stellarator news

Published by Oak Ridge National Laboratory, J. A. Rome and J. F. Lyon, editors.

A Message from the Editors

At the Fourth U.S. Stellarator Workshop held at Oak Ridge National Laboratory (ORNL) in April 1983, the Stellarator Committee endorsed the idea of starting a newsletter for the stellarator community. The success or failure of this effort will depend upon you, the reader.

In each issue, we hope to present short articles primarily about projects people are working on and what sort of results are being obtained. Also, we will publish meeting announcements and a list of recent publications in the stellarator field. Finally, we wish to keep you informed about people and events in the stellarator community.

However, we will only publish information supplied to us by you. The best way to do this is to type it in TEDI format and send it to us over the CTR network. This can be done by doing

TELL ROME@ORN/FILE:File-Spec.

Then, we can edit the newsletter and convert it to UNIX to be set on a phototypesetter so that it is more readable.

NEWS

High Power Density Stellarator Reactors (LANL)

A small group at Los Alamos is continuing to search for equilibria that would be compatible with a compact, high-power density stellarator reactor. Helical axis systems are of particular interest. Various stellarator field expansions are under study in an effort to identify optimum machine characteristics. Vacuum field studies will be supported by 3-D MHD equilibrium computations using the Bauer-Betancourt-Garabedian code in collaboration with the New York University group and the Chodura-Schlüter code obtained from ORNL with authorization from Garching. Transport analysis will also be needed. The heating of the stellarator plasma using ICRF is also under study at Los Alamos.

Reactor studies of the $l = 2$ Modular Stellarator Reactor (MSR) have been conducted by a group including researchers from Los Alamos, Westinghouse Electric Corporation, and Stone & Webster Engineering Corporation. Final results are reported in the Los Alamos National Laboratory report LA-9737-MS, "The Modular Stellarator Reactor — A Fusion Power Plant," by R. L. Miller, *et al.* (in press).

Other recent publications include R. L. Miller, R. A. Krakowski, and C. G. Bathke, "Parametric Systems Analysis of the Modular Stellarator Reactor," Nuclear Fusion *23*, 467-479 (1983) and R. L. Miller, *et al.*, "Modular Stellarator Reactor Conceptual Design Study," presented at the 5th ANS Topical Meeting on the Technology of Fusion Energy, Knoxville, Tennessee (April 26-28, 1983).

ATF Project Status (ORNL)

The engineering design for the Advanced Toroidal Facility (ATF-1) project has begun. The ATF-1 is an $l = 2$, $m = 12$ continuous torsatron with $R_o = 2.1$ m, $a_c = 0.458$ m, and $\langle a_p \rangle = 0.3$ m. With the present ISX-B toroidal field power supply, pulse lengths greater than 2 s, at a magnetic field of approximately 1.75 T, can be obtained. The neutral beam heating capability will be 4.5 MW for 0.3 s at 40 keV with tangential injection. Lower power levels may be sustained for longer pulse lengths with only minor modifications. Initial operation is scheduled for October 1986.

Two changes have been made to the design of ATF-1 since the proposal in October 1982 and the conceptual design review in April 1983. Both changes were made to allow more clearance between the outer flux surface and the vacuum vessel. First, the helical field coil cross section was reduced and the number of turns was decreased to 14. This has several effects: it allows the vacuum vessel to be moved radially outward from the plasma; it reduces the maximum field that we can obtain from our present power supply to about 1.8 T; but it allows longer pulses since the rise time is faster and more energy is available for the flat top portion. Second, the vacuum vessel was enlarged while, at the same time, the helical field coil to vacuum vessel gap was increased. This not only increases the clearance around the plasma but also allows the vacuum vessel to be completely fabricated in advance by leaving enough clearance for the helical coil segments to be installed around the completed vacuum vessel.

Development tasks have been initiated on the helical coil segments, the helical coil joints, and the helical coil fabrication fixtures.

Stellarator Transport Studies at ORNL

It has now become clear that the presence of a radial electric field is required to obtain good transport in stellarators. The $\vec{E} \times \vec{B}$ drift dramatically reduces the size of helically trapped particle orbits, even if $e\phi/kT \sim 1$. This effect dominates those arising from small changes in the magnetic configuration.

