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CERN STUDY GROUP ON FUSION

Third Meeting

Geneva, 5 and 6 March, 1959

TECHNICAL SESSIONS

Note

This summary of the Technical Sessions has not been checked by the authors and therefore errors or omissions are not to be attributed to them.

E.R.

Kistemaker reported on cathode sputtering, cross-sections for capture and loss of electrons, and on Ixion type of gas discharge.

1) Cathode sputtering.

In thermonuclear research it is interesting to know what quantity of material will sputter off from the walls and come into the discharge. The sputtering coefficient can be defined as

$$S = \frac{\text{number of atoms flying off}}{\text{number of ions hitting on surface}}$$

The beam can impinge on the surface at various angles of incidence.

In the experiments an isotope separator was used essentially as an ion source giving 10 mA, 20 - 30 keV beams of ions and the plates were weighted before and after the beam impact. Fig. 1 shows the results for normal incidence on commercially available polycrystaline copper.

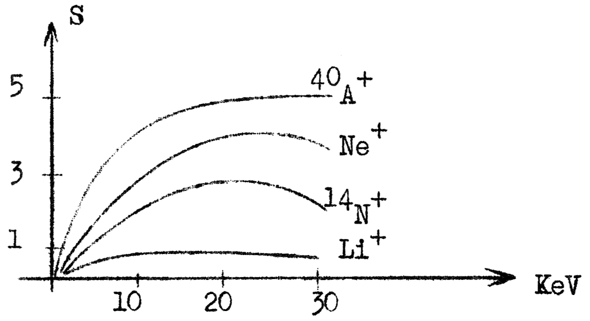


Fig. 1.

With nitrogen there is clearly a maximum at 20 keV, for higher masses the maxima occur at higher speeds. For thallium and mercury maximum coefficients of about 9 were found. For other incidences than normal the same behaviour is found but the magnitudes are different. In the case of argon, for instance, the maximum reaches 9 for 40° incidence. As a rule S goes up according to a cos Θ law and this can be understood in terms of impulse transfer from the ion beam to the crystal surface and reaction forces.

Another result is that as a function of $\sqrt{m}$ S is a fairly straight line (fig. 2).

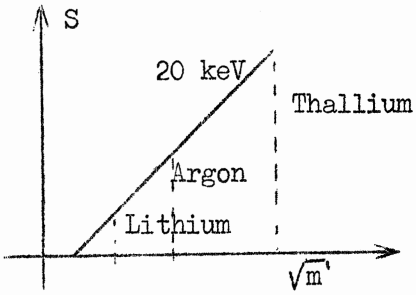


Fig. 2

For lower masses than lithium S is very small so that for hydrogen one hardly expects sputtering ($S = 0.05$ found at Oak Ridge). With silver instead of copper $S = 8$ instead of 5 was found for argon.

Shooting at single Cu crystals in the 100 direction one finds $S = 8$ instead of 5 for argon. As a function of the incidence angle S follows then a $\cos^2 \Theta$ law rather than a $\cos \Theta$ law and this can be explained by assuming that not only surface layers but also deep layers got off.

An exceptional behaviour is shown by Mg, Al, St, Zn which make very stable oxyde layers.

2) Cross-sections for Capture and Loss of Electrons

When a positive ion and a neutral particle are in a gas there is a chance that the ion robs an electron from the neutral particle. The transfer probability is maximum for

$$\frac{a \Delta E}{h v} \approx 1$$

where a is the interaction length, v the velocity of the particle and ΔE the difference between ionization and neutralization energy. If N_o is the initial number of particles of a beam shot into the gas, one has

$$N = N_o e^{-n_{gas} \sigma \ell}$$

For a vacuum of 10^{-6} mm Hg one can take $n_{gas} = 10^{10}$; for $\sigma_{res} = 10^{-15}$ and $\ell = 1$ m one would lose 1/3 of the beam in 1 m.

Capture processes and excitation spectra of a beam passing through a gas chamber are being studied. A vacuum spectrograph is used to determine the energy levels.

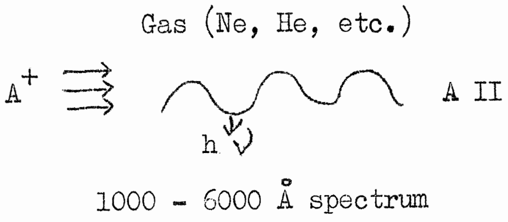


Fig. 3.

Knowing the beam characteristics and the gas density, one can deduce the absolute cross-section for such processes.

Experiments with beams of O++ shot into hydrogen gas will be started soon.

3) Gas Discharges.

The work on gas discharges started from simple configurations

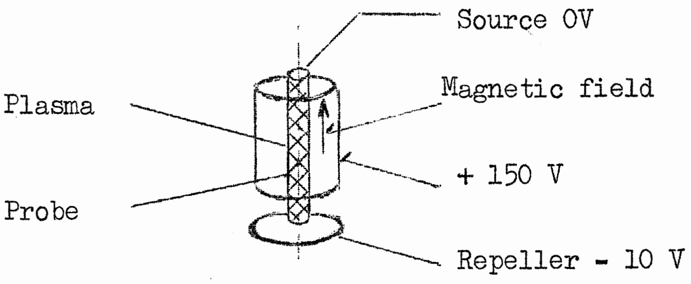


Fig. 4

A cylinder was used with a plasma column in the middle (fig. 4). Probe measurements were made to study the potential distribution inside the discharge. A symmetrical distribution was found, the central potential depending on the nature of the gas. For noble gases (Argon, etc.) the centre was found at 130 V but when one brings in air one gets a deep potential trough (about 50 V in the middle).

Superimposing a magnetic field to the potential well one gets rotation as in a magnetron. As usually the drift velocity of the particles $v = E/B$ is independent of mass. For $E = 100$ V/cm, $B = 100$ Gauss one gets $v = 10^8$ cm/sec.

