MEETING REPORTS

SUMMARY OF THE THIRD JOINT VARENNA-LAUSANNE INTERNATIONAL WORKSHOP ON THEORY OF FUSION PLASMAS, VARENNA, ITALY, AUGUST 27-31, 1990

INTRODUCTION

This workshop provides a European forum to present and discuss the advances in theory of magnetically confined fusion plasmas. It is intended to be the equivalent of the Sherwood meetings in the United States, and it is held in even-numbered years. It is not restricted to European countries; correspondingly, the Sherwood meetings (held in odd-numbered years) will become international.

There were ~80 participants from 40 institutions; 20 were from non-European countries, including 13 participants from the United States and 3 from Japan. The meeting was held at Villa Monastero on the shore of Lake Como, Varenna, Italy. Nineteen invited papers and 42 posters were presented. Eight of the invited papers were broadly related to stability problems, seven more treated the transport phenomena, and four talks were dedicated to current drive and heating. Most of the posters were also on these three subjects.

Conference proceedings may be obtained from Editrice Compositori, Via Stalingrado 97/2, 40128 Bologna, Italy.

INVITED PAPERS

The first paper was presented by J. Hugill (Culham Laboratory), and it was a "personal view of an experimentalist on anomalous transport." He presented a list of features that theory should explain, e.g., the high ratio of heat conduction to convection in the central zone, the ambipolarity of the diffusion, and the evidence that the transport at the edge is caused by a different mechanism. The usefulness of the scaling laws was also discussed.

D. Montgomery (Darmouth College) reviewed the recent work on the existence and effects of helical vortex pairs in tokamaks. The three-dimensional numerical simulations of driven dissipative flows have shown the appearance of self-organized, long-lived helical structures whose shapes and symmetries were not related to those of the container. He discussed some of the implications of these findings on stability and transport, and he presented a scenario for L- to H-mode transition based on the simulation results.

W. M. Tang (Princeton University) focused on the strong plasma current dependences of the empirical confinement scaling laws. He analyzed the linear and nonlinear properties of collisionless trapped-electron modes and found a significant scaling with the safety factor, as they are destabilized by precession resonances. He also discussed the role of trapped-ion modes as well as the anomalous exchange of energy between ions and electrons that appears in the power balance analysis of the experimental data when fluctuations are present.

J. W. Connor (Culham Laboratory) presented a series of ignition studies for IGNITOR and listed approaches that would predict confinement properties in future tokamaks, decide parameters, and optimize their design. The most robust approach is to use similarity principles; if the confinement in ohmic devices is due to plasma physics (excluding Debye), the confinement time τ_e should be a function of a few variables: $B\tau_e = F(na^2, Ba^{5/4}$, geometry). Because the Joint European Torus (JET) and IGNITOR have similar geometries, extrapolation should be possible. However, profile effects are very important, and radial transport codes are necessary: $\frac{1}{2}$-, 1-, and $1\frac{1}{2}$-dimensional codes have been used. Sawteeth turn out to be an obstacle to ignition so they have to be avoided by using energetic particles or parameter control, for example.

D. J. Sigmar (Massachusetts Institute of Technology) described recent progress in understanding the observed up/down (poloidal) asymmetries in impurity density and in density fluctuations at the edge. The first can be explained in the framework of a "strong ordering" neoclassical theory, applicable in the outer regions of the tokamak. In these regions, the poloidal modulation of the impurity density can be of $O(\epsilon)$, which implies that some of the equations become nonlinear (i.e., these nonlinearities allow the existence of bifurcated solutions). Some recent Texas Experimental Tokamak (TEXT) results agree with the predictions of the theory. The asymmetry in density fluctuations is explained by a theory of the impurity density gradient-driven rippling instability, which includes the strong poloidal asymmetry in impurity density.

