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STATUS OF PLASMA PHYSICS RESEARCH ACTIVITIES IN EGYPT

M.M. MASOUD
Plasma Physics Department,
Nuclear Research Centre,
Atomic Energy Authority,
Cairo, Egypt

Abstract

The status of plasma physics research activities in Egypt is reviewed. There are nine institutes with plasma research activities. The largest is the Atomic energy Authority (AEA), which has activities in fundamental plasma studies, fusion technology, plasma and laser applications, and plasma simulation. The experiments include Theta Pinches, a Z Pinch, a coaxial discharge, a glow discharge, a CO_2 laser, and the EGYPTOR tokamak.

Plasma physics laboratory research in Egypt started 1959 in National Research Center by a group working in the Z-pinch , DC glow discharge Hollow cathode discharge , RF discharge , using electric probes and other conventional diagnostics. In 1962 two experimental plasma physics groups are formed in Atomic Energy Authority (AEA) to study cold and hot plasmas where National Research Center group joined them. First group worked in hot plasma machines such as , Theta and Z-pinches , shock wave tubes, using electric and magnetic probes , microwaves , high speed streak camera , pick up coils, and spectroscopy for diagnostics. The second group studies were in, gas discharges , ion sources of different types , acceleration of charged particles , and low energy beam injectors.
The plasma physics program has slowed down from 1970 to 1985 due to several reasons.

Today there are several research institutes working in plasma physics theory and experiment. These institutes and their facilities are :-

1- Plasma Physics Department, Nuclear Research Center, AEA.
- Tokamak, Plasma Focus, Theta Pinch, Z-Pinch, Coaxial Plasma gun, Glow discharges, Lasers, Theory, Simulation, groups

2- Plasma Laboratory, Physics Department, Faculty of Science, Al-Azhar University, Cairo.
- Plasma Focus, Z-pinch, R.F. Discharge, Glow Discharge.

3- Plasma Laboratory, Faculty of Engineering, Zagazig University, Zagazig.
- Plasma Focus, Z-pinch, Microwave, R.F., DC, Glow Discharges.

4- Physics Department, Faculty of Science, Zagazig University, Zagazig.
- Z-Pinch.

5- Physics Department, Faculty of Science, Cairo University, Cairo.
- Glow Discharge, Vacuum spark.

6- National Institute of Laser Enhanced Sciences, NILES, Cairo University.
- Laser produced plasma, Glow Discharge.

7- Electrical Engineering Department, Faculty of Engineering, Cairo University.
- Glow Discharge, Z-Pinch, Theory.

8- Nuclear Engineering Department, Faculty of Engineering, Alexandria University, Alexandria.
- Glow Discharge, Simulation .

9- Physics Department, Faculty of Science, Assyout University, Assyout.
- Glow Discharge, Arc Discharge.

This is beside some individual works in the other universities and research institutes .

This does not include the research institutes works in accelerators, ion sources, and beam injectors . In that field the main Institute is sited in AEA, Ion Sources and Accelerator Department.

In the following sections a short description of the research facilities and activities in Plasma Physics Department, AEA.

The research activity in the department is divided into four groups :
1) Fundamental plasma studies, theoretical and experimental.
2) Fusion technology, theoretical and experimental.
3) Plasma and laser applications.
4) Plasma simulation.

1) Fundamental Plasma Studies

Theory

The theoretical studies are mainly directed to investigate the problems of :
- Nonlinear interactions and wave generations in plasmas.
- Instabilities specially, Beam-plasma, Electro- acoustic, current convective, Buneman, and Drift.
- Surface waves, excitation and interaction.

The new trend in the theoretical study is the use of the analytical method to describe the nonlinear plasma dynamics in situation closely to the experiments.

Experiments

a) Z-Pinch

Four meter z-pinch [1] is used for pre ionization and preheating of the rest gas in the 3.5 m. theta pinch experiment . It is also combined with the theta pinch to produce a stable screw pinch.
Another 0.3 m length, 0.25 m diameter , z-pinch operated with relatively slow rise time (~ 10 μs.) capacitor bank is used to produce a stable hot plasma for the study of additional heating problems. The plasma temperature reached

50 eV and electron density up to 10^{14} cm^{-3}. Microwave and particle beams will be introduced to the pinched column later.