In fact an Ixion type machine has thus been realized before this machine became known at the September Conference. However, the potential was not high enough to create neutrons.

Pease gave the following interpretation of sputtering curves

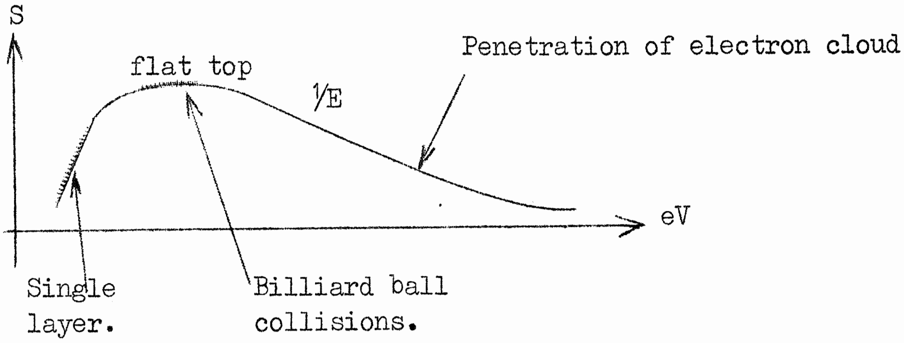


Fig. 5.

Linhart made the remark that in Zeta unipolar arcs are more important for evaporating atoms from the wall than sputtering.

Curran reported on AWRE work.

1) Linear Dynamic Pinch.

In carrying out the straight z-type pinch work at Aldermaston the main aim was to achieve early heating. This was done by shocking the gas by means of a very low inductance bank, Consequently much work had gone into the design of such banks and several equipments were in use. These were in order

Minni	3 - 5 kV, 3 KJ	
Oswald I	10 kV, 4 - 5 KJ	to be replaced by Oswald III of 15 kV, 10 KJ, 8 - 10 mμH.
Oswald II	10 kV, 5 KJ	
Maggie	25 - 30 kV, 40 - 50 KJ, 5 mμH.	

The z-pinch work has shown interesting results regarding neutron emission, particularly some differences from the results obtained by U.S. and Russian experimenters. Thus the emission was not nearly so sensitive to applied magnetic fields (up to 2000 G before pinch) unless an external inductance of 100 - 200 mμH was added. The instability responsible was not the $m = 0$ mode. There was nevertheless an accelerating mechanism producing particles with energies of 10 - 20 keV on a sizeable fraction of the emission. Subsequently the diagnostic techniques were improved and better photographic and spectroscopic studies have been carried out. For example it has been shown that on Oswald II the oxygen ions had an energy of 640 eV. This came from photographic records giving time to first pinch and was in agreement with energy balance ($\int p\, dv$) measurement.

2) Thetatron.

Following the work at Princeton on Scylla-type apparatus, Niblett has worked on discharges of the θ type, i.e. B in the z- and i in the θ-direction, E round the minor circumference. He drew attention to various attractive features and especially to the better prospect of stability in the θ-form as distinct from the z-form. The work is continuing on an increasing scale and the stability prospects seem most promising. Small units are used in conjunction with Maggie. Mostly the vessel is a straight quartz tube of 2 m long and 2 - 3 inches in diameter with a single copper driving loop of 6" length. In general no attempt is made to compress as in Scylla. Ideally one would like the straight section to behave as an element of a toroidal vessel but that would require end-correction; escape from the ends does occur therefore. Photographic studies made through the end and through a slit in the electrode show promising stability features over a few complete half-cycles of current. The pinching is regular and sustained for the duration of the current. Crow-barring is required to extend the duration of the pinching time (10 pinches in about 10 μsec) further.

Preionization is employed but must be improved. Consequently there is evidence in the photo-records of trapping of magnetic fields within the sheath and possibly of diffusion across the sheath. If definitely substantiated, this could be an important element in determining sheath temperature. The oscillations are such that the period can be related theoretically to the particle line density and the field strength (B^2). The agreement is very good. The heating is probably mainly by shock, though adiabatic heating may prove of considerable value.

The time to first pinch is of the order of 1 μsec and likewise the time between successive pinches. The neutrons appear (10^4 - 10^5/pulse) at the time of peak current and X-rays at approximately peak voltage.

3) Hitex.

The z-pinch and thetatron work is accompanied by a study of a D.C.X. type of experiment called Hitex (high temperature experiment). It is still under discussion whether or not to proceed with an experiment proposed mainly by Sweetnam and which would use a neutral hydrogen beam at an energy of 30 - 50 keV and a containing vessel of about 1 ft cubed (with C vacuum arc). The DCX region, molecular ions of 600 - 800 kV, is more demanding. The neutral atom source seems possible if difficult and the clear conception of the DCX job itself makes the higher energy experiment attractive. On the other hand the flexibility and general convenience and economy of the lower energy are strong points in its favour. Meanwhile some work proceeds on various elements of such a system, e.g. neutral beam source, C arc, etc.

Pease reported on Harwell results.

1) Zeta 1 A.

Zeta 1 H has now been completed. The main modifications consisted in providing a stainless steel 0.02 Ω liner and ignitron switches. With these two modifications and the existing capacitor bank one should be able to go up to 350 kamps.. Actually 300 kamps have been obtained.

The stainless steel liner can be baked but parts of the vacuum system cannot. The best pressure achieved is 3×10^{-7} mm Hg.

About 50 discharges have been studied. The current was 10,000 A, the electric field 30 V/turn. A high amount of X-rays has been observed. No neutrons were found. The $H\rho$ is 200 Gauss x 100 cm. The direction in which the current flows matters, probably because of stray fields.

The threshold pressure is higher than previously, 0.5 μ instead of 0.1 μ. The law p_{th} prop. to $1/E$ has been checked experimentally. It has been found that with preheating of about 5 kA, the pressure is lowered by a factor of two (0.25 μ).