R. White (Princeton University) discussed alpha-particle confinement theory. Alpha particles must be contained in the plasma long enough to transfer their energy to other particles and, once thermalized, must be removed ("ash removal"); premature loss of alpha particles is undesirable, as it means a loss in the heat source for the plasma and an additional load on the first wall of the vessel. Collisional losses are much less important than collisionless ones; the latter are due to field perturbations [ripples, magnetohydrodynamic (MHD) activity], and electrostatic and electromagnetic turbulence. The speaker also made some comments on the controlled loss of the particles, induced by toroidal Alfvén eigenmode, fishbone modes, or enhanced ripple.

M. Okamoto (Nagoya University) focused on the bootstrap current in stellarators and compared it with that of tokamaks. He presented an analysis of the phenomenon in the banana and the plateau regimes. In the banana regime, the current is very sensitive to the position of the magnetic axis and to the shape of magnetic surfaces, so it can be controlled by the poloidal fields (dipole and quadrupole). In the plateau regime, it is sensitive to the toroidal pitch number, but not to the poloidal fields. He also discussed the effects of the ripple diffusion.

L. M. Kovrizhnykh (General Physics Institute, Academy of Sciences of the USSR) presented a very instructive account of the similarities and differences between tokamaks and stellarators. He surveyed some different areas: magnetic field structure, equilibrium, stability (current- and pressure-driven modes, microinstabilities), transport (neoclassical, anomalous), auxiliary heating, L and H modes, and hollow density and temperature profiles. He finished by arguing the possible advantages of a tokamak-stellarator hybrid.

W. A. Cooper (Centre de Recherches en Physique des Plasmas) explained the use of the three-dimensional ideal MHD stability code TERPSICHORE to investigate the effect of induced toroidal plasma currents on the equilibria that model the Advanced Toroidal Facility (ATF) torsatron in its standard configuration (beta limit of 3.1% imposed by the $n = 1$ mode family). It was found that, if the additional current reduces the externally applied rotational transform by 15%, the stability properties deteriorate, and the configuration is unstable below $\beta = 1\%$. If the current increases the transform by 15%, the $n = 1$ family is stabilized, and the $n = 2$ family imposes a limit of $\beta = 4.25\%$.

J. C. Hosea (Princeton University) discussed the stabilization of sawteeth by ion cyclotron resonance heating (ICRH). In the Tokamak Fusion Test Reactor (TFTR), the experiments were initially conducted in the gas-fueled regime, and the results were comparable to those obtained in JET: existence of a power threshold, temperature and density peaking, and monster sawtooth at termination. These results are qualitatively consistent with energetic ion stabilization of the $m = 1$, $n = 1$ ideal/resistive mode. In the supershot regime, ICRH appears to complement the beam-induced sawtooth stabilization. Further experiments in the TFTR are needed to explore the application of this mechanism to the Compact Ignition Tokamak (CIT).

V. P. Bhatnagar (JET) spoke about the fast-wave current drive using ICRH. The current limitations of the lower hybrid current drive, which relies on electron Landau damping, could be overcome by the use of frequencies just below the lowest ion cyclotron frequency. This current drive mechanism relies on transit time magnetic pumping, and it has been evaluated in a recent set of experiments in JET. He reviewed some important considerations relative to this mechanism (frequency, Alfvén resonance, poloidal field, antenna septum) and presented the results of some experiments and of ray-tracing calculations of the current drive.

J. M. Rax (Cadarache Research Centre) compared two types of current drive: fast magnetosonic (fast waves) and lower hybrid (slow waves). He reviewed various physical aspects (electrodynamics, Hamiltonian, and kinetic) of the two schemes within the perspective of the present and future large tokamaks. He concluded that the fast modes, which have neither density nor accessibility limitations, could be a good candidate for current drive in the hot and dense core of a reactor, whereas the lower hybrid current drive should be restricted to the outer regions.

R. Pozzoli (University of Milan) presented recent work on the nonlinear plasma interaction with high-power electron cyclotron waves. The situation arises when gyrotrons and free electron lasers are used for heating and current drive. Taking into account the spatial and temporal localization of the interaction, the relativistic Hamiltonian formulation is used to calculate the modifications to the electron distribution function caused by the electron trajectories in phase space. Low field strengths ("regular" regime) allow the theoretical calculation of the absorbed power, even in the nonlinear regime. The stochastic regime and the transition to it are also discussed, and the relevant diffusion coefficients are compared with the numerical results.

