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INTERNATIONAL ENERGY AGENCY
COMMITTEE ON ENERGY RESEARCH AND TECHNOLOGY

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FUSION POWER CO-ORDINATING COMMITTEE

35th Meeting - February 28 – March 1, 2006–IEA Headquarters, Paris

Agenda Item No. 11

Implementing Agreements on Large Tokamak Facilities - Annual Report 2005

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IEA IMPLEMENTING AGREEMENT ON CO-OPERATION ON THE LARGE TOKAMAK FACILITIES
Annual Progress Report (June 2004 to May 2005)

EXECUTIVE SUMMARY

1. Mission of LT IA and relevance to the international fusion program

The objective of this Agreement is to enhance the scientific and technological achievements of the Large Tokamaks by means of co-operative actions for the advancement of the tokamak concept. This IA is one of the largest cooperations among the fusion IAs under the IEA. The achievements of the large tokamaks under this Agreement provided essential data and operating experience towards the next step device, ITER, and the advancement of the tokamak concept. The breadth of the activities of this IA has expanded during this reporting period with the inclusion of Poland and Slovenia as parties in the EFDA Agreements, and with the enhancement of university collaborations with JT-60U in Japan. Furthermore the ITPA/IEA Joint Experimental program, as described below, included participants also from Russia Federation, China, and Korea.

2. Current foci and objectives of LT IA

Current foci of large tokamak experiments are the control of plasma instabilities and the long-duration sustainment of steady-state high plasma pressure plasmas, ITER demonstration discharges, and trace-tritium experiments. JET received approval in the EU to embark on a longer-term JET programme aimed at installing on JET an ITER-like combination of first wall and divertor materials and increased heating power. These enhancements will enable JET to make major contributions to ITER first wall and materials issues and to the development of ITER scenarios. ITER scenario development is also a major element of DIII-D in the U.S. and JT-60U in Japan.

Through this IA, experiments, theory and modeling in these topical areas, especially joint experiments requested by ITPA were performed using JET (EU) and JT-60 (Japan) devices with contributions from the U.S. national devices such as DIII-D, C-Mod, and NSTX. A workshop on "Implementation of the ITPA coordinated research recommendations" was held near Oxford, U.K. in December 2004. This activity is indeed maturing and making substantial contributions to the advancement of tokamak research for burning plasmas and ITER. In this third in the series of such workshops, leaders representing 19 major world tokamaks from EU, Japan, the U.S. and Russia Federation participated. Current foci of large tokamak technology are the development of negative-ion-source-based neutral beam injector (N-NBI) in JT-60U, tritium and remote handling in JET, and feedback control of plasma instabilities in the U.S. as well as diagnostics improvements.

3. Highlights and accomplishments of the reporting period June 2004-May 2005

JET in the EU was in shutdown for all of this reporting period for modifications and improvements, including the installation of the Mark II HD (High Triangularity) Divertor and ~ 16 major new diagnostics, and improvements to both the neutral beam and ICRF heating systems. JT-60U was operated for about six weeks in the first half of the reporting period and then it was shutdown for about six months for the repair and commissioning of the motor-generator system, for improvements to the neutral beams, and to install ferritic tiles. DIII-D completed an intensive run schedule of 33 weeks in a period of 13 months extending from March 2004 to April 2005. The experimental results and their analysis from these and other programs in the collaboration were extensively reported at the 19th IAEA Fusion Energy Conference held in Villamoura, Portugal in October 2004, and at numerous other international conferences. Working closely with the ITPA, results from this collaboration have been regularly communicated to the ITER International Team (IT) to the benefit of the ITER physics design.

The physics-related work in the collaboration is conducted in seven topical areas which are similar to those used in the ITPA. These are Transport and ITB Physics, Confinement database and modeling, MHD, Edge and pedestal physics, SOL and divertor physics, and Steady state operation. In addition, Tritium and ICRH technologies are conducted in a separate Task Area. Accomplishments in these task areas are described in Attachment A.

In the EU, the JET-EFDA program extension to Dec 31, 2006 was approved. In Japan, JAERI and the National Fuel Corporation were joined in a new organization, called the Japan Atomic Energy Agency (JAEA). In the U.S., a US ITER Project Office (USIPO) was formed to manage the U.S. hardware and fund contributions to the ITER Project, and a US Burning Plasma Organization (USBPO) was established to involve the U.S. scientific community with the ITER Physics issues. The BPO will coordinate U.S. fusion research on ongoing experimental facilities, theory and modeling, and plan for burning plasma experiments on ITER. A summary of the Status and Plans of Three Parties is included in Attachment A.