The most interesting results in small z-pinches that if high current discharge flows through it, current disruption occurs [2] accompanied by hydro -magnetic instabilities.

b) Theta-Pinch

There are two Theta-pinch machines in operation during the last 10 years, the 3.5 m. and 0.8 m.. Both machine's capacitor banks were developed several times.

The 0.8 m. θ-pinch is one of the old machines in the plasma department. With the use of 4 kJ.- 25 kV. capacitor bank, a peak discharge current of 120 kA. with 10 μs rise time was obtained. The peak plasma temperature and density were 180 eV. and 1.4 x 10^{15} cm^{-3} respectively. A burst of microwave radiation referred to the excitation of the lower hybrid electron cyclotron oscillations and its harmonics was detected. Most of the radiating energy was carried by the second harmonics. Magnetic reconnection was one of the interesting phenomena observed, which imposes the modification of the system.

The latest modification of the 0.8 m. θ-pinch is the use of two banks, fig.(1), to enhance magnetic field reconnection. The current research course is the study the relation between magnetic reconnection and other process such as energetic particles and the different instabilities.

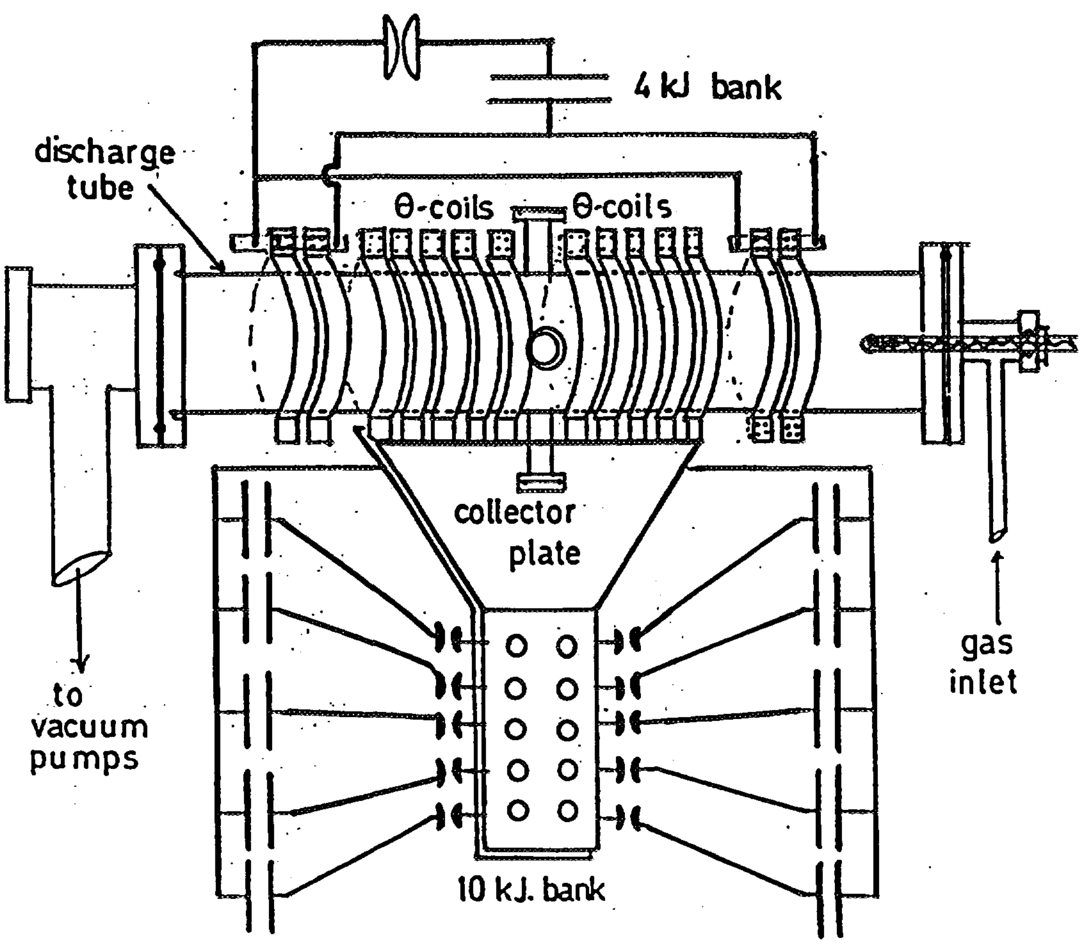


FIG. 1. Modified 80 cm θ-pinch.