R.F. preionization is used down to a pressure of 10^{-4}.

In shot operation the discharge is cleaner than it was previously. During the first few hundred shots the spectrum is full of C , N originating from pump oil. After 500 shots these disappear and Fe, Ni and Cr lines appear.

Partial short-circuit to the main aluminium body and the stainless steel liner occurs and upsets operation.

The stainless steel liner is corrugated. Length of corrugation 3/4", depth 1". Cu rings are placed in the corrugations to exclude B_z. The internal field due to current in the liner - called B_y - is about 1 Gauss/kA.

2) Results.

Resistance $10^{-3}\,\Omega$

Pinch compression $= \dfrac{\text{actual } I}{\text{critical pinch } I} \approx 2.5$

The magnetic field distribution is the same as in Zeta 1.

From probe measurements it seems that there is a skin effect with heavy gases.

The ion temperature is estimated to $6 - 7 \times 10^6$ °K.

Microwave noise curve

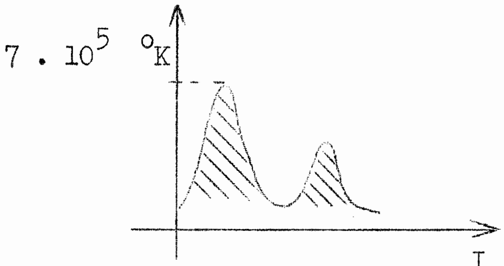


Fig. 6

This is probably not a genuine electron temperature since spectral experiments do not check (non-maxwellian noise).

3) Small Scale Work (Bickerton).

A) Fast toroidal pinch.

A 4-sector quartz torus is available together with facilities for feeding 30 keV/gap. Bore of the torus is 10 cm, main diameter 60 cm. This device has not yet been run up to its full capacity. Present figures are 100 kA, 1 μs rise time.

Results: a) Skin effect.
Observed in deuterium and heavy gases (more pronounced with preheating). The skin depth is in the region 1 - 2 cm. Line density 10^{17} - 10^{18}.

b) Stability.
The time for which the skin effect lasts is disappointingly short.

c) Shock wave effects and bouncing.
Observed in heavy gases (A).

Generally, all phenomena observed in straight discharges can be reproduced.

B) Fast linear pinch.

A straight tube is available for studying skin effects. Bore of the tube is 25 cm, length 1 m. A current rising in 3.5 µs to 100 kA can be obtained. Skin thickness is 4 - 5 cm. Rapid growth and signs of instabilities have been observed.

Attention is now given to un-pinch (hard core) experiments.

4) Future Programme.

Some thought is being given to run-away electrons.

The line density will be increased considerably, $N \approx 5.10^{18}$.

Currents in the region 500 - 100 kA are contemplated.

Arguments on the form of the next machine are being considered.

Colgate reported on some experiments in pinch work at Livermore.

1) Sodium Model.

At present the energy loss in a stabilized pinch is explained in terms of a major runaway flux but the basic stability problem is not yet understood. According to calculations of Rosenbluth, Tayler, etc. on the stability of current carrying layers, the pinch configuration is unstable unless H_z extends outwards to negative values (fig. 7).

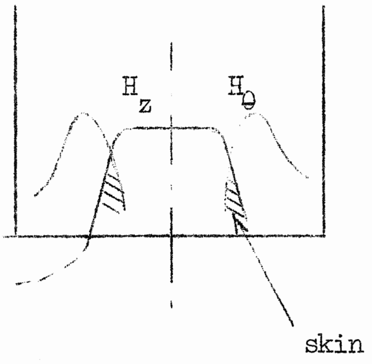


Fig. 7.

It looks that at best one can only achieve marginal stability.

An experiment has been designed (fig. 8) to simulate the pinch by a sodium layer and look at hydromagnetic instabilities of this configuration. The problems associated with plasma structure and runaway electrons are thus eliminated. The aim of the experiment is then to establish whether the layer is stable and if not, what the time scale of the instability is.

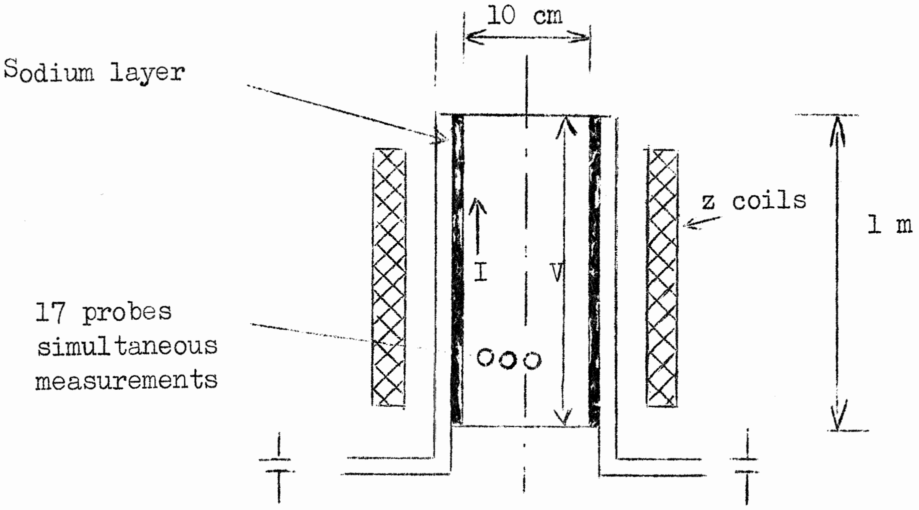


Fig. 8.

The layer is connected to the electrodes of the pinch tube. The Θ field distribution is then the desired one.