Three workshops were held during this period. These were:

- W58: Third Joint Workshop on Large Tokamak, Poloidal Divertor, and TEXTOR IA's on "Implementation of the ITPA Coordinated Research Recommendations", near Oxford, UK on December 8-10, 2004.

- W59: Shape and Aspect Ratio Optimization for High beta, Steady State Tokamak; February 14-15, 2005; General Atomics, San Diego, CA

- W61: Satellite Workshop on "Heating and Control for Long Pulse Operation in Large Tokamaks" held at Giorgio Cini Foundation in Large Tokamaks: on September 23, 2004.

Summary reports from these workshops are included in Attachment B.

There were substantial personnel exchanges among the three Parties. A list of these exchanges is shown in Attachment C.

The 20th meeting of the IEA Large Tokamak LT was held at the Princeton Plasma Physics Laboratory on May 9-10, 2005. This meeting was held jointly with the IEA Poloidal Divertor IA. The minutes of this meeting is shown in Attachment D.
The next meeting of the Executive Committee will be held at Cadarache, France on June 28-29, 2006.

4. Future strategy

The implementation of the ITPA coordinated research recommendations was successfully started in 2002 under the IEA LT IA . This joint experiment arrangement among JT-60U-JET-USDOE will be strengthened to prepare for the successful start-up of ITER operation with wider participation from the other IEA/IAs and Bilateral Agreements. Also technological cooperation under this Agreement will be strengthened in the areas of tritium and remote handling, heating system development such as N-NBI, and diagnostic development.

5. Collaborations inside/outside IEA

Responding to FPCC requests on cooperation among IEA IAs, Workshop W58 was held jointly by the IEA LT IA, the IEA PD IA, and the IEA TEXTOR IA with participation from the ITER IT and the Russian Federation. Some of the personal exchanges for the ITPA joint experiments were made under Bilateral Agreements. The IEA LT homepage (http://www-jt60.naka.jaeri.go.jp/lt/), which is open to all IEA IAs and the public, was developed to improve the visibility of our activities.

6. Message to policy makers

The IEA Large Tokamak Implementing Agreement is one of strongest fusion IAs and has been effective in developing tokamak research to reach break-even conditions and in developing the necessary databases for the next step device ITER and a steady-state tokamak reactor. This Agreement provides leadership in coordinating ITPA joint experiments with other tokamak related IEA IAs. Please visit our homepage to understand our activities and send us any comments for improvements.

7. List of attachments

(These reports can be found on the IEA LT web-site, http://www-jt60.naka.jaeri.go.jp/lt/index.html, in the 'Internal Use' sub area. Please contact Kouiji Shinohara or Erol Oktay for password to access this part of the website.

A1: Accomplishments in Task Areas
A2 : Status and Plans of Three Parties
A3 : Summary reports on Workshops
A4 : Minutes of Executive Committee meeting at PPPL
A5 : List of personnel exchanges

Appendix A1

IEA Cooperation Among Large Tokamak Facilities
Reports and Plan on Task Assignment Programmes (June 2004 - June 2005)

Task 1: Transport and ITB Physics

International collaborative experiments were proposed by ITPA and coordinated through IEA IAs. In the experiments on hybrid scenario, duration of high beta sustainment has been extended in JT-60U; □$_N$ = 2.5 (a figure of merit for fusion performance G = □$_N$ H_{89}/q_{95}^2 = 0.4-0.5) was maintained for 15.5 s (~9.5□$_R$; □$_R$ is the current diffusion time), and □$_N$ = 2.3 for 22.3 s (~13.1□$_R$). In DIII-D experiments with collaboration with JT-60U, □$_N$ = 2.6 (G = 0.58) was maintained for 9.5 s (~9.2□$_R$). The effect of NTM on the current diffusion was investigated in DIII-D by NTM suppression with ECCD. In the experiments on steady-state scenario, a weak shear q profile with q_{min} ~ 1.5, q_{95} ~ 4.5, f_{BS} ~ 43-50% and □$_N$ of 2.4 was successfully maintained for 5.8 s (2.8□$_R$) under nearly full non-inductive current drive condition (f_{CD} >90%) in JT-60U. In DIII-D experiments on QH-mode with collaboration with JT-60U, the operating space was significantly expanded to higher density by using higher elongation plasmas, and the effects of squareness of plasma shape was investigated. In the experiments on spontaneous (no external momentum input) rotation, change of toroidal rotation to the co-direction was observed in the central region of L-mode discharge during ECH in JT-60U, while a hollow rotation profile was observed during ECH in DIII-D H-mode discharges.