K. N. Stepanov et al. (Kharkov Institute) discussed the nonlocal effects at ion cyclotron resonances in plasmas confined by magnetic traps. Considering the finite Larmor radius and Coulomb collision effects on the wave-particle phase decorrelation, the authors built an ion cyclotron resonance theory for fast magnetosonic waves for high-energy ions and for ion Bernstein waves. Then they applied it to the case of a circular-section tokamak and studied cases in which the nonlocality is important.

R. Horiuchi (Nagoya University) spoke about the finite Larmor radius effects on field-reversed configuration tilt disruption. These effects are good candidates to explain the absence (up to 30 to 100 Alfvén times) of the predicted MHD disruptions. A three-dimensional macroscale particle simulation showed that the growth rates of the instability decreased with increasing ion gyroradius, which is in good agreement with the predictions of the linear theory.

B. N. Breizman (Institute of Nuclear Physics, Novosibirsk) presented a review of his recent work with H. L. Berk on the saturation of a single mode driven by high-energy particle injection in a plasma. They studied the cases of hot particles (with drag) interacting with a single electrostatic wave: one-dimensional, drift wave in sheared magnetic field (slab) and Alfvén wave in a tokamak. Then they estimated the saturation level of the waves.

F. Romanelli (Frascati Research Centre) analyzed the stabilization of the internal kink mode by an energetic ion population. He considered the different kinetic mechanisms affecting the kink modes and concluded that the effect of the transit and bounce resonances of the hot ions is to stabilize the internal kink for sufficiently high hot-particle density; if this density is too large, the fishbone mode is destabilized.

F. Pegoraro (Scuola Normale, Pisa) spoke about the internal $m = 1$ modes and large ion gyroradius effects. From a model with fluid electrons and to all orders in the ion gyroradius inside the singular layer, and by matching to the mode amplitude outside the layer, a dispersion relation of these modes is obtained that contains the full ion dynamics in the directions perpendicular to the magnetic field. The dispersion relation is then used to examine the growth rates of the modes in different cases.

E. I. Yurchenko (Kurchatov Institute of Atomic Energy) gave the final talk, on dissipative ballooning modes in tokamaks. In the resistive MHD model, the electrostatic branch is stabilized by the finite value of the ratio $(C_s/C_A)^2$, so the second stability zone should exist for dissipative ballooning modes. The kinetic theory allows the consideration of the magnetic drift: it has also a stabilizing effect.

Xavier Llobet

Centre de Recherches en Physique des Plasmas
Association Euratom-Suisse
21 avenue des Bains, CH-1007
Lausanne, Switzerland

February 8, 1991

SUMMARY OF "ANOMALOUS NUCLEAR EFFECTS IN DEUTERIUM/SOLID SYSTEMS," AN INTERNATIONAL PROGRESS REVIEW, PROVO, UTAH, OCTOBER 22-24, 1990

An international gathering of 160 scientists met at Brigham Young University (BYU) to scrutinize observations of small nuclear effects associated with deuterium loaded into various solids. The workshop was sponsored by the Electric Power Research Institute, the U.S. Department of Energy, and BYU. Nuclear physics and geophysical experimental data were emphasized, and theoretical issues were also explored. Calorimetry and electrochemistry were discussed only as adjuncts to investigations of nuclear reaction products.