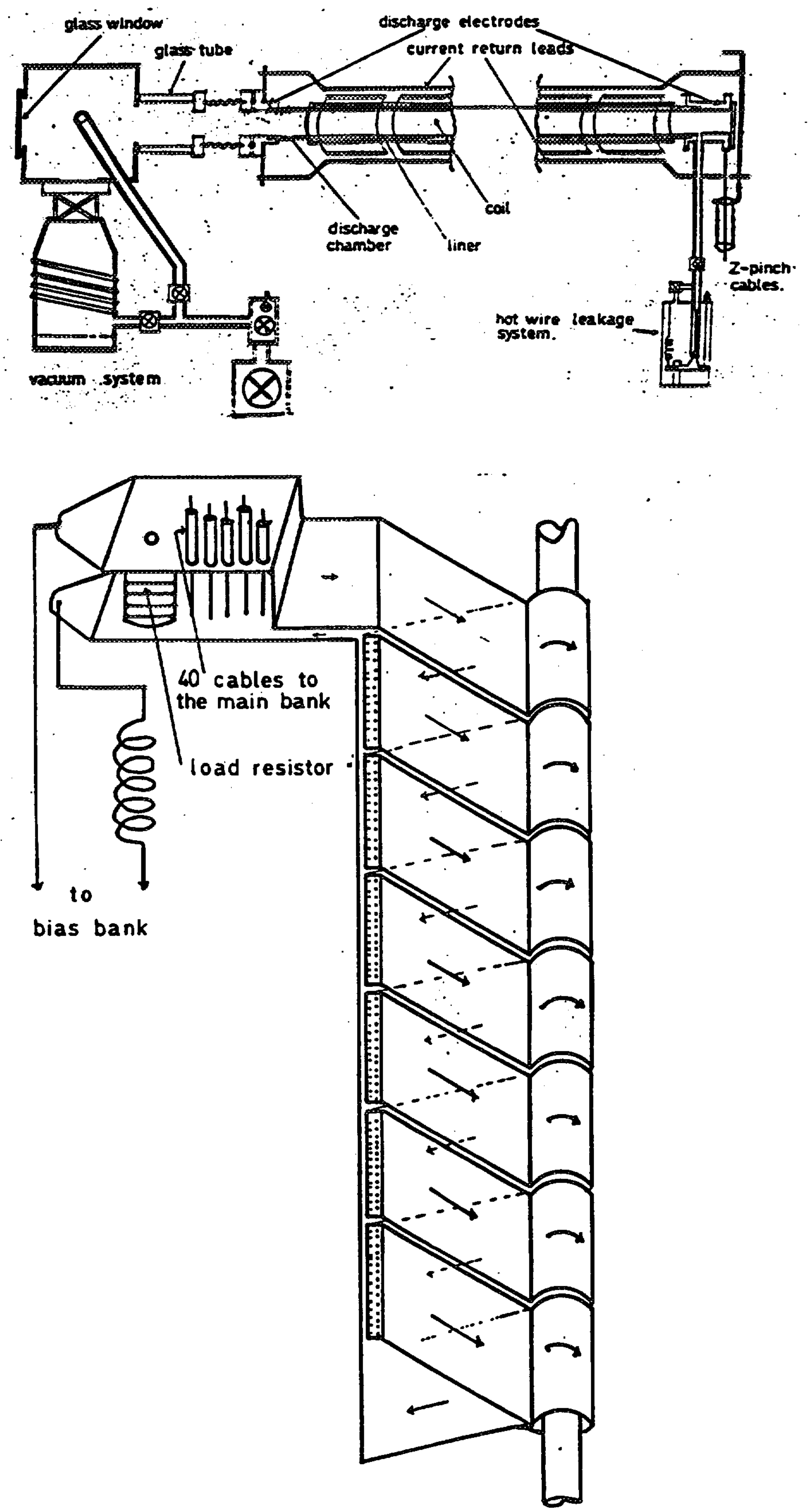


FIG. 2. 3.5 meter θ-pinch assembly.

