PLASMA DYNAMICS

XIX. PLASMA DYNAMICS

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XIX. PLASMA DYNAMICS

A. Basic Plasma Research

1. NONLINEAR WAVE INTERACTIONS

National Science Foundation (Grant ENG77-00340)

Abraham Bers, George L. Johnston, Abhijit Sen, Gérard P. Leclert,
Vladimir B. Krapchev, Allan H. Reiman, Charles F. F. Karney,
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This continuing theoretical research concerns itself with studies of large-amplitude waves in a plasma; in particular, their time-space evolution, their relation to plasma heating, and their connection to strong turbulence phenomena. The onset of stochastic particle motion in a finite-amplitude coherent wave is a particularly striking example of a plasma heating mechanism, and may also give a possible link to strong turbulence. In addition our studies are chosen to have a direct impact on the current interest of plasma heating by means of RF power. This includes work on: parametric excitations in a magnetized, inhomogeneous plasma; their nonlinear evolution in time and space; nonlinear propagation and self-modulation of large-amplitude wave packets; and the interaction of these waves with the plasma particles.

This work has been presented in detail in journal papers and at conferences.[1-23]

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2. STUDIES OF NONLINEAR WAVE-PARTICLE INTERACTIONS

National Science Foundation (Grant ENG77-00340)

Peter A. Politzer, Stanley R. Shanfield, Ady Hershcovitch

We are studying the influence of turbulent electric fields on the spatial and velocity diffusion processes in a plasma. In order to do this in a controlled experiment, we use a counterstreaming electron beam facility to observe the time evolution of the particle velocity distribution function in the presence of either externally applied electric fields or the spectrum generated by instabilities of the electron beam itself. The externally applied fields have a controllable spectrum and thus we can observe the velocity-space diffusion rates as they depend on the spectral width and amplitude of this turbulence. We have modified the formalism of strong turbulence theory to include the effects of externally applied turbulence and have found that, in certain cases, it is possible to suppress plasma instabilities with a suitably chosen external spectrum.[1] This calculation has been applied to the counterstreaming electron beam configuration, and we find that there is good agreement between experiment and theory with regard both to the velocity-space diffusion coefficient and the level of turbulence required to suppress the half-cyclotron frequency instability[2] which appears in this system. This theory has also been applied to the interpretation of several RF stabilization experiments in which the drift-cone mode in magnetic mirror systems has been suppressed. Again, we find good agreement.[3] We have also considered the use of this stabilization scheme to influence trapped particle modes in Tokamaks.

The experimental facility is being modified so that we can measure the electron velocity distribution directly in two dimensions ($v_\perp$ and $v_\parallel$), rather than in only one ($v_\parallel$). We are planning to study further the effects of applied turbulence near the cyclotron frequency. We hope to be able to establish whether phase space clumps are generated in this system, and to measure their lifetime.

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3. COHERENT SCATTERING EXPERIMENT MEASUREMENT OF LOW-FREQUENCY TURBULENCE

National Science Foundation (Grant ENG77-00340)

Lawrence M. Lidsky

We have extensively modified and rebuilt the apparatus used to detect and resolve the high-frequency scattering from thermal level density fluctuations in our "standard" laboratory plasma source, the HCD. Calculations and preliminary measurements indicate that the source as built will have sufficient sensitivity and resolution to investigate the relatively low-frequency turbulence that plays the most important role in ion transport and heat transfer. The calculations used for this experiment are based on the low-frequency "clump" model of fluctuation phenomena in plasmas developed by T. H. Dupree, and the experimental results will be analyzed in the light of that theory.