Inductive characteristics are required so that the time of formation is short with respect to "resistive" time $t_R = L/R$ which is the characteristic diffusion time of the pinch. On the other hand $H^2/8\pi$ should be large enough so that the layer is acted on as a fluid. This sets $H \geqslant 5000$ Gauss but in fact 50 - 100 KGauss have been used (sodium at room temperature). Finally one wants $t_R/t_s = \frac{\text{"resistive" time}}{\text{"sound" time}} >$ about 300. The reason is that one would expect the instabilities to develop in a time $\approx 100\ t_s$ and the experiment should be designed so as to allow plenty of time for the instabilities to grow if they want to.

The voltage and current observed as a function of time were

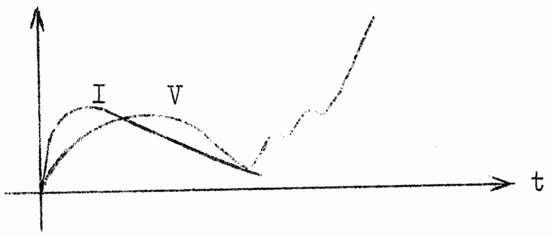


Fig. 9.

It was observed that after a while H_θ diffuses in and the current becomes uniform in the layer. However, after the current has circulated long enough, the layer breaks up and a major disruption of symmetry occurs in the range of $t/t_s = 100$. One can say that with respect to hydromagnetic stability no convincing results were found, the best one could do was to measure H_z inside and H_θ inside and outside but not in the layer. For dynamic instabilities the most drastic behaviour is observed for pinch ratios 2.5 to 3.

After an experiment the apparatus can be taken apart and one can look at the sodium form, and determine the number (m) of the instability and its $\lambda \approx 2\pi r/d$. The growing instability may cut a slot in the tube thus transforming the cylindrical conductor into a helical conductor. This leads to a leakage of H_z field and a further growth of instability (Rosenbluth's theory). This has actually been observed and one is, therefore, convinced that hydromagnetic instabilities can grow.

The gas pressure inside the tube can replace H_z. Escape occurs then through the holes and t_s is much shorter.

A hard core experiment (fig. 10) has been set up to check the stability situation in a case where a stable configuration can be predicted a priori.

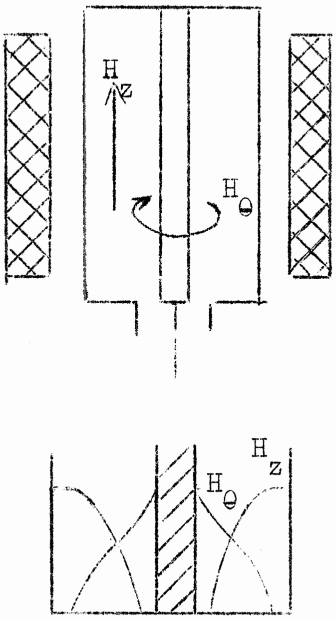


Fig. 10.

One would indeed expect stability in this case provided $\beta < \beta_{critical}$ where $\beta_{critical} = 30 - 50$ o/o in current layer for stability limit. In the case of sodium β approaches zero so that no instability in sodium should be observed in the hard core configuration.

The components of the experiment are ready. Practically, the sodium layer will be formed and put near the equilibrium position to see what happens.

2) Experiments on Turbulence.

Runaway electrons should cooperate to carry current. In fact they don't and one reason for this might be turbulence. The effect might be similar to having scattering centers. High energy electrons are able to go through turbulence and pick up more energy, low energy particles cannot.

An experiment (fig. 11) has been set up to find out whether there is turbulence and at what frequency it occurs (hydromagnetic or plasma frequency).

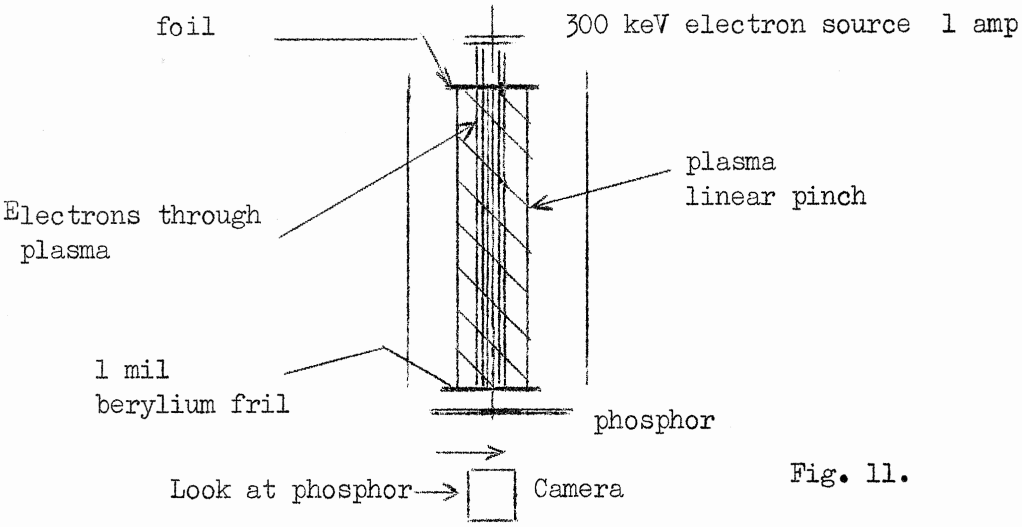


Fig. 11.

One would expect a defocused picture in case of turbulence
Turbulence will also be studied in the layer of a hard core pinch. Energy going into turbulence may increase β and be therefore the origin of instability growth.

Biermann reported on the theoretical work of the Munich group.

