408 (1926).

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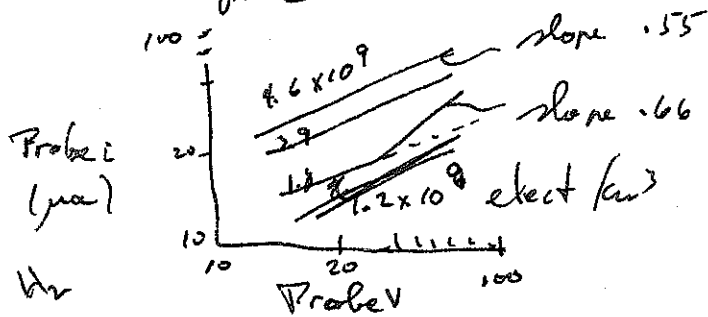
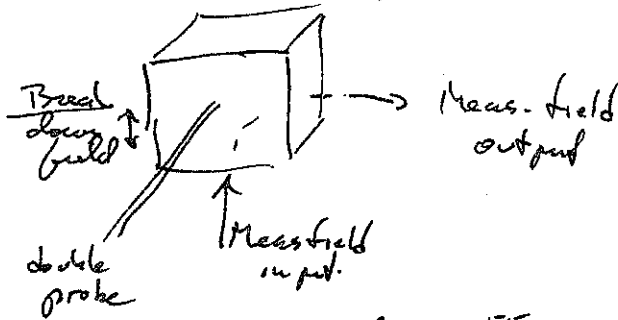
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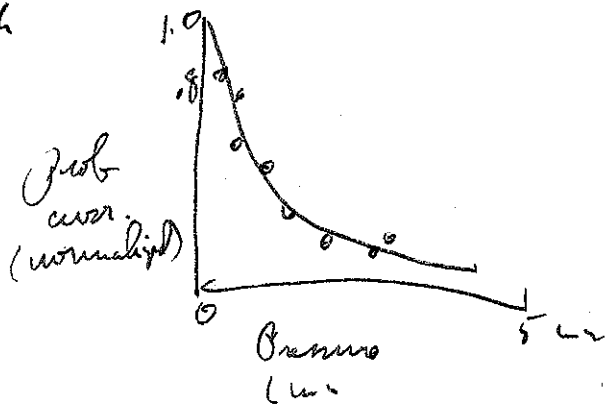
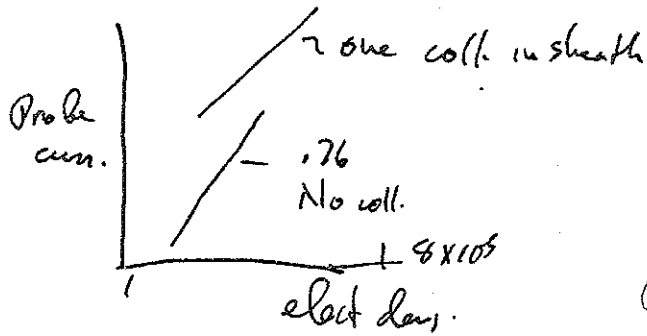
NOTES

Schultz + Brown B-6
electron saturation current

Gas	(predicted) Langmuir	Obs.	New (pred.)
H ₂	5×10^3	2-400 (Howe)	390
A	3100	110-250 (Boyd)	180

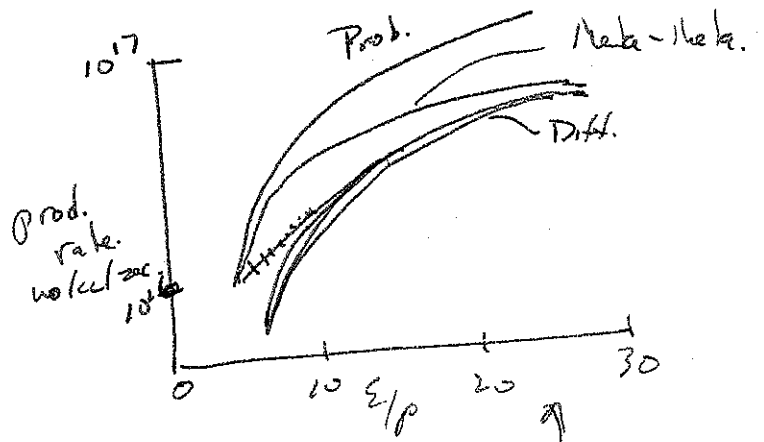
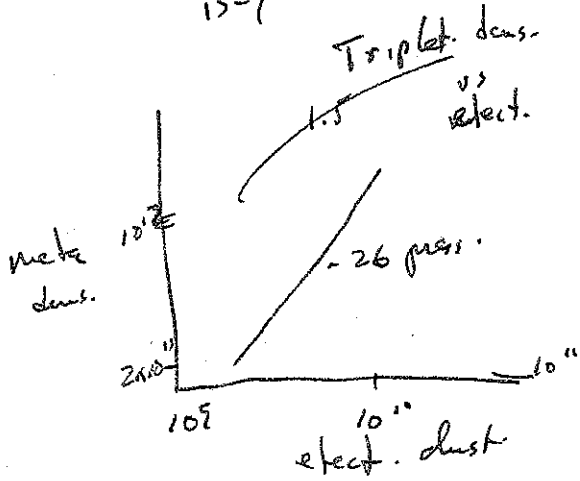


At higher p , all have .66 slope



NOTES

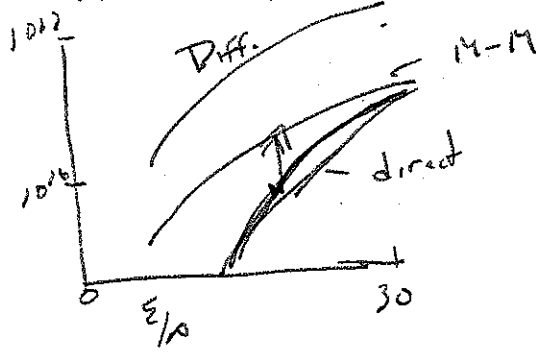
13-7



Electron balance

$$2\gamma_{Du} + 2\gamma_{Mz} + \gamma_{M-M} = -D_n D_n^2$$

Direct
Meta-Meta
elect-meta



Difference at high E/p prob. due to elect-Meta.