4. RENORMALIZATION METHODS IN PLASMA TURBULENCE THEORY

National Science Foundation (Grant ENG77-00340)

Thomas H. Dupree

Plasma fluctuations with velocities of the order of or less than the thermal velocity are being studied. In the stationary case these fluctuations are known as B. G. K. modes. In the turbulent case, they have been referred to as clumps. A clump is an excess or deficiency in the local phase density as compared with the local average density. We can picture the deficiency case as a hole and it has the interesting property of being gravitationally bound. These structures persist on a long time scale in the plasma and have important effects on a variety of plasma phenomena. The earlier theory of these fluctuations is being improved and a more rigorous theory developed. In particular, the new theory conserves both the electric energy of the fluctuations and the kinetic energy of the particles.

5. INTENSE RELATIVISTIC ELECTRON BEAMS

National Science Foundation (Grant ENG77-00340)

U. S. Energy Research and Development Administration (Contracts E(11-1)-2766 and EY-76-S-02-2766)

U. S. Air Force – Office of Scientific Research (Grant AFOSR-77-3143)

George Bekefi

Two areas of research are now being studied, both of which make use of our pulsed high-voltage facility, Nereus (voltage 500 kV, current 70 kA, pulse duration 30 nsec).

Magnetron Design

We are continuing with our studies of the relativistic electron beam magnetron. These studies include optimization of magnetron design, studies of its frequency spectra, and scaling with voltage and magnetic field. The experimental program is being supplemented by some detailed analytical studies being carried out by Masayuki Karakawa (a graduate student supervised by Dr. Kim Molvig).

Electron Beam Pinching

The self-pinching of a relativistic electron beam in a high-voltage diode is aided by plasma formation in the anode-cathode gap. In conventional diodes the plasma is formed by a precursor of the electron beam. As a result, one has little control over the time of formation of the plasma and one has equally little control over its density, temperature, and particle species of which it is composed. In the present experiments under way the aforementioned plasma is generated independently by means of a laser. The light from a pulsed CO_2 laser (energy 1.5 J, pulse length 100 nsec) is focused by means of a germanium lens onto the cathode surface. A dense plasma plume of known characteristics is thus generated. As this plume expands with known velocity across the diode, the Nereus high-voltage facility is fired. The pinched beam with and without laser radiation is studied from x-ray pinhole camera pictures and from detailed time-resolved impedance measurement of the diode.

XIX. PLASMA DYNAMICS

B. Plasma Research Related to Fusion

Confinement Systems

1. PHYSICS OF HIGH-TEMPERATURE PLASMAS

U. S. Department of Energy (Grant EG-77-G-01-4107)

Bruno Coppi

An understanding of the physics of high-temperature plasmas is of primary importance in the solution of the problem of controlled thermonuclear fusion. One of our goals is the magnetic confinement and heating of plasmas with densities in the range 10^{14} to 10^{15} particles/cm^3 and thermal energies in the few kiloelectronvolt range. The macroscopic transport properties (e. g., particle diffusion and thermal conductivity) of plasmas in these regimes are weakly affected by two-body collisions between particles. The relevant transport coefficients, in fact, are influenced significantly by the type of collective mode that can be excited, such as density and temperature fluctuations caused by microinstabilities.

Relevant theoretical and experimental contributions have been presented at national and international conferences or published in professional journals. The primary focus has been on the experimental effort involving the Alcator A machine. Our purpose has been to realize plasmas that can sustain very high current densities without becoming macroscopically unstable, in order to achieve the highest possible rate of resistive heating of the plasma.

Alcator's unique properties – lack of impurities ($Z \approx 1$), high current density, and large toroidal field, have made it one of the most referred to toroidal confinement devices. Specifically, we can point to the following achievements.

(i) Peak plasma densities in excess of 10^{15} cm^{-3}, with energy replacement times of ~20 ms have been attained. This yields $n\tau$ values approximately 3×10^{13} s/cm^3 which exceed by a considerable factor those of any existing confinement system.

(ii) Since the particle density can be varied over two orders of magnitude, while the temperature can be independently controlled by the plasma current, and macroscopically stable plasmas can be obtained, we have continued to study a sequence of plasma regimes with a varying degree of collisionality and to derive valuable information about the nature of various transport coefficients such as electrical resistivity and energy replacement time.

(iii) By programming properly the rate of rise of the particle density and of the plasma current, it has been possible to avoid the onset of disruptive instabilities that limit, for a given value of the magnetic field, the maximum plasma current density. Therefore, record high current densities have been obtained with low values of the so-called safety factor ($q \approx 2$). The plasma current pulse has been extended to more than 300 ms in the high-density regimes. Thus, we expect new interesting results to be produced by increasing the plasma current over the 290 kA mark achieved so far and programming its time evolution.

(iv) The anomalous transport coefficients that we had employed in a transport code developed to reproduce the main characteristics of the plasma temperature and density profiles obtained in Alcator experiments have been found to interpret a larger set of experiments produced by other machines. The same transport code has been used in the analysis of compact experiments for the study of α-particle confinement and heating. These are generally called Ignitors. In fact, the main purpose of these experiments is to achieve the ideal ignition temperature where the electron energy loss by bremsstrahlung emission is compensated by the α-particle heating.

The Alcator C device that we proposed in 1975 for funding to the U. S. Department of Energy has been under construction all during 1977, and its assembly is expected to be completed in early 1978. A new power supply to exploit the design parameters of this device is being installed at the Francis Bitter National Magnet Laboratory. The major aim of this experiment is to increase the value of $n\tau$ to approximately 10^{14} s/cm^3 with particle temperatures in the range $2 \div 3$ keV. The main parameters are: minor plasma radius $a \approx 17$ cm, major radius $R \approx 64$ cm, magnetic field up to 140 kG, and plasma currents up to 1 MA. This device will also complement the results that are expected from the FT machine of Frascati whose design features are: $a \approx 21$ cm, $R \approx 83$ cm, magnetic fields up to 100 kG, and plasma currents up to 1.2 MA.

Direct measurements of temperature and density profiles have been performed on the Rector experimental device with the plasma cross section elongated vertically (noncircular) by an appropriate mesh of Thomson-scattering measurements. Thus, for the first time, direct identification of the relevant magnetic surfaces has become possible. This technique will permit a detailed investigation of the confinement properties of a toroidal system with noncircular cross section. With this objective in mind, the Rector machine has been rebuilt in a more suitable experimental area, and provided with upgraded facilities for its operation and diagnostics.

We have continued to benefit from collaboration with visiting scientists from other national and foreign institutions.

Research – Theoretical

2. DYNAMICS OF TOROIDAL DISCHARGES

U. S. Department of Energy (Grant EG-77-G-01-4107)

James E. McCune, Jay L. Fisher, Daniel E. Hastings, Kenneth Rubenstein, George M. Svolos

a. Quasi Equilibria in Rotating Toroidal Discharges at Low and Moderate Collisionalities

James E. McCune, Jay L. Fisher

Increasing interest in the effects of plasma fluid inertia on neoclassical transport and the resulting quasi equilibria in tori continues to develop as experimental evidence of plasma rotation in a variety of Tokamak experiments accumulates. The present program has led to the development of a drift-kinetic equation of sufficient generality to include significant ordered flows of the species present. The resultant inertial effects cause appreciable changes in both ion and electron behavior. Plasma ions are directly affected, while the electrons respond to the overall flows primarily through the electrostatic fields associated with the ion motion. A prominent feature associated with such motion is the development of strong radial (cross-flux) electric fields. If these fields are present, as indicated in a variety of experiments, a class of particles can develop which possesses purely circular orbits around the major diameter of the torus. The particles thus see no magnetic field modulation and can escape such orbits only through collisions. Interestingly, the presence of these particles can play a role competitive with more familiar neoclassical effects, including those of trapping, banana orbits, etc. In the case of electrons, moreover, the trapping boundaries can be altered through the electric potentials already mentioned.