Various reports have been circulated or are being prepared for publication:

1. Ionization equilibrium. Theory of cross-sections of electrons on 0^5 (Knorr).

2. Heating mechanism by forced oscillations of a magnetic field (Koropa).

3. Work on gyro-relaxation expanding previous results. Three cases have been considered:
   a) Increasing frequency. $\lambda_{\text{imposed osc.}}$ = mean free path
   b) Transit time heating
   c) Gyro-relaxation

(Schmidt)

4. Magneto-hydrostatic equilibrium configurations (Mayer and Schmidt)

5. Several lines of attack on stability problems.

6. Motions of single particles.

7. Shock waves in absence of collisions and other simplifying assumptions.

Von Gierke reported on preparation of experiments at Munich.

1) Discharge Devices.

Four discharge devices are working or in preparation:

T 1 Glass torus with Cu sheeth, 5 cm bore, 1 m main diameter, pulsed B, a few volts/cm. Mainly to investigate ignition.

Minikry Aluminium torus, 25 cm bore, 1 m main diameter, 10 - 20000 gauss, three types of liners:

a) stainless steel, 0.2 mm, corrugated

b) Copper spiral (for the production of a small reversed field outside discharge to improve stability)

c) Ceramic-aluminium oxyde torus in small sections.

Simplizius Linear version of Minikry. Same liners as above. 10,000 Gauss.

Wendelstein About Stellarator B size. 5 cm bore, 70 main diameter. 25,000 Gauss. The discharge can be programmed to keep field strength inside constant.

In operation at present only T 1.

2) Diagnostic Groups.

Sputtering experiments like Kistemaker.

Development of ultra-high vacua and measurement of impurities.

Microwave group investigating the size of a dynamic pinch.

A microwave interferometer is being constructed.

A discharge device is in construction for developing spectroscopic techniques. High densities (10^{16} - 10^{18} atoms/cc) will be used to look at thermodynamic equilibrium. This is a straight pinch experiment with $B = 50,000$ Gauss. Another experiment is running to check spectroscopic measurements against probe measurements. R.F. made plasmas are used kept by magnetic fields; in practice impurities have shown up originating from the vacuum system. Electron density and temperature are measured spectroscopically, ion temperature by interferometry, all this in comparison with probe measurements,

Sources in the ultraviolet region are looked for for absolute measurements of the spectrum.

Probe measurements as usual plus a Hall generator 1 mm x 2 mm for magnetic probes (much higher signals than with the usual coils). Also semicoductor measurements.

Hubert gave an account of the work done at Fontenay.

Torus TA 2000 has been completed. Characteristics: bore 30 cm, main diameter 2 m. Trouble was experienced in starting the discharge. Vacuum was 5 x 10^{-4} mm Hg but as work went on on outgassing, the conditions improved and 10^{-8} was obtained. Preheating at low fields will be used.

During the first experiments at relatively high pressure an X-ray survey was made. A high amount of X-rays was found outside the discharge volume.

Work on smaller tori proceeds.

In Equateur the resistance of the discharge was found higher than expected. This is being looked at.

A new project (fig. 12) is now being considered. It is essentially based on

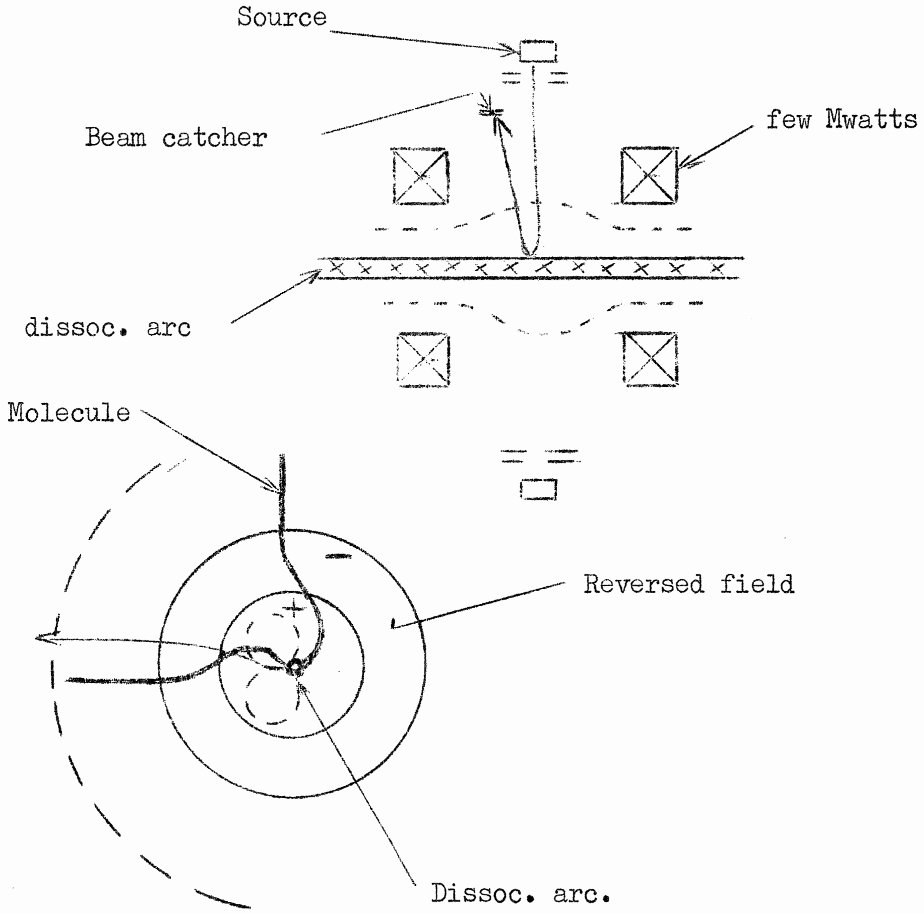


Fig. 12.

the idea of a continuous mirror machine with fast ion injection like DCX. A molecular high intensity source would be used going all around the mirror. The circumference of the source would be 3 m and if injection occurs from outside the trajectories will automatically go through the axis. Design parameters are actually being worked on. It does not seem meaningful to attempt full performance at present because high currents would certainly violate the $\beta < 1$ condition. 100 μA, 100 - 200 keV accelerating voltage are contemplated.

