BOOK REVIEWS

Selection of books for review is based on the editor's opinions regarding possible reader interest and on the availability of the book to the editor. Occasional selections may include books on topics somewhat peripheral to the subject matter ordinarily considered acceptable.

Theory of Fusion Plasmas

Editors	J. Vaclavik, F. Troyon, and E. Sindoni
Publisher	Editrice Compositori, Bologna, Italy (1989)
Pages	718
Price	$110.00
Reviewer	Allen H. Boozer

Theory of Fusion Plasmas is the proceedings of one of the Varenna-Lausanne workshops on the theory of magnetic fusion plasmas. The workshop was held at Chexbres (near Lausanne), Switzerland, in October 1988. The 62 papers in the proceedings deal with the major areas of theory: magnetohydrodynamic (MHD) equilibrium and stability, microstability, transport, and heating and current drive. There are no summary or review papers. Most of the papers are similar in style and length to a journal article and report on research in Europe, the United States, the USSR, Japan, and Australia. The book is an essential addition to any institutional library on magnetic fusion or plasma physics. Although the papers are too technical to serve as an introduction to a new area of plasma physics, any researcher in magnetic fusion or plasma physics will find several excellent articles in areas of personal interest.

The number of essentially independent topics makes the proceedings difficult to summarize, and a somewhat arbitrary selection of papers is discussed in this review.

Papers by Schwab and by Anderson et al. describe the collaborative effort at Garching and Lausanne on codes that calculate the ideal stability of MHD modes in three-dimensional plasma equilibria. The PEST and ERATO codes for calculating the ideal MHD stability of axisymmetric tokamaks have become essential elements in the design of new devices and in the interpretation of experiments. Until recently no similar code existed for three-dimensional toroidal devices such as the stellarator. In a stellarator with no net current, the only drive for MHD instabilities is the pressure. The operational and design limits on the pressure in stellarators have been ascertained by the relatively simple ballooning mode codes or by the even simpler calculation of the Mercier criterion. However, it is not clear that optimal stellarator devices will have zero net current due to the presence of a bootstrap current, nor is it obvious that the localized modes associated with ballooning or the Mercier criterion are more limiting than global modes, such as those studied using the PEST or ERATO code. Schwab studied the MHD stability of a set of stellarator equilibria using global perturbations formed from five Fourier coefficients ($3 \leq m \leq 5$). Her results indicated that the Mercier modes are only slightly more limiting than the global modes that she considered. And, it is not clear that Mercier modes will provide the correct limits once perturbations with a richer Fourier spectra are analyzed. Anderson et al. described the work on the code TERPSICHORE, which is spectral in the two angular coordinates of a torus and uses hybrid finite elements in the radial direction. Both this work and that of Schwab are based on the formulation of the energy principle by Nührenberg and Zille, which was published in the proceedings of the 1987 workshop in the Varenna-Lausanne series.

Parker and Dewar discussed their work on nonlinear resistive instabilities in a strictly two-dimensional system. By a two-dimensional system they mean that the magnetic field has the form $\boldsymbol{B} = \hat{z} \times \nabla\psi(x,y,t)$, and velocity the form $\boldsymbol{v} = \hat{z} \times \nabla\varphi(x,yt)$. The system is assumed periodic in y with period L_p and to have a fixed resistivity profile $\eta \propto \cosh^2(x)$. As noted by the authors, the fixed resistivity profile is unphysical and does modify the results from the more physical assumption that $\boldsymbol{B}\cdot\nabla\eta = 0$. Though not noted by the authors, the two-dimensionality can be justified by the addition of a strong, $\hat{z}$-directed, uniform magnetic field. Despite its simplicity, the model illustrates some of the richness of resistive MHD through its bifurcations as a function of the y period L_p. For small L_p the system is stable. As L_p increases, an island opens, a transition occurs to a chain of asymmetric islands that have a nonzero phase velocity, and then a transition occurs to a static state with alternate large and small islands.

The so-called η_i mode was a major topic in eight papers. This mode appears to explain many of the anomalies (though certainly not all) that are seen in tokamak transport. The η_i mode is unstable when the logarithmic derivative of the ion temperature relative to the density, $\eta_i \equiv d\ln(T_i)/d\ln(n)$ is greater than a critical value that is roughly unity. It exists even in a two-fluid model of the plasma, has a frequency of order $\omega_* \approx \rho_e(v_e/L)k_\perp$ with ρ_e the electron gyroradius, v_e the electron thermal velocity, L the density scale length, and $k_\perp$ the perpendicular wave number. Since the phase velocity along the field lines, $\approx\omega_*/k_\parallel$, must lie between the electron and the ion thermal velocities to avoid Landau damping, the mode must have a long parallel wavelength and can be stabilized by a high ratio of the ion to the electron temperature. The long parallel wavelength implies the mode can be modified near the magnetic separatrix of a tokamak plasma with a divertor. Briguglio found such an effect, but it was small compared to the effect of the separatrix on other modes. Tang and Hahm argued that the improved confinement of the so-called supershots could be explained by the stabilization of the η_i mode, which is in part due to its stabilization by the high-ion temperature.