Solutions of these governing equations have now been obtained in relevant parameter regimes, giving a description of quasi-steady ion and electron "equilibrium" distribution at low collisionalities with inertial effects included. As the importance of collisions increases, these results go over to those appropriate to the Pfirsch-Schlüter (MHD) regime reported earlier. At lower collisionalities, the results exhibit the physical effects described above to a varying degree.

Portions of this research are available in report form; the completed research will be submitted as the doctoral thesis of Jay L. Fisher.

b. Time Development of Rotating Toroidal Discharge at Low Collisionalities

James E. McCune, Kenneth Rubenstein

If rotating quasi equilibria in tori are to exist, it becomes important to understand their development in time during the discharge phase. This information is required both for the eventual control of such plasma devices and for a true understanding of the physical circumstances under which rotation in tori either develops or eventually dies out. In the Pfirsch-Schlüter regime, the concept of a multiple-time-scale history was successful in providing the essential features of the time development of such toroidal discharges. Recent Tokamak experimental results suggest strongly the occurrence of a similar series of events at lower (more practical) collisional rates. Various kinetic processes for the possible development of plasma rotation (or, equivalently, nonambipolar radial fields) have been put forward by various researchers in this field. Rotation can occur with or without beam injection. The current program is concerned with the analysis of the time history of ion and electron behavior during the possible development of the inertial equilibria described by Fisher. The study relies upon the time-dependent version of the drift-kinetic equation used there. Cases with and without injection can be studied in this model.

c. Drift Modes in Tori

James E. McCune, George M. Svolos

The study of the "slow" time development of inertial neoclassical equilibria which we have described is not designed to resolve instabilities or other natural oscillatory modes of such systems. As results from large Tokamak experiments (especially for those with beam injection) become available, however, an increasing need for improved understanding of drift-type instabilities in practical toroidal systems arises. The present study is focused on the analysis of drift modes in such systems. Since a straight cylinder (even with a helical field) is not a true natural limit of a Tokamak discharge, toroidal effects are included from the beginning. Insofar as the familiar model of localization of such modes on flux surfaces is a valid one, an assessment of the relative importance of such toroidal effects can be made relatively quickly. This, in turn, provides increased incentive for an improved understanding of the validity of the localization model. A systematic study of the cross-flux eigenvalue problem is under way as a central part of this research.

d. Drift and Drift-Cyclotron Modes in Tandem Mirror Systems

James E. McCune, Daniel E. Hastings

A unique feature of the tandem mirror concept is its a priori goal of obtaining a high-beta plasma in the main confining region. This provides a challenging area for an improved understanding of plasma behavior for such devices. From the point of view of the system itself, there is a need to establish once more which instabilities, if any, can be expected to be important and what their physical effects are. The present program is, in that sense, exploratory. After appropriate assessment of the results, the most important of these is to be explored in detail; special emphasis is being placed on eventual nonlinear (or quasi-linear) effects on the tandem mirror system as a practical device.

3. RF HEATING AND MICROTURBULENCE

U. S. Department of Energy (Grant EG-77-G-01-4107)

Abraham Bers, George L. Johnston, Abhijit Sen, Gérard P. Leclert, Vladimir B. Krapchev, Charles F. F. Karney, Allan H. Reiman, John L. Kulp, Jr., Nathaniel J. Fisch, Miloslav S. Tekula, Kim S. Theilhaber, Bruce E. Edwards, Stavros M. Macrakis

During the past year we have continued our theoretical studies related to the supplementary heating of Tokamak plasmas, and the microturbulence due to the high-energy tail of the electron distribution function. Our interest has been to develop an understanding of all aspects of plasma heating in the lower hybrid range of frequencies (LHRF).