The optical spectroscopy programme is being prepared. A Perot-Fabry interferometer (1 Å resolution) will be used to measure the broadening of H lines. It is planned to use a monochromator with grating and a concave mirror. A Photomultiplier will permit to explore a small range of wavelengths.

Brinkman reported on theory of particles in bottles. Orbit tracing of single particles in quadrupole magnetic bottles has been performed and a check on the constancy of the magnetic moment has been made. It was found that in the central region of the quadrupole bottle the magnetic moment is not constant, i.e. a particle can be lost by gaining momentum.

Braams reported on work at Utrecht.

An approach is being considered involving bottles with either stationary magnetic or R.F. confinement or a combination of both of them. The power required for pure R.F. confinement of a plasma of reasonable density and temperature proves to be very high.

The device actually considered (fig. 13) comprises two R.F. cavities and two toroidal cavities and looks more promising than an apparatus based on R.F. confinement only.

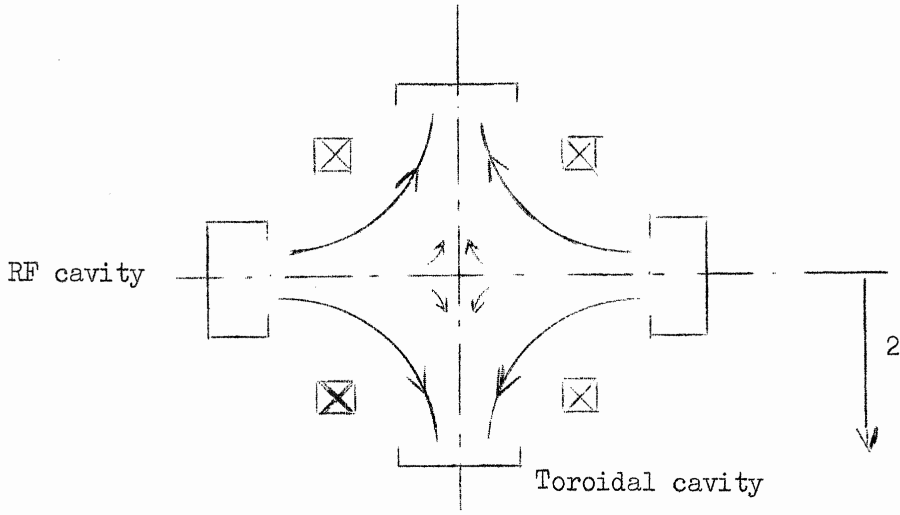


Fig. 13

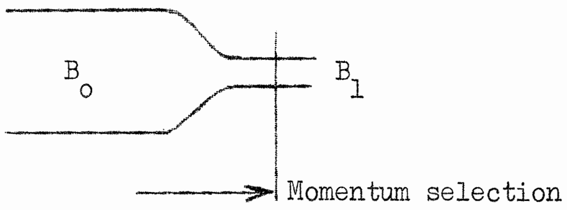


Fig. 14

If one considers a flux tube in a region B_o, B_1 (fig. 14) and if one assumes an isotropic distribution of the magnetic field, only a fraction of particles can reach B_1 and their $v_{\shortparallel}$ will be reduced. The area over which the R.F. field must exert the pressure being inversely proportional to the strength of the stationary magnetic field, one can choose a magnetic bottle to take care of the main confinement, R.F. confinement being used at the necks. In other words the R.F. field is in touch with plasma only in a small fraction of the surface and therefore the stored R.F. energy will be small compared with the magnetic energy of the main static coils.

A design study is being made. At present confinement of a low density medium temperature plasma is considered to investigate the efficiency of the method. The stationary magnetic field will have an axial symmetric quadrupole shape: $B_z = 2\ az$, $B_r = -\ ar$. Coils are being designed to produce this field shape in a volume extending to 10 - 20 cm from the origin with $a = 100$ gauss/cm for continuous operation and $a = 1000$ Gauss/cm in pulses lasting a few seconds. For an electron density of $10^{12}/\text{cm}^3$ and a temperature of 10 eV one needs an R.F. magnetic field of 30 Gauss maximum amplitude. This field will be produced by external coils; frequencies of the order of a few Mc/s are being considered, in which case the power consumption will be of the order of a few kW.

Dattner reported on experiments going on in Stockholm.

1) Coaxial Discharge.

This is a pulsed discharge in a coaxial structure.

The outer conductor is stainless steel, the inner conductor is made of iron. The discharge proceeds from the top to the bottom in an irregular conical shape. Plasma speed 6 - 7 cm/µs. Probe measurements were tried but did not work; the signal was irregular, of small amplitude and any obstacle put in the path of the plasmoid destroys it.

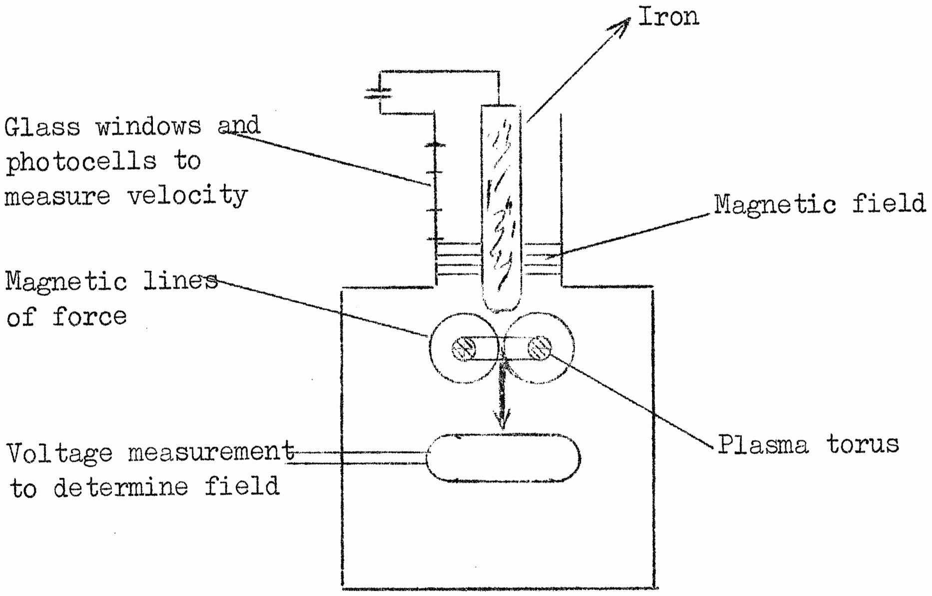


Fig. 15

2) <u>Microwaves in Plasma</u>.