There was one US to EU personnel exchange outside ITPA coordinated international collaborative experiments in this task. Dr. W. Houlberg visited JET for the transport modeling of JET trace tritium experiments. The diffusion and convection velocity were close to neoclassical values for high density plasmas, while a higher level of anomalous transport was found in lower density H-mode regimes

Task 2: Confinement, database and modelling

CDB-2	□ confinement scaling in ELMy H-modes: □ degradation
TG: Conf DB & Mod.	Spokesperson: C.C. Petty

Background - Previous results

Joint experiments in 2003 between JET and DIII-D measured the beta scaling of energy confinement in similar ELMy H-mode plasmas. For both devices, the beta scaling was found to be weak, possibly non-existent, regardless of the kind of ELMs (Type I or Type III). This result is in disagreement with the IPB98(y,2) scaling, but in agreement with electrostatic confinement scaling. In 2004, experiments on JT-60U in high beta-poloidal discharges measured a square-root beta degradation of energy confinement in H-mode plasmas. This result is intermediate between the JET/DIII-D result and the prediction of the IPB98(y,2) relation. Recently AUG did a database search to verify that a factor of 2 scan in beta is possible on that device. In addition to the experimental studies, a reanalysis of the H-mode database by Cordey, et al., showed that a weak beta scaling of energy confinement can be obtained from regression analysis using the error in variables technique.

Device	Period	Local Key Person
JET		D.C. McDonald
DIII-D		C.C. Petty
JT-60U		T. Takizuka
AUG		F. Ryter
MAST		M.Valovic
NSTX		S.Kaye
TS		G.T.Hoang

Outline of Experiment

JET: Drift wave theory of turbulent transport predicts that electromagnetic effects should become important as the ideal ballooning stability limit is approached, leading to a strong, unfavourable beta scaling of energy confinement in this regime. JET proposes in 2005 to look for this effect by extending their study to β_N>2.5 using the Hybrid mode.

AUG: Proposes in 2005 to measure the beta scaling of confinement in the same regime as JET and DIII-D if the existing data do not provide the required data.

JT-60U: Will complete analysis of 2004 experiments

DIII-D: No proposed experiments in 2005.

MAST: Propose to complete a 2 point β scans.

NSTX: Propose to do a β scan in 2005

Tore Supra: Propose to do an L-mode β scan in 2005.

Status April 05

JET: experiments planned for late 2005 or early 2006

AUG: experiments postponed to 2006

NSTX: experiments planned for 2005 if operation at higher field is allowed

JT-60U: Experiments done, no new experiments in 2005, analysis continuing

MAST: TBD

TS: TBD

CDB-4	Confinement scaling in ELMy H-modes: □* scans at fixed n/n_G
TG: Conf DB & Mod.	Spokesperson: J. Snipes

Background - Previous results

Recently C. Petty published a comparison of data from DIII-D and JET which indicated that □* governed transport rather than n/n_G. This favours applying the principle of scale invariance to ITER confinement predictions whereas the ITER projections to date have been based on scaling with n/n_G. Joint experiment between JET and C-Mod. JET began work in Jan. 2004 with a discharge to be used for a JET/C-Mod identity comparison. C-Mod is considering these experiments for their 2005 campaign, and further follow up experiments may be required on JET.

Device	Period	Local Key Person
JET		J.G. Cordey
DIII-D		C.C. Petty
C-Mod		J. Snipes
AUG		J. Stober

Outline of Experiment

Determine □* scaling with the two tokamaks that can achieve the widest range in □*, JET and C-Mod and study the issue of whether □* or n/n_G is the relevant scaling parameter. □* scans will be completed on JET and C-Mod starting from a JET/C-Mod identity discharge pair. The scans would be continued until the Greenwald fraction reached that of the identity discharge of the other device. This involves decreasing □* from the identity discharge on JET and increasing □* from the identity discharge on C-Mod. If these experiments are successful then AUG and DIII-D could produce the midrange matches.