The 3.5 m. θ-pinch is an ex-Culham UK machine re-installed and modified to reduce its electrical noises and to suit the safety regulation in the laboratory.
It consists of main bank (48 kJ. -700 kA. -7 μs. rise time), preionization z-pinch bank(3 kJ.-125 kA.-1.5 μs.),bias magnetic field bank(4.8 kJ.-3.5 kA.-2 ms.),and screw pinch bank, z-pinch bank,(6 kJ. -50 kA.-7 μs). Schematic diagrams of the θ-pinch coils and z-pinch assemblies are shown in fig.(2). The pinched plasma column temperature and density are 150 eV. and $4x10^{15}$ cm^{-3} respectively.
The current course of study on 3.5 θ-pinch is directed toward the dynamics of the plasma sheath, the heating mechanism of the pinched column, and spectral line's transition probabilities.

Fusion Technology Experiments

The two main experiments are the Egytor tokamak and Aton plasma focus.

Aton Plasma Focus

A powerful plasma focus system "Aton", Mather type, has been designed , 1992, fig. (3), constructed and operated in 1993.
The power supply of the system consists of two modules, each has 25 capacitor, 1.5 μF. 45 kV., which can store 38 kJ. energy. Each module gives a peak current of 0.5 MA. for charging voltage of 35 kV with rise time of 3.2 μs.

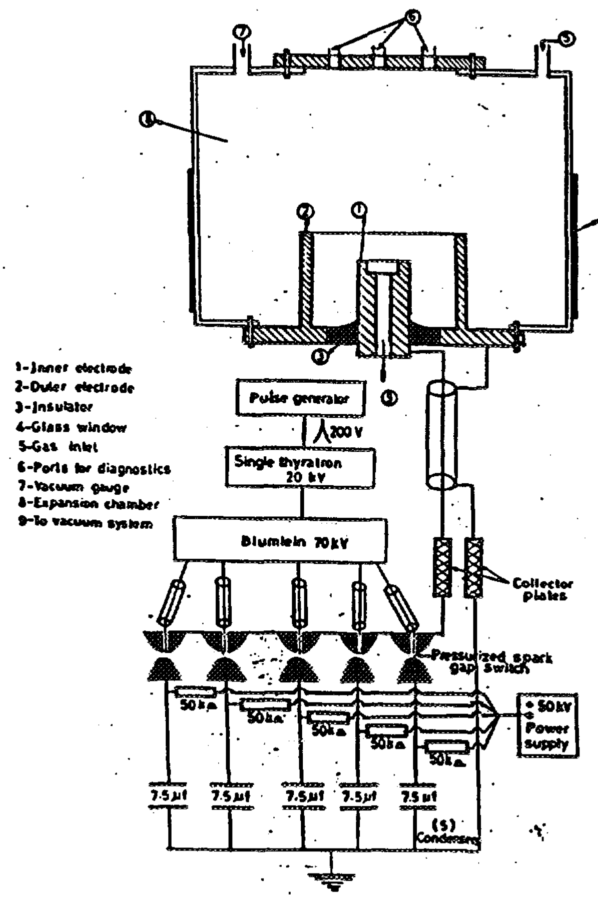


FIG. 3. Cross-section of the plasma focus apparatus (1 M.A. Aton).

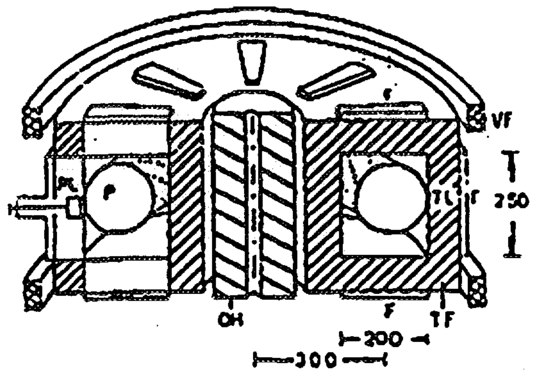
The research program carried on plasma focus from 1993 to 1995 was:
-- Matching condition.
-- Axial and radial phase dynamic.
-- Self induced axial magnetic field and its effect on the focus stability.
-- X-ray and energetic particles emission.
-- Introduce other diagnostics, laser shadow graph, spectroscopy.

The results [3] show that the radial plasma sheath current has a curvilinear structure that is responsible for the induced axial magnetic field. This field reduces the sheath velocity and depresses the instabilities.

To increase the plasma focus temperature and density, a fast rise time high discharge current, single pulse, will be used. A developed design to change the capacitor bank, to Marks type, has been done by using the same component. The system is under construction and will be operated 1996.

Egytor Tokamak

Egytor tokamak is a small one, Taylor type, which was operated successfully for several years (Unitor) in Dusseldorf university. It has been reconstructed in 1995 in Plasma department, AEA, Egypt. Schematic view of Egytor is shown in figure (4).



OH Transformer for Ohmic heating
TF Toroidal field coils
VF Vertical field coils
PL Poloidal limiter (optional)
TL Toroidal limiter
P Plasma
F Window

FIG. 4. Schematic view of the tokamak.

Egytor main parameters are:

Large radius R	= 0.3 m.	Minor radius a	= 0.1 m.
Discharge Duration	= 50 ms.	Loop voltage U	= 1.2 V.
Ohmic power	= 60 kW.	Toroidal field	= 1.4 T.
Poloidal field	= 0.08 T.	Vertical field	= 0.01 T.
Filling pressure	= $1.5x10^{-3}$ mbar	Plasma current	= 36 kA.
Electron temperature	= 180 eV.	Ion temperature	= 80 eV.

The above parameters have been obtained previously [4] according to the current running conditions. An additional bank's energy will be demonstrated within the next year to increase the plasma current. Also auxiliary heating methods will be considered later.

The training of the young scientist is the main goal of the running program. They are studying, the cleaning discharge, continues scanning of the mass spectrum, discharge sequences, ohmic current shaping, fed back system using the microprocessors, laser scattering, microwave interferometer, laser induced fluorescence, spectroscopy, data acquisition system, and the conventional diagnostics.

The tokamak simulation group have started their task. They use the available codes beside they start to do their own code tailored to the problem under investigation. The theoretical group now are familiar with the tokamak physics. They are involved in studying the transport phenomena and edge physics problems.

The proposed experimental program that will start in 1996 is :
i --Plasma stability dependence on the discharge and plasma parameters.
ii --Eroded material from the limiter, and plasma behavior near limiter.
iii--Introducing other diagnostic techniques.(CCD camera and Helium ion beam)

Plasma and Laser Applications

The main interest of this group is to be familiar with the technology of plasma and laser for material science and medical uses. The running machines are glow discharge, coaxial gun, small plasma focus, and tunable dye laser.

A powerful CO_2 laser is designed for industrial applications and will be constructed this year.

The glow discharges are simple experiment but rich in physics and technology. The study of normal glow discharge reveals a complicated structure of the electron beams of the discharge. It has been found that the detecting of different electron beams energy sometimes was due to the diagnostic method.
Hence the diagnostic tools fundamental theory has to consider the distribution function specially in the overlapping area of two electron beams. The sputtered material parameter from the glow discharge electrodes for different conditions is under investigation.

The coaxial plasma gun produces a stream of wide range of plasma parameters, plasma stream velocity, temperature, and density. The research studies are carried on 4-10 kJ. coaxial discharge to control and stabilizes the plasma. The interaction of the plasma and different material substrate will be carried later.

A small plasma focus works with heavy gases is used as a x-ray source for medical application study.

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