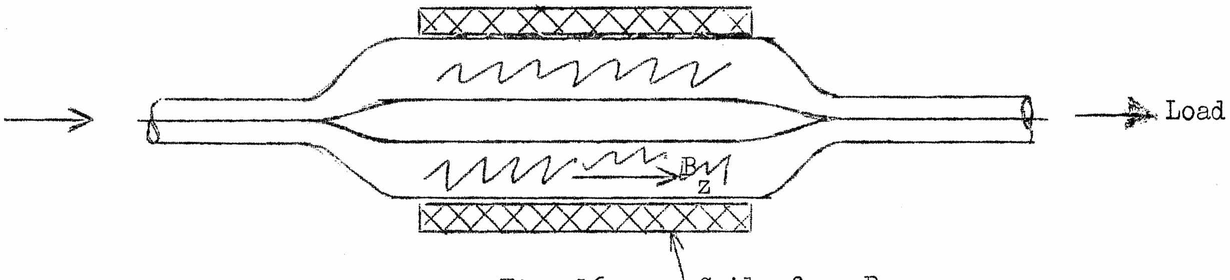


Fig. 16

One finds a very broad band of absorption in the plasma

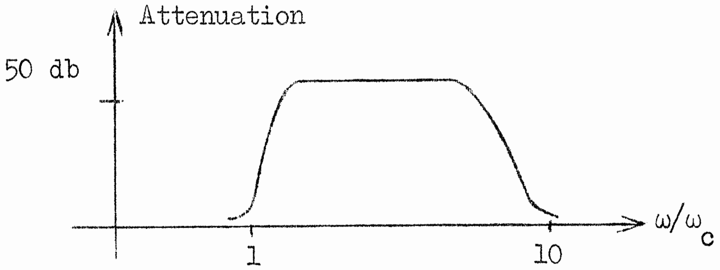


Fig. 17.

Frequency range 100 to 3000 Mc/s, plasma frequency 100 Mc/s, collision frequency 10 Mc/s.

3) Plasma filled Waveguides.

Theoretical work is proceeding on fast electrons interacting with plasma.

4) Long Tube Experiment.

A 1 mA, 1 keV electron beam is shot into an evacuated (10^{-6} mm Hg) 4 m long metal wall tube of about 3 cm diameter. A B_z field of about 1000 Gauss is applied. For some unknown reason (inhomogeneity in the magnetic field?) the beam is deflected to the wall about halfway along the tube and continues along the wall to the end.

5) Confinement Experiment.

An experiment has been carried out to check the possibility of confining charged particles in the field of a current loop (fig. 18)

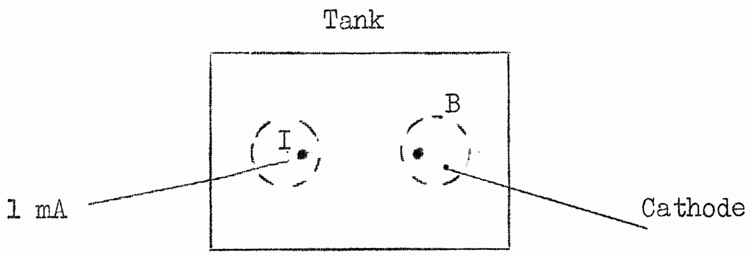


Fig. 18.

The escape of electrons from a cathode through the magnetic bottle has been measured and the current to the tank shows the following behaviour

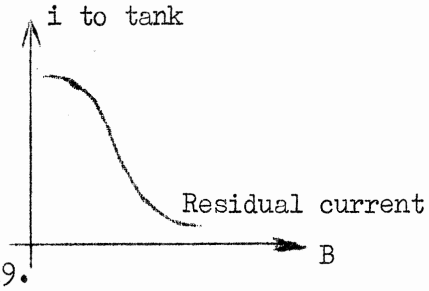


Fig. 19.

The residual current proves to be very sensitive to pressure.

With a mirror geometry (fig. 20)

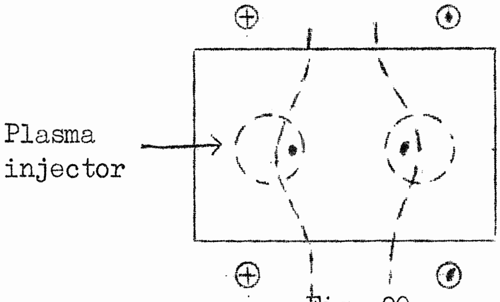


Fig. 20.

one finds for the current

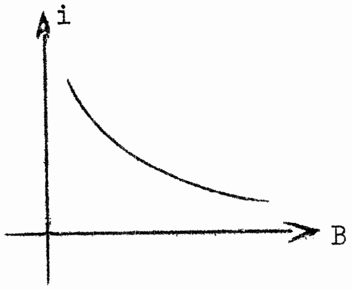


Fig. 21.

A new model is being built similar to the previous one and having 2 m x 2 m dimensions.

Jordan reported on work at Aachen.