Nearly 70 papers were presented, with discussions divided into five broad categories with chairs as indicated:

1. *Neutron Measurements*: W. Meyerhof (Stanford University), K. Nagamine (University of Tokyo), A. Vitale (University of Bologna), K. Wolf (Texas A&M University), F. Scaramuzzi (Frascati Research Centre), H. Menlove [Los Alamos National Laboratory (LANL)], and V. Tsarev (Lebedev Physical Institute)

2. *Charged Particle Detection*: J. Ziegler (IBM) and E. Cecil (Colorado School of Mines)

3. *Geophysical Considerations*: F. Goff (LANL), E. P. Palmer (BYU), and G. McMurtry (University of Hawaii)

4. *Tritium/Helium Studies*: G. Miley (University of Illinois), N. Hoffman (Rockwell International), and M. Srinivasan (Bhabha Atomic Research Centre)

5. *Theory*: J. Rafelski (University of Arizona), V. Belyaev (Dubna), Y. Kim (Purdue University), and E. Tabet (Istituto Nazionale di Fisica Nucleare).

NEUTRONS

Significant improvements in neutron detectors and signal/noise ratios were reported. Techniques now include plastic and liquid scintillators often used in conjunction with neutron capture detection using lithium-doped glass or ^{3}He-filled proportional counters. Time-of-flight and pulse digitization techniques are also employed. Groups in the United States [S. Jones (BYU), H. Menlove and T. Claytor (LANL), K. Wolf], Italy [A. Bertin (University of Bologna), F. Scaramuzzi, and F. Celani (Frascati Research Centre)], Argentina [J. Granada (Centro Atomico Bariloche)], and China [R. Zhu (Institute of Atomic Energy)] reported on neutron studies in deep underground locations. Observations of neutron emissions from D_2 gas-loaded metals, D_2O electrolysis cells, and deuterium ion-implanted metal foils in low-background environments (very low cosmic-ray fluxes particularly) and with redundant detectors confirmed earlier observations, with rates broadly consistent with the early Jones et al. report.[1] Neutron bursts of the order of a few hundred neutrons produced in $\sim 100\ \mu s$, consistent with early observations of Menlove et al.,[2] were also reported in detectors of various types, including segmented neutron counters in underground locations.

Neutron bursts were measured in an underground lead mine at Leadville, Colorado, with both temperature-cycled titanium deuteride samples and a palladium electrolysis experiment (S. Jones, H. Menlove, and K. Wolf). Frequency and magnitude of large burst events were consistent in the mine and aboveground at an altitude of 10 000 ft (gas-loaded titanium only aboveground) in Leadville. These experiments evidently rule out neutron cascading from cosmic nuclei as a possible explanation of neutron bursts. R. Anderson discussed the need for redundant detectors and exclusion of cosmic-ray effects based on negative experiments carried out at LANL a year ago. In fact, redundant detectors, exclusion of cosmic rays, adequate hydrogen controls, and improved reproducibility based largely on controlled sample preparation techniques were of paramount importance in recent experiments.

CHARGED PARTICLES

Several experimenters reported searches for energetic charged particles from deuterium-loaded metal foils. E. Cecil, G. Chambers (Naval Research Laboratory), and R. Taniguchi (ARL, Japan) observed charged particles having a few mega-electron-volts energy using silicon surface-barrier detectors, while K. Wolf has not yet found any evidence. X. Z. Li (National Tsing-Hua University) reported numerous ion tracks in etched plastic detectors exposed to deuterided palladium and showed a dramatic slide of etched tracks that had the appearance of arising from a localized "burst" of ions.

GEOPHYSICAL INVESTIGATIONS

P. Britton (Reiss Foundation) reported evidence for increasing ^{3}He and tritium with depth in boreholes in the Hamilton shear zone. E. P. Palmer reviewed the geophysical "cold fusion" hypothesis, which was responsible for the inception of cold fusion experiments at BYU in 1986. F. Goff presented evidence for several tritium units in "magmatic" water from Mount St. Helens. He and G. McMurtry collected samples from the Pu'u O'o vent of the Hawaiian volcano Kilauea that will be analyzed for tritium content. Their adventure was the subject of a most interesting after-banquet slide and video talk by McMurtry at Robert Redford's Sundance Resort on the second night of the conference.

TRITIUM/^{4}He

Reports of tritium production from deuterided metals and of tritium contamination in metal samples generated considerable discussion. The possibility of tritium contamination