To determine the full implications of radial electric fields in ATF-1, ORNL is using a three-pronged approach. K. C. Shaing has employed the harmonics of the actual ATF-1 magnetic field in flux coordinates to derive the particle and heat fluxes in the presence of an electric field in both the ν and $1/\nu$ regimes. For the usual model field, he has also spliced these regimes together at their resonant transition where the $\vec{E} \times \vec{B}$ and $\vec{B} \times \nabla B$ drifts cancel. For reasonable values of $\vec{E}$, the height of the peak in D at this transition is significantly reduced, and the ions enter the collisionless ν regime at a higher value of ν. than had been previously thought. Indeed, for typical projected ATF-1 parameters, the ions are well into the ν regime.

The electrons are more collisional and are usually in the $1/\nu$ regime. To determine the correct level of electric field, J. F. Lyon and W. A. Houlberg have examined the radial ion and electron fluxes using the above diffusion coefficients. For some range of temperatures, there may be several values of $\vec{E}$ for which the fluxes are equal. Usually, one root confines electrons, one confines ions, and the third is unstable. Occasionally, there may be five roots. On the ion root, the electric field decreases as T increases, while on the electron root, it remains high. Thus, for optimum transport results, it seems preferable to be on the electron root. Because $\vec{E}$ is a function of radius, W. A. Houlberg is trying to put these results into the WHIST transport code. However, this is very difficult to do since the correct root may change at different radii. Work is continuing.

The ORNL Monte Carlo code is being used by R. H. Fowler and J. A. Rome to try to verify the diffusion coefficients of Shaing. Since transport in stellarators is an inherently nonlocal process, this is difficult to do. For small values of radial potential, the orbits are very large and quickly reach the loss cone, even when those particles which are initially on collisionless loss orbits are not included. At large values of potential, the results are dominated by tokamak neoclassical effects. In between, the statistics are poor. Nonetheless, our results so far support Shaing's theory.

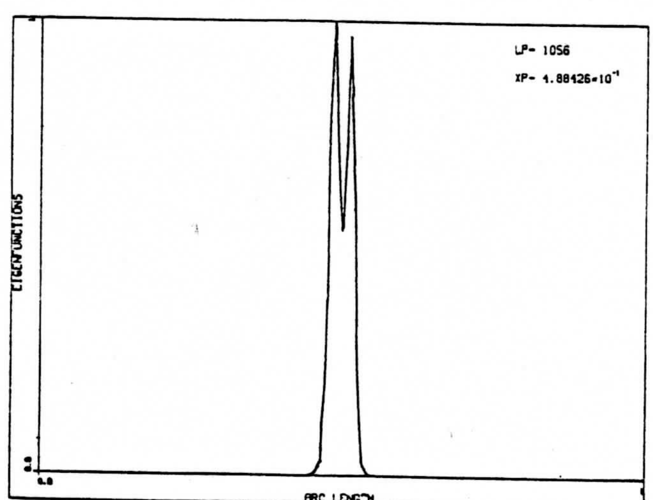
For further information see K. C. Shang and S. A. Hokin, "Neoclassical Transort in a Multiple Helicity Torsatron in the Low Collisionality ($1/\nu$) Regime," ORNL/TM-8556 (to be published in Physics of Fluids); K. C. Shaing, "Neoclassical Transport in a Multiple Helicity Torsatron in the Low Collisionality Regime-Strong Radial Electric Field Limit," ORNL/TM-8773.

Ballooning Stability of 3-D Vacuum Equilibria

W. A. Cooper (ORNL)

The ballooning stability of 3-D stellarator equilibria is determined by solving a second-order ODE along each magnetic field line that lies in well-defined flux surfaces within the plasma. A ballooning mode code has been developed and applied to the vacuum flux surfaces of a torsatron configuration onto which pressure has been added arbitrarily. The purpose of this exercise is to test the behavior of the code and to obtain benchmark results for future applications of the code to self-consistently determined 3-D toroidal equilibria with shear.

The results obtained so far indicate that the growth rates depend sensitively on the radial wave number and on the flux surface but vary only weakly from field line to field line on any given flux surface. The growth rates are largest on surfaces close to the edge of the plasma where there is a magnetic hill in the vacuum, and decrease noticeably towards the magnetic axis where there is a magnetic well. On the average the modes tend to peak where the magnetic field line curvature is most destabilizing. The peaking points do not necessarily coincide with the outermost point of each flux surface. The eigenfunction for the field line labelled and $\alpha = 0.1$, a flux surface $\rho = 0.8$, radial wave number $\theta_k = \Lambda$ with $\beta_o = 5\%$ is shown in the figure. The dominant peak of the mode is at $\theta = 142°$.



β_c=5% ρ=0.8 θ_k=π θ_{min}=-25.133 radians θ_{max}=31.416 radians

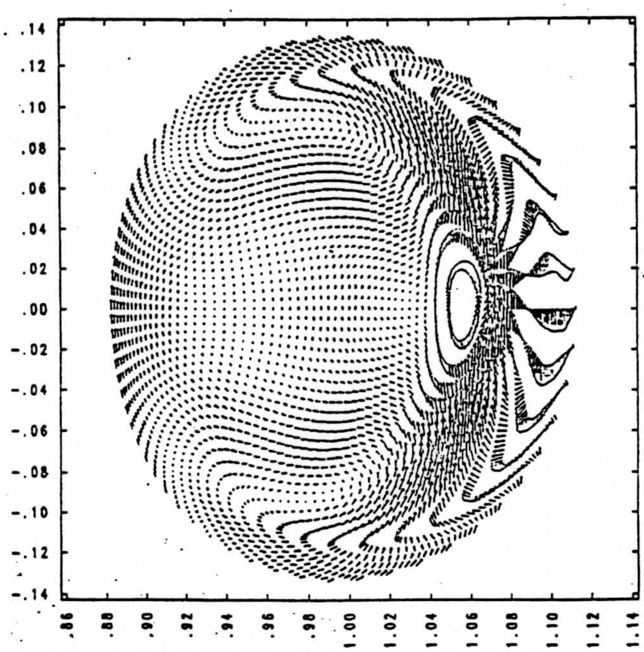
Peak at θ=2.49 radians = 142° α = 0.1

ATF-1 Stability Studies

G. Rewoldt and J. Johnson (PPPL)

Greg Rewoldt and John Johnson are continuing the stability studies of ATF-1, which were begun by Giorgio Anania, with the toroidally averaged vacuum fields from the actual coils used as input data for the stellarator expansion. With a parabolic pressure distribution Giorgio found an equilibrium with $<\beta>$ = 2.5% (β_o = 6.5%) which was at least marginally stable to free boundary modes. We now have an equilibrium with $<\beta>$ = 2.6% (β_o = 7.5%) which is unstable to low-n modes such as the n = 1 case shown in the figure. The n = 1 mode can be stabilized by a conducting wall at $b/a \approx 1.6$. For both n = 2 and n = 3, b/a must be $\sim$1.5. These numbers are smaller than those contemplated in the actual device.

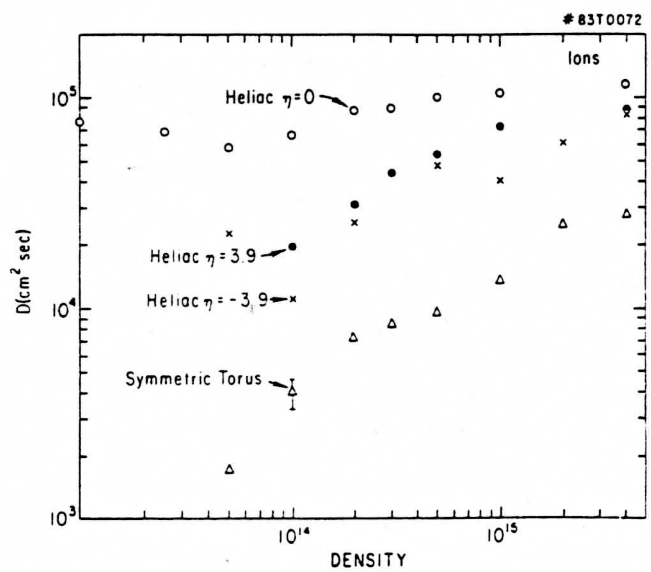
This instability has interchange properties centered around the ι = 0.5 rational surface, which has been pushed onto a magnetic hill by the finite pressure effects. Since the theoretical results are strongly dependent on the exact shape of the equilibrium parameters, this study can only indicate that experimental study of β limits in stellarators will be interesting.



Heliac Transport Studies

G. Kuo-Petravic and A. H. Boozer (PPPL)

Monte Carlo transport calculations have been made for the H1 design for a Heliac (helical axis) stellarator. The parameters of this design are 1.5 m major radius, 25 cm average minor radius, 1 T magnetic field, three periods, and a transform of 1.6. The relatively small size of this device causes the ion confinement time to be only about a factor of 10 longer than the ion collision time at the desired plasma parameters, $n = 10^{14}/cm^3$ and T = 1 keV. The shortness of the confinement time invalidates the concept of a radially local diffusion coefficient. However, a typical diffusion coefficient can still be defined as a function of density and temperature for global confinement time studies. To evaluate this coefficient a group of 64 particles was launched with an energy of 3 T/2 about half way out radially. The particle trajectories were followed using Hamiltonian drift equations in magnetic coordinates for the exact field of the H1 design. The test particles suffered energy and pitch angle scattering on a uniform density and temperature background plasma. The diffusion coefficient was evaluated from the time it took half the test particles to leave the plasma volume. The procedure gives a reasonable estimate of confinement times even when they are sufficiently short that the ion distribution function is a heavily truncated Maxwellian. A scan of the diffusion coefficient versus density is illustrated for various values of the ambipolar potential, $\eta = e\Phi_o/T$. An equivalent axisymmetric configuration was also studied for comparison purposes.



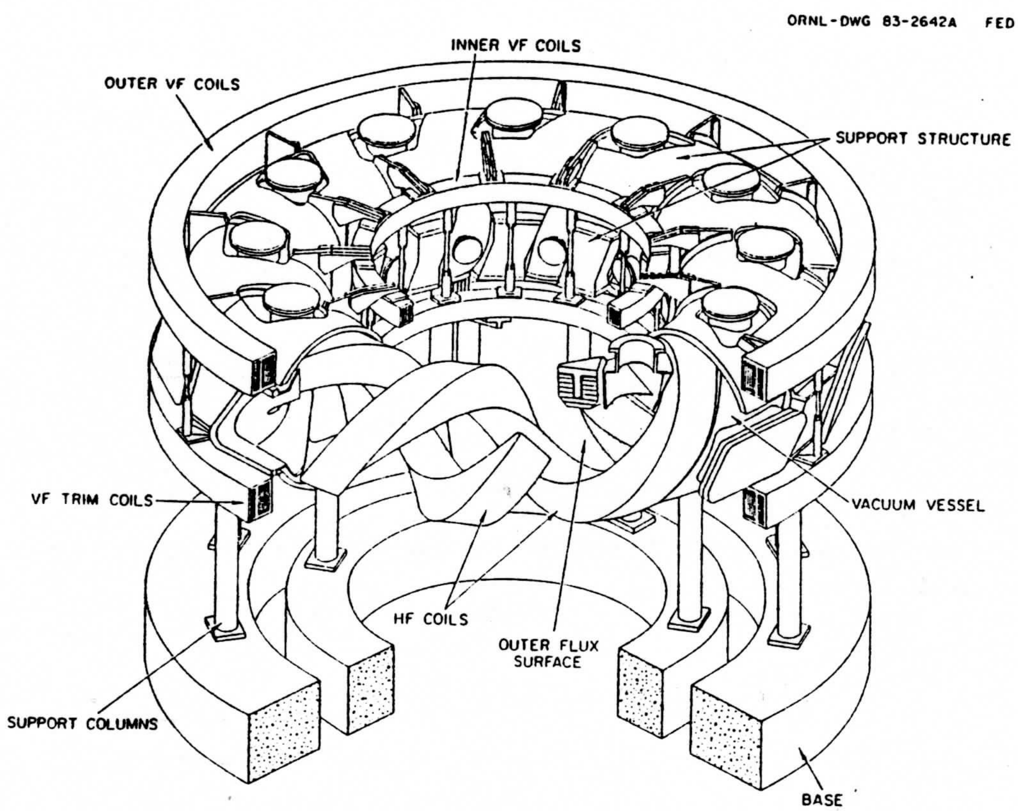
people & events

Extended Travel

Jeff Harris at Kyoto from June-September.
Jim Lyon at Garching from June-September.
John Johnson at Garching in July.

Events

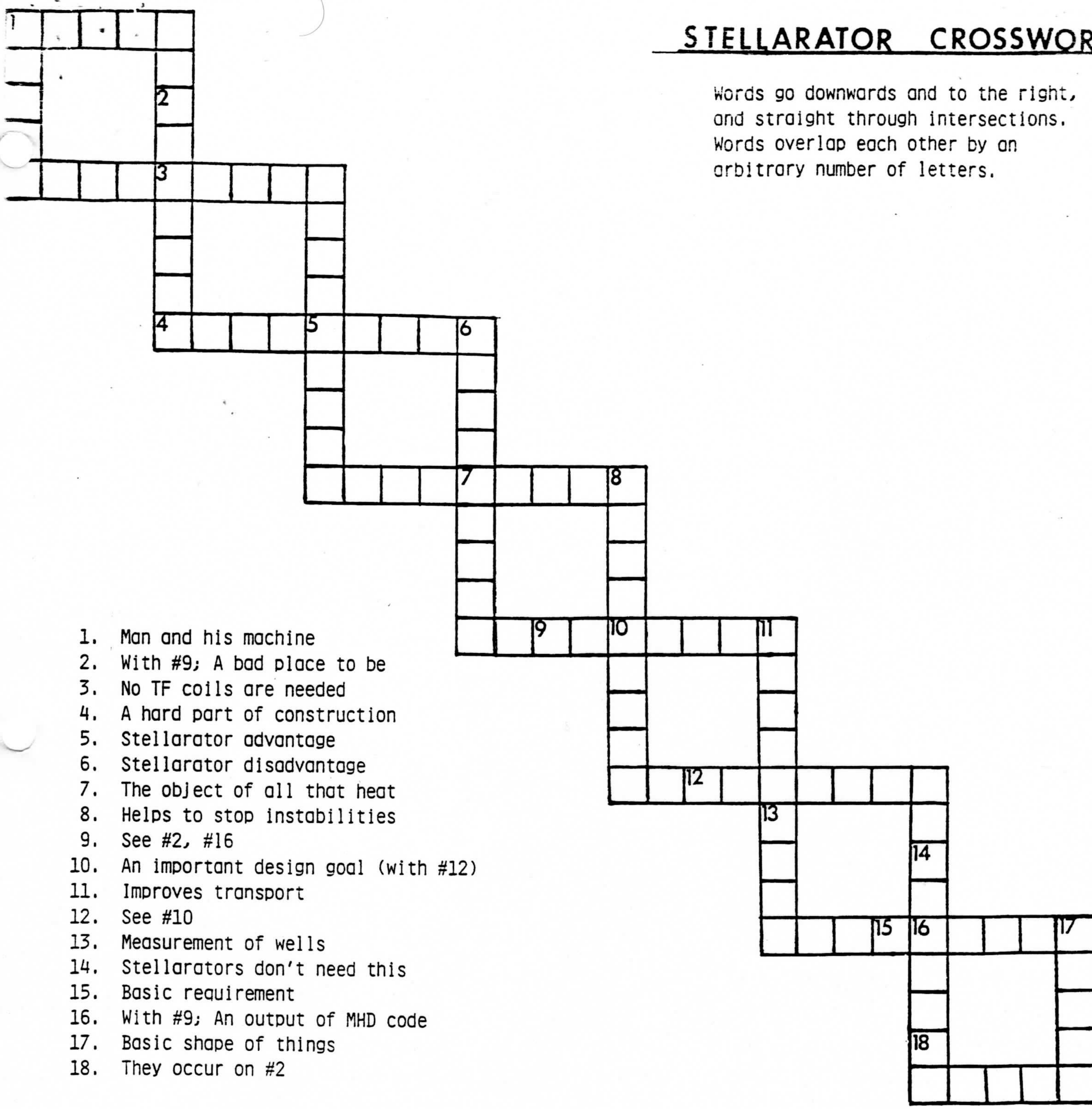
There was a meeting at DOE on Monday, June 6, 1983 to discuss an agreement between the U.S. (DOE) and E.C. (Euratom) on the correlation of stellarator programs. Japan (Kyoto) intends to join at a later time. Present at the meeting were G. Grieger and H. Wobig Max-Planck Institute of Plasma Physics; J. Lyon (ORNL); A. Boozer (PPPL); and R. Blanken, E. Oktay, W. Dove, C. Head, and W. Sadowski (DOE).



ATF-1
Advanced Toroidal Facility

STELLARATOR CROSSWORD

Words go downwards and to the right, and straight through intersections. Words overlap each other by an arbitrary number of letters.



1. Man and his machine
2. With #9; A bad place to be
3. No TF coils are needed
4. A hard part of construction
5. Stellarator advantage
6. Stellarator disadvantage
7. The object of all that heat
8. Helps to stop instabilities
9. See #2, #16
10. An important design goal (with #12)
11. Improves transport
12. See #10
13. Measurement of wells
14. Stellarators don't need this
15. Basic requirement
16. With #9; An output of MHD code
17. Basic shape of things
18. They occur on #2