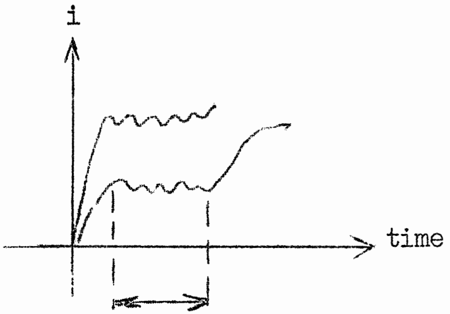
Unfortunately a fire destroyed most of the labs and equipment. However, part of the workshop and the spectroscopic equipment could be saved.

Experiments are being prepared and the work will be resumed in a few months.

1) Old Pinch Experiment.

The current in a pinch placed in an axial magnetic field exhibits the occurrence of two regimes. The first is a resistive regime with low current, the second is a regime with high current, apparently not in contact with the walls.

Fig. 22



Resistive regime

This experiment is now being considered in greater detail.

2) Fast Magnetic Compression (Main Interest).

A small device is being rebuilt to get higher magnetic fields in a smaller volume than previously. Vacuum spectrography, monochromator and rotating mirrors will be used for measurements. The dimensions of the device are 3 cm inner diameter, 10 cm long. The storage capacity of the condensor bank is being increased to 10 - 15 KJ. An essential point is to have a good conducting plasma at the beginning. A low voltage pinch will be used as a preionizing agent. An R.F. oscillator giving a few kW for preheating is being set up.

3) Large Condensor Bank.

A large condensor bank of 400 KJ storage capacity and low inductance is being installed, This should give 100 kGauss or more in larger volumes. Characteristics of a unit 18 kV, 400 kc/s frequency.

Brunelli reported on work at Rome.

1) Condensor Bank.

A 150 KJ, 40 kV, 5 Mc/s condensor bank is being built.

2) Field Configuration Experiment.

This experiment is very similar to that described by Colgate at the last Geneva Conference. A 5 cm diameter, 50 cm long glass tube surrounded by copper coils is fed by a 5 KJ discharge. The period of the oscillatory discharge is about 20 µs. The main object of the experiment is to study the weak plasma formed between the walls and the collapsing main plasma when, possibly, the thermal velocity of the neutrals from the walls is greater than the collapse velocity.

Meanwhile magnetic measurements are in progress to study the profile of the magnetic field along the radius of the tube.

3) Sheet Formation Experiment.

This experiment is concerned with the plasma sheath formation in a magnetic field.

Due to the electric field penetration, positive ions reach the sheath with an energy comparable to the thermal energy of the electrons. The aim of the experiment is to study what happens in the presence of a magnetic field. For this purpose a mercury vapour discharge at 0° C temperature is ready with two Langmuir probes placed at a variable distance.

4) Experiments with the Large Condensor Bank.

A shock experiment is planned with the large condensor bank to study the conditions under which plasma detaches itself from the walls and also to investigate the formation of thin sheets of current during the collapse. More generally, the experiment will be devoted to study the dynamics of rapid compression of a plasma contained by a magnetic field.

Following an idea of J.E. Allen, a multisector device will be used on a straight discharge tube (20 cm in diameter, 120 cm long). Fig. 23 represents a cross section of the copper shell split in M sectors connected to the bank.

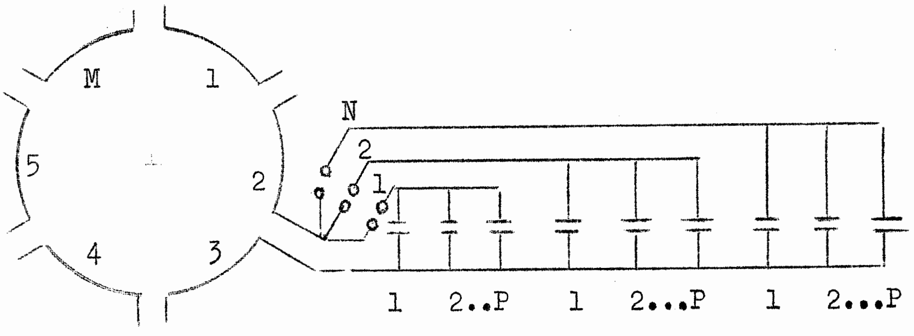


Fig. 23.

The period of the discharge is

$$T = 2\pi \sqrt{\left(\frac{L_c}{MNP} + \frac{L_{s+c}}{MN} + \frac{L}{M^2}\right) C}$$

where L_c is the inductance of one condensor, L_{s+c} the inductance of the connections and spark gap, L the inductance of the discharge tube, C the total capacity, M the number of sectors and NP the number of condensors per sector.

The advantages of this multisector device are mainly a greater rise of current and a greater effective voltage around the shell.

Design figures are:

M = 6 sectors
NP = 30 condensors/sector
C = 180 μF total capacitance
V = 40 kV charging voltage } 144000 Joules
L = 4 mμH
L_c = 100 mμH
T = 4 μs
Peak current = 1.9×10^6 A
Effective voltage = 120 kV

The number (N) of groups per sector has not yet been chosen. This number will be taken so that the inductance of spark gaps and connectors has the same influence as the inductance of the condensors.

The gas will be preionized before the rapid magnetic compression takes place. Magnetic fields of 24000 Gauss in 1 μs are contemplated and the experiment will be performed using different gases.

Shock heating experiments will be attempted with argon, with the following parameters:

$$\left.\begin{array}{l} 3 \times 10^{15} \text{ ions/cm}^3 \\ H_o = 8000 \text{ Gauss} \end{array}\right\} \begin{array}{l} \text{Alfvén velocity} \\ 5 \times 10^6 \text{ cm/s} \end{array}$$

Due to radiation losses it may be difficult to achieve such initial conditions in argon. A powerful preionizing discharge may therefore be required.

Pease raised the question of power balance and information conveyed by such a device.

E.R.

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