Several papers dealt with the loss of the energetic alpha particles by an ignited deuterium-tritium plasma. Two of these papers considered the destabilization of Alfvén waves by a resonance between the velocity of the energetic alpha particles and the Alfvén speed. Cheng et al. found that toroidicity stabilizes the otherwise unstable interaction of the alpha particles with ordinary shear Alfvén modes of low mode number. However, they found that the toroidal couplings give a new type of shear Alfvén mode, which is called the toroidal Alfvén eigenmode (TAE mode). The TAE modes are destabilized by the alpha particles. Chen et al. also considered the destabilization of the TAE modes by passing alphas as well as the alpha destabilization of ballooning modes near the beta limit. The destabilization of the ballooning modes would not itself be an important limitation on tokamak performance since the modes must be near marginal stability. However, the destabilized ballooning modes can lead to a rapid loss of the alpha particles.

The number of toroidal field (TF) coils and the size of the ports in tokamaks are largely set by the level of toroidal magnetic field ripple. The most restrictive limit on the ripple in ignited plasmas comes from the requirement that the alphas be confined for a slowing down time. Mynick and White discussed the various loss mechanisms that arise from the ripple due to the TF coils. The stochastic loss mechanism is dominant and causes the trapped alphas to diffuse radially on a rapid time scale compared to their slowing down wherever the local value of the ripple exceeds a critical value δ_S. For International Tokamak Reactor (INTOR) parameters $\delta_S \approx 0.002$, and the local ripple exceeds this critical value in the outer half of the minor radius. They find that MHD activity, such as the sawtooth, does not alone destroy alpha confinement, but it can throw a significant number of alphas into a region in which the ripple exceeds δ_S.

Free electron lasers, which have been under rapid development, can provide short, intense pulses of radio-frequency power. Cohen et al. described new methods of heating and current drive that utilize these pulses and described some of the instabilities that may arise. Some of the pulsed electron cyclotron schemes for driving current are the rising bucket method, stochastic drive, and beat-wave drive. They also described a method of getting lower hybrid waves into regions of excessive Landau damping by using the intense pulses to temporarily form a plateau on the electron distribution function.

Waves in the ion cyclotron frequency range are of increasing importance for plasma heating, but the propagation and the interaction of such waves are difficult to calculate. Five papers in the proceedings describe methods for carrying out these calculations. For example, Gambier et al. describe the code ALCYON, which is based on Hamiltonian methods for describing the particles and variational methods for the fields.

Five papers discuss lower hybrid waves, which are the most successful waves for driving currents in tokamaks. Barbato discussed the basic methods used in lower hybrid codes. These codes give results that agree in many ways with experiments on lower hybrid current drive. A basic issue that has not been fully understood, however, is that of the spectral gap. Only electrons that have a velocity along the field lines that equals the phase velocity of the waves interact strongly. The phase velocity of the waves that are launched in lower hybrid experiments are much higher than the electron thermal velocity, so one might expect a weak interaction. But if a small fraction of the wave power is shifted to a lower phase velocity, the electron distribution function can form a high-energy tail that can interact strongly with the waves. Barbato calculated the production of low phase velocity waves due to toroidal effects near the radial turning points of the trajectories of the waves.

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Cold Fusion, The Making of a Scientific Controversy

Author	F. David Peat
Publisher	Contemporary Books, Chicago and New York (1989)
Pages	188
Price	$16.95
Reviewer	George H. Miley

The cover flap states that "Cold Fusion is the story of that (as yet unresolved) controversy. It is a tale of scientific discovery and intrigue, of experiments done around the world that continue to contradict each other, and of politics among scientists, universities, and the U.S. Government. It is also the story of how cold fusion may yet prove to be the solution to many of the world's energy problems."

When I spotted this small book in our university book store last January, two thoughts flashed through my mind: I knew someone would write such a book; I could not believe it had happened so quickly—it must be premature and incomplete! Then when I sat down to read *Cold Fusion*, I was pleasantly surprised. David Peat has done a remarkable job of producing this book in the midst of the "controversy." Indeed, as quoted above, the book provides a story about the discovery and intrigue. As readers of *Fusion Technology* will realize, I have been involved personally in cold fusion, including testimony at the Senate hearing in March 1989, and