Status April 2005

A suitable C-Mod discharge (1001018013) has been compared to a number of C-Mod/JET identity discharges in JET and good matches to □* and n/n_G were obtained. These comparisons indicate that □* provides the best match. To obtain conclusive results, C-Mod intends to do a □* scan with the JET shape and MP392 was approved for these experiments. If the proper machine conditions are reached, the experiment should be run before July 2005. EPS paper on these experiments submitted by JET and C-Mod. Both DIII-D and AUG experiments possibly in 2006.

CDB-6	Improving the condition of Global DBs: Low A
TG: Conf DB & Mod.	Spokesperson: S.Kaye

Background - Previous results

Initial experiments have been performed on NSTX and MAST to establish low aspect ratio confinement scalings and to connect to conventional aspect ratio tokamak data in the ITPA database. Results of NSTX experiments indicate that the parametric dependences with respect to current and power are consistent with those observed at conventional aspect ratio, although confinement enhancement values can be high and the confinement exhibits a stronger toroidal field dependence than is observed at conventional aspect ratio. Analysis of the MAST data with respect to the conventional aspect ratio data in the ITPA database confirmed the aspect ratio scaling previously derived from only the high and conventional aspect ratio data. The analysis in dimensionless variables shows a strong interplay between beta and aspect ratio scalings introduced by MAST. The MAST data show a correlation between confinement enhancement and reduction of collisionality. The data that have already been contributed to the ITPA database have extended the range of inverse aspect ratio in the database by a factor of 2.2 (up to values of 0.7), and have also extended the range of beta by a factor of 5 (up to values of approximately 20%).

Device	Period	Local Key Person
NSTX	2005	S. Kaye/E. Synakowski
MAST	2005	M Valovic/R. Akers
DIII-D	2005	C. Petty

Outline of Experiments

Identity experiments will be carried out between MAST and NSTX in order to establish parametric confinement scalings at low aspect ratio. The experiments will be performed using both engineering and dimensionless variables. Of particular importance is to establish the scaling of confinement with both toroidal beta and collisionality in L and H-mode discharges. NSTX and MAST operate at comparable engineering parameters (it is expected that MAST will have increased beam powers, up to 5 MW, in 2005).

The *scaling of confinement with aspect ratio* will be investigated by joint experiments with DIII-D. It is proposed to perform a dimensionless parameter scaling experiment between DIII-D and NSTX, matching all dimensionless parameters except aspect ratio (match poloidal rather than toroidal dimensionless parameters such as beta). DIII-D will match an existing NSTX discharge in order to determine the aspect ratio scaling. Both devices will then individually perform a rho-star scan to determine scaling with toroidal rho-star. MAST is planning also to participate in this experiment. A separate MAST-DIII-D aspect ratio scaling experiment, in which ρ^*, ν^* and *toroidal* beta are matched, has also been proposed. It is planned to begin this study in 2005.

Status April 2005

Experiment has been performed recently on DIII-D. Reasonably good discharge matches in plasma shape and poloidal dimensionless parameters to NSTX/MAST were obtained in H-mode discharges. It is expected that a further iteration will be needed in NSTX and MAST to obtain the best possible matches. DIII-D also performed a □* scan to match □* in NSTX and a □* scan to allow confinement results at fixed poloidal parameters to be extrapolated to a comparison at fixed toroidal parameters. Transport analysis of the DIII-D discharges is expected to be completed by the next ITPA meeting in the fall. MAST/NSTX comparison will be performed in 2005.

CDB-8	Title: rho* scaling along an ITER relevant path at both high and low beta
TG: Conf DB & Mod.	Spokesperson: D.C. McDonald

Background - Previous results

The dimensionless gyroradius (□*) is the only parameter needs to vary from present day tokamaks to ITER. The energy confinement time is strongly dependent on □*; confinement scaling relations imply $B\tau_E$ ~ □*$^{-2.7}$ while perfect gyro-Bohm scaling is $B\tau_E$ ~ □*$^{-3}$. Dedicated experiments in H-mode plasmas on JET, JT-60U, ASDEX-Upgrade, DIII-D and Alcator C-Mod generally support gyro-Bohm scaling of transport, but owing to the small □* scan possible in an individual machine (factor of 1.6) the uncertainty in the □* scaling ITER is large. