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ORNL FOREIGN TRIP REPORT
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DATE: May 7, 1999

SUBJECT: Report of Foreign Travel to Abingdon, United Kingdom, by Donald L. Hillis, Research Staff Member, and John T. Hogan, Research Staff Member, Fusion Energy Division, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee

TO: Dr. R. G. Gilliland

FROM: Donald L. Hillis and John T. Hogan

PURPOSE: Perform Hydrogen Change-over Experiment on the Joint European Torus (JET) tokamak with the ORNL-designed species-selective Penning gauge.

SITES VISITED: 4/26 – 4/30/99 JET Joint Undertaking, Abingdon, United Kingdom — P. Thomas, M. von Hellermann

ABSTRACT: During this trip to JET in Abingdon, England, the travelers successfully completed a series of measurements to study the change-over of the JET working gas from deuterium to hydrogen utilizing the ORNL-designed species-selective Penning gauge, which measures simultaneously the concentration of hydrogen, deuterium, or tritium in the sub-divertor of JET. This diagnostic coupled with other JET diagnostics provides an opportunity to study the link between the edge plasma and the tokamak wall. The travelers previously participated in the Deuterium-Tritium Experiment 1 (DTE1) campaign on JET and used that data to arrive at a rather detailed model for plasma-divertor-wall particle exchange and to test extant rate coefficients for the plasma-wall exchange. (D. Hillis, J. Hogan, et al., Phys. Plasmas, May 1999). These earlier deuterium-tritium experiments led naturally to the present set of hydrogen change-over experiments on JET where the working gas is changed from deuterium to hydrogen. These hydrogen changeover experiments will provide an opportunity to extend the plasma-wall exchange database by making more stringent comparisons with wall models. The analysis will also utilize the extensive JET/University of Strathclyde molecular spectroscopy expertise to provide additional information which is needed to develop the model for particle-induced desorption.

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REPORT OF FOREIGN TRAVEL TO ABINGDON, UNITED KINGDOM
April 26 - April 30, 1999

Donald L. Hillis and John T. Hogan

1. Visit to JET Joint Undertaking, Abingdon, United Kingdom

The primary purpose of this trip to the JET Joint Undertaking was to perform a series of experiments to investigate the change-over of the JET working gas from deuterium to hydrogen utilizing the ORNL-designed species-selective Penning gauge, which measures simultaneously the concentration of hydrogen, deuterium, or tritium in the sub-divertor of JET [D.L. Hillis et al., Rev. Scien. Instrum. 70 (1999) 359]. This gauge system is fully operational and has been a major contributor to the JET experimental program throughout this year. Data analysis software for the diagnostic has been developed by one of the travelers to provide routine measurements of the tritium concentration, as well as calibrated partial pressures of hydrogen, deuterium, and of the hydrogenic isotopes (H, D, or T) every 250 ms during a JET discharge. Using this Penning gauge measurement system, it is possible to follow the evolution of the hydrogen, deuterium, and tritium concentrations during a JET discharge as the inventory is dynamically changed during neutral beam injection or gas fueling. The spectra obtained from JET plasmas during the past year have resulted in excellent high resolution signals, such that tritium and hydrogen can be readily separated from the deuterium background. This diagnostic coupled with other JET diagnostics provides an opportunity to study the link between the edge plasma and the tokamak wall.

The tritium isotopic inventory in the walls of a tokamak with graphite plasma-facing components is important since the hydrogenic composition which is due to external fueling of the discharge is dominated by that from the wall. In addition, if the tritium retention in the wall is not properly controlled there can be serious detrimental consequences for the safety and environmental acceptability of future fusion reactors. The travelers previously participated in the DTE1 campaign on JET and used that data to arrive at a rather detailed model for plasma-divertor-wall particle exchange and to test rate coefficients (such as, recombination, trapping, detrapping, and particle induced detrapping) for the plasma-wall exchange. (D. Hillis, J. Hogan, et al., Phys. Plasmas, May 1999). These earlier deuterium-tritium experiments led naturally to the present set of hydrogen change-over experiments on JET where the working gas is changed from deuterium to hydrogen. These hydrogen changeover experiments will provide an opportunity to extend the plasma-wall exchange database by making more stringent comparisons with wall models.

In addition to the primary focus, the travelers are participating in the JET program in a study of divertor recycling and enrichment processes for helium, neon, and argon impurities. Helium enrichment is of fundamental interest for fusion research, and the latter are of current topical interest related to the production of enhanced-performance radiative-improved (so-called 'RI-mode') regimes. This topic involves interaction with the JET divertor modeling group and the use of the IPP-Garching B2-Eirene code. Thus, this trip report will summarize our work at JET in the areas of: (1) plasma-wall particle exchange; (2) helium transport and divertor enrichment; and (3) ORNL - Garching collaboration and future divertor modeling at JET.

1. Plasma-wall particle exchange

The travelers previously participated in the DTE1 experimental campaign on JET and used this data to arrive at a detailed model for plasma-divertor-wall particle exchange and to test rate coefficients for this exchange. Previous to DTE1, only post-shot pressure decay data had been available to provide quantitative information for first principles wall models. With the

DTE1 data, however, an empirical model for particle-induced desorption, developed by J. Ehrenberg (ex-JET, now European Commission-Brussels) for JET trace tritium injection experiments, was validated. Several other models (Moeller-Scherzer, Grisolia et al.) were tested against the same data set. (D. Hillis et al., Phys. Plasmas, to be published, invited paper, 1998 APS).

So, participation in experiments during the change-over of the JET working gas from deuterium to hydrogen provided an opportunity, first of all, to extend the database to make more stringent comparisons with wall models but also, and more importantly, to focus the extensive JET spectroscopic diagnostic arrays and molecular spectroscopy expertise on the exchange to provide information needed to develop a first principles model for particle-induced desorption, to improve the Ehrenberg empirical model.

The discharges in the deuterium-hydrogen change-over series were designed to match, as nearly as possible, the conditions of the prior DTE1 change-over (pulses 41677 et seq.). They were ohmic pulses, with single-null vertical target divertor configuration, established ~10 s after current flattop. As with the deuterium-tritium changeover, the largest change occurred in the first five seconds of divertor operation, and again the sub-divertor minority species concentration (hydrogen in this case), measured by the ORNL-designed Penning gauge, was observed to lag the strike point minority species concentration, determined by spectroscopy, again indicating the wall recycling status. However, in contrast with the prior DTE1 experiments, relatively high-resolution molecular spectra were obtained in the wavelength vicinity of the CD band head, and the transition of the location and amplitude of this band and band-head was continuously monitored during five pulses in which the hydrogen concentration was raised from ~1% to ~80%. After 10 s of ohmic divertor operation, Deuterium beams were injected. These data should be useful in determining the effectiveness of particle-induced desorption as a function of range.

Participation of the atomic physics group of the University of Strathclyde (Drs H.P. Summers and G. Duxbury) in future quantitative analysis of these data was arranged by M. von Hellermann of JET, so the relative strength of hydrocarbon emission as a factor in particle-induced desorption should result from subsequent analysis of the data.

The travelers produced data files for the Strathclyde molecular spectroscopic analysis from the original spectroscopic measurements, using the SHOW98 code with the assistance of A. Meigs of JET.

2. Helium transport and divertor enrichment

On a previous visit (January–February 1999) the travelers had established a work plan in coordination with Dr. H.Y. Guo of JET for analysis of JET results on the effect of configuration on divertor helium enrichment, and on the effects of type I edge-localized modes (ELMs) in determining the enrichment. The agreed plan at that time had been for Dr. Guo to analyze configuration effects (horizontal/corner/vertical strike point positions), using the time-independent version of the JET EDGE2D/NIMBUS codes, in a paper to be presented at the 1999 European Physical Society (EPS) meeting (Maastricht, June 1999), while the travelers would analyze the ELM effects in a selected pulse (36529, vertical target configuration, MKIIa) with B2-Eirene for discussion at the forthcoming fall Helium Transport and Exhaust Workshop, organized by ORNL and Forschungzentrum-Jülich.

On this visit, however, painful consequences of the personnel changes mandated by the European Commission were apparent, since the original plan could not be met from the JET side, and corrections have had to be made. In particular the travelers have advanced the B2-Eirene Type I ELM impurity modeling, which is now to be included in Dr. Guo's EPS paper. Work on configuration comparisons, using the ORNL b2.5 analysis code is also to be pursued for the EPS meeting.

3. ORNL - Garching collaboration, future divertor modeling at JET, and future planning of the JET experimental program

Work has continued on the generation of high resolution grids for B2-Eirene modeling of JET. This development is needed jointly by IPP-Garching and ORNL and requires an upgrade of the present JET EFIT capability to create 65 x 65 grids. The development is being undertaken by W. Zwingmann (ex-JET now at Cadarache). Because of continuing limitations on access to the JET Analysis Cluster system from outside the site, the new version of EFIT can only be tested while at JET. Although the code had been declared to be operational shortly after the end of the travelers previous visit to JET earlier this year, work done during the present visit disclosed that the solutions were not converged and that additional development is needed. W. Zwingmann will revisit JET in a few weeks time to continue this.

Through our involvement with JET divertor modeling, and the need to make an agreed work plan between the JET EDGE2D/NIMBUS work and ORNL B2-Eirene work, the travelers have been involved in discussions for over a year about the future course of JET divertor modeling in the transition from the Joint Undertaking to the European Fusion Development Agreement (EFDA) regime. There has been interest during this period from the JET side for the adoption of the IPP-Garching B2-Eirene code at JET, but also considerable uncertainty about the future roles of the individuals involved at JET. At present this is fairly well established, and one of the travelers (John Hogan) was asked to participate in a JET - IPP discussion concerning the future of divertor modeling at JET. Attendees were A. Taroni, J. Spence, and J. Corrigan from JET; D. Coster and K. Borrass from IPP-Garching, G. Maddison from Culham, and J. Hogan. The situation, as described by Taroni, is that, because of personnel departures (including his own), further development activity on EDGE2D/NIMBUS will have to cease. In his view, since development activity will continue with B2-Eirene, then JET should adopt B2-Eirene. This is not a simple matter, because the employment of the JET divertor code support group must be specifically requested from the future United Kingdom Atomic Energy Authority (UKAEA) operators of JET so that the operators can hire them and provide them to the project. Absent such a request, they would be forced to leave JET. D. Coster described the present status of B2-Eirene and Garching's (and Greifswald's) future plans for 3-D divertor code development. A coupled version of b2.5 and a new version of Eirene for a full 3-D scrape-off layer geometry is to be developed on approximately a ten year schedule. R. Schneider (presently Garching, soon to move to Greifswald) will lead this effort. It was felt that the best role which the JET divertor code development group could play was to serve as the interface between the JET data acquisition system and the divertor code development activity. There was agreement that this was the best solution for the future, and assurance that the authorities would indeed support it.

As part of this discussion, the framework under which the future JET divertor program would be planned was also discussed. A meeting will be held at IPP-Garching on July 27-28, 1999, in which the next phase of the JET divertor physics experimental plan will be developed. A letter soliciting input has been sent from IPP-Garching to the member associations. Dr. K. Borrass is organizing the meeting. During the meeting at JET it was stated that, while the U.S. is not an association, participation in collaborations is welcome, and that such collaborations will be integrated into the JET experimental plan though mechanisms such as the July divertor meeting in Garching. Apparently similar meetings are being planned by the associations in the other JET Task Force areas. The mechanism is that association-led working groups are to be established, to define the JET physics plan, and the UKAEA operator is to provide the support personnel to facilitate the activities of the association teams, which will travel to JET to carry out experiments.

During this trip discussions were held with various research groups at JET. Future areas of involvement for the travelers will continue to be focused on impurity transport and exhaust, as well as the influence of the tokamak walls on hydrogen and tritium transport and recycling. The following areas were identified as areas of collaboration for the next couple of years:

1. Trace tritium transport experiments and modeling. A trace tritiumexperimental campaign is being discussed for November 1999.

2. Modeling and interpretation of the hydrogen wall loading experiments which were conducted during this trip. Compare hydrogen uptake of the graphite walls of JET with the tritium wall uptakeexperiments performed during 1998.

3. Modeling of recent helium exhaust experiments on JET in ELMing H-mode. Utilize Box divertor configurations.
4. Compare helium, neon, argon divertor enrichment during ELMing H-modes between DIII-D and JET for the differing divertor configurations.

5. Support the RI-mode experiments at JET by investigating the neon and argon. This JET/ORNL collaboration is covered under the existing "Agreement for Co-operation between the European Atomic Energy Community and the United States Department of Energy in the Field of Controlled Thermonuclear Fusion."

APPENDIX A

ITINERARY

4/24 - 4/25/99	Travel from Oak Ridge, Tennessee, to Abingdon, United Kingdom
4/26 - 4/30/99	JET Joint Undertaking, Abingdon, United Kingdom
5/1/99	Travel from Abingdon, United Kingdom, to Oak Ridge, Tennessee

APPENDIX B

LIST OF PRINCIPAL PERSONS CONTACTED

JET, Abingdon, England

P. Thomas	Division Head
L. Horton	Research Staff
M. von Hellermann	Research Staff
G. Matthews	Group Leader

APPENDIX C

LITERATURE ACQUIRED

1. Report on JET-ASDEX Upgrade Divertor Workshop, April 22-23, 1999, at JET.

2. JET contributed papers presented to the 13th International Conference on Plasma Surface Interactions in Controlled Fusion Devices (PSI 13) (San Diego, USA, 18-22 May 1998) JET Report number: JET-P (98) 58.

3. A.C. Maas, et al. “Diagnostic Experience during Deuterium-Tritium Experiments in JET, Techniques, and Measurements,” JET Report number: JET-P (98) 80.

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