For parameters characteristic of Tokamak plasmas the LHRF falls in the microwave regime ($\Omega_i \ll \omega \sim \omega_{pi}$). In this regime large units of cw power (10^6 watt tubes) at high efficiencies (50-70%) are readily available. This power can be coupled to the plasma with phased arrays of waveguides at the plasma wall, and does not require any coupling structure inside the plasma wall. These uniquely advantageous characteristics of the LHRF have generated considerable interest in its use for supplementary heating of Tokamak plasmas. In the past two years, experiments at Princeton (ATC Tokamak) and Grenoble (WEGA Tokamak) have shown significant heating with power in the LHRF. Important experiments are now being planned on the M. I. T. Tokamaks (Alcator A and C and Versator II). Our work interacts with and impacts directly upon these and other experiments, and aims at an understanding of the scaling characteristics of heating in the LHRF. Our work has included studies of: (a) Linear and nonlinear aspects of coupling from phased arrays of waveguides at the plasma wall. (b) Nonlinear propagation of the excited fields in the plasma. (c) Heating mechanisms for the electrons and ions in the plasma. Our studies of the high-energy tail of the electron distribution function are now becoming very relevant to understanding the details of electron mechanisms with RF power.

An important result of our recent work is a calculation that shows a new way in which RF power can be used to generate a significant current in the plasma. This offers the possibility of achieving a steady-state toroidal reactor driven by microwave power in the LHRF.

Journal and conferences publications, as well as conferences presentations, of our work in the past year are listed below.[1-33]

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4. NONLINEAR THEORY OF TRAPPED-PARTICLE INSTABILITIES

U. S. Department of Energy (Grant EG-77-G-01-4107)

Thomas H. Dupree, David J. Tetreault

The phenomenon of clumps is being studied in a plasma with a magnetic field. In particular, the effect of clumps on the drift and trapped particle mode instabilities is being studied. Clumps in the ion phase space density produce an enhanced ion viscosity which appears to be very effective in damping these modes and providing a nonlinear stabilization.

Concepts from strong plasma turbulence are being used to investigate magnetic islands in Tokamaks. Turbulent magnetic fluctuations induced by drift waves as well as those formed through self-consistent currents are being studied. The purpose is to determine how the resulting turbulent destruction of magnetic surfaces affects Tokamak plasma confinement.

Work is also beginning on computer simulations of the structure of clumps in plasma.

5. PLASMA CORRECTIONS TO THE BOHM DIFFUSION

U. S. Department of Energy (Grant EG-77-G-01-4107)

Claude Deutsch

The nodal expansion of equilibrium properties of two-component classical plasma in $2 + \epsilon$ dimensions ($0 \leq \epsilon \leq 1$) is used to investigate higher order corrections, with respect to the plasma parameter, of the transverse diffusion coefficient relevant to an arbitrarily strong and constant magnetic field. Only the short-range compact nodal graphs decaying faster than Debye contribute to the third and higher nonvanishing orders.

The usual fluid limit ($k \to 0$) procedure delivering the first-order Bohm result is shown to be consistent[1] for any dimension $2 \leq \gamma \leq 3$. These results obtained from the hydrodynamic derivation of transport (Taylor-McNamara) are now currently extended to include the microscopic derivation of transport based on conveniently renormalized kinetic equations, and also the standard Ichimaru-Rosenbluth derivation. In all three cases, the thermal spectra are rather similar, so the algebra of the nodal expansion works in the same way.

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6. STRONGLY COUPLED CLASSICAL PLASMAS FOR LASER FUSION

U. S. Department of Energy (Grant EG-77-G-01-4107)

Claude Deutsch

We have summarized[1] the most relevant results of the theory of strongly coupled classical plasmas which include: nodal expansions, numerical simulations, variational schemes, and integral equations for $g_r(r)$.

The applications to laser fusion and astrophysics have been emphasized. They include: lowering of the ion-ion coulomb barrier and establishing a lower bound for thermal transport in the partially degenerate electron component. They also relate to the exoenergetic behavior of Jupiter and other massive planets.

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7. EQUILIBRIUM PROPERTIES OF TWO-COMPONENT CLASSICAL PLASMAS

U. S. Department of Energy (Grant EG-77-G-01-4107)

Claude Deutsch

The overall two-component neutral classical coulomb gas is considered in the canonical ensemble for any value ν of the space dimension. The equilibrium properties, i. e., pair correlations and thermodynamic functions, are investigated in a two-complementary approximations approach. The first one is adequate in the low-temperature range and uses as a zero-order starting point the "molecular" approximation within a pair of unlike charges. On the other hand, the high-temperature fully ionized and translation-invariant plasma is considered within the nodal expansion with respect to the classical plasma parameter. This program is made possible through the use of effective temperature-dependent classical interactions for $\nu < 2$. As a by-product, we obtain a unified treatment of the coulomb gas thermal properties with respect to ν, and also a contrasting comparison with the already known corresponding properties of the one-component plasma model. The $\nu = 2$ two-component coulomb gas appears as a landmark in this analysis. Degeneracy effects are neglected. Diffraction corrections are considered in a first-order expansion with respect to the interaction. A paper on this subject has been submitted for publication to Ann. Phys. (N. Y.).

Research – Experimental

8. TOKAMAK RESEARCH

U. S. Department of Energy (Grant EG-77-G-01-4107)

George Bekefi, Miklos Porkolab

On May 1, 1977 a new device, the Versator II Tokamak, went on the air. It is a research device with a major radius of 40.5 cm and with a rectangular cross section of 30 × 30 cm. It contains 20 diagnostic portholes 5 cm wide and 28 cm long.

The machine is running reliably, with good equilibrium at a toroidal magnetic field not exceeding 8 kG. Typical discharge currents are 25-30 kA with current pulses lasting up to 16 ms.

An upgraded version of the Versator II device is under construction. Its principal purpose is to permit operation at 15 kG rather than at 8 kG. It is expected that the upgraded version will be in operation by January 1978.

The major purpose of the research to be carried out on the Versator II Tokamak is the study of various RF heating mechanisms. The first series of experiments to begin in February 1978 are concerned with RF heating at the lower hybrid frequency, which in our case occurs at approximately 800 MHz. Some 200 kW of RF power will be injected into the torus by means of a specially constructed 4-waveguide (grill) antenna. This work will be carried out in cooperation with the Princeton Plasma Physics Laboratory which is going to provide the requisite RF power and plumbing.

In the second series of experiments to begin in the Fall of 1978 microwave power will be injected into the torus at a frequency corresponding to the electron cyclotron frequency. For this purpose a novel gyrotron microwave generator is being developed by the Naval Research Laboratory. It will be capable of supplying approximately 200 kW of microwave radiation at a frequency of 35 GHz.

These RF heating studies will be accompanied by detailed plasma diagnostics including Thomson laser scattering measurements, neutral charge-exchange experiments, synchrotron radiation measurements, and RF fluctuation measurements.

9. EXPERIMENTAL MIRROR STUDIES

U. S. Department of Energy (Grant EG-77-G-01-4107)

Louis D. Smullin, Robert E. Klinkowstein, Michael E. Mauel

The purpose of this study is to investigate the stabilization of DCLC (drift-cyclotron loss-cone) instabilities by hot electrons. Last year (1977), in the apparatus described in Progress Report No. 119, January 1977 (p. 83), we demonstrated the stabilization of the DCLC by the action of an axially injected electron beam (~50 kW). The stabilization is believed to be due to the trapped hot electrons produced by the beam-plasma instability.

During this year (1978) we plan to continue our detailed studies of this stabilizing mechanism. We have proposed the construction of a somewhat larger mirror system to the Department of Energy. This would permit the direct comparison of stabilization by electron beam-plasma interaction, and ECRH (electron cyclotron resonance heating) used by Joffe' in the USSR.

10. NEUTRAL BEAM STUDIES

U. S. Department of Energy (Grant EG-77-G-01-4107)

Louis D. Smullin, Peter T. Kenyon, Barry N. Breen

We have essentially completed the work on our "Magarc" high-current positive ion source, and are shifting our attention to the problem of generating high-current, high-voltage negative ion (H^- or D^-) beams for ultimate transformation to neutral beams.

The Magarc source has achieved the following results: Collected positive ion current = 200 amps, arc power = 40 kW, cathode heater power = 150 W, gas pressure ≈ 2 mT. Beam-line tests are scheduled to be made in January 1978 at the Oak Ridge National Laboratory.

Fusion Technology Studies

11. THE FUSION TECHNOLOGY PROGRAM

U. S. Department of Energy (Grant EG-77-G-01-4107)

Lawrence M. Lidsky

The Fusion Technology Program is an interdepartmental effort supported by the Development and Technology branch of the Division of Magnetic Fusion Engineering. The program's goal is to investigate various engineering problems of controlled fusion reactors with particular emphasis this year on reactor fueling, reactor blanket analysis, safety and environmental studies, and "new concepts development." The program is centered in the Department of Nuclear Engineering, M. I. T., but a substantial portion of the work is carried out under the auspices of the Research Laboratory of Electronics. In addition to the work order on pellet fueling the following tasks were completed:

a. The consequence code for the Wash-1400 Fission Reactor Safety Study was modified to include the appropriate isotopes for fusion reactor applications.
b. A numerical model of lithium spill phenomena was developed.
c. A methodology was developed for generic analysis of fusion reactor blanket design and applied to the case of a gas-cooled solid breeder design for operation with isolated failed modules.
d. The effect of fuel cycle costs on hybrid and symbiotic fissile breeders was analyzed and used to guide the design of an optimized 233 U breeding hybrid blanket.
e. A system cost analysis of a commercial EBT reactor was completed and conjoined with a similar study performed at ORNL.
f. A liquid-metal flow loop was constructed and used to measure the effect on right-angle bends on MHD pressure drops with interaction parameters in the proposed reactor regime.

We are currently engaged in:

a. The establishment of design windows for lithium-cooled fusion reactor blankets;
b. Continued development of the methodology required for safety and environmental analysis of proposed fusion power plants and generation of the physical models needed for this analysis;
c. A large-scale study of the economic and technical feasibility of the stellarator-torsatron confinement geometry as the basis of a steady-state commercial reactor.

The torsatron reactor design study is being carried out in close collaboration with the University of Wisconsin group directed by Professor J. L. Shohet. We have completed the preliminary design of a large-scale torsatron experiment suitable for construction at the National Magnet Laboratory in the near future. A full-scale design program has been proposed to the U. S. Department of Energy and presumably will be initiated in the near future.

12. PELLET FUELING OF FUSION REACTORS

U.S. Department of Energy (Grant EG-77-G-01-4107)

Peter A. Politzer, Mark L. McKinstry, Clarence E. Thomas

In order to operate a quasi-steady-state fusion reactor, a source of deuterium and tritium fuel must be provided that is distributed throughout the reactor plasma cross section. The most promising scheme for introducing this fuel is the injection into the plasma of solid D-T pellets at high velocity. In order to determine the velocity required, we need to know the ablation rate of a solid D-T surface in the presence of a hot, dense plasma. We are approaching this problem in a number of ways. We have constructed a Z-pinch discharge facility which can sustain reactorlike conditions of plasma energy density and flux for several microseconds. We are now diagnosing this plasma in order to determine the appropriate operating regime. We plan next to insert solid pellets into this plasma in order to obtain an experimental measure of ablation rates under reactor-like conditions. In addition, we have undertaken a cooperative experiment with the Oak Ridge National Laboratory to measure the ablation rates of pellets injected into the ISX Tokamak. We are designing a holographic and spectroscopic diagnostic system for this experiment. Our third effort has been to develop an analytic model for the ablation process and, particularly, for the self-shielding mechanisms involved. The dominant shielding process under reactor conditions is the exclusion of the magnetic field from the region surrounding the pellet by the high-pressure blow-off plasma cloud. A computer code has been written to model this effect and we find significant reduction of the ablation rate and, consequently, of the pellet-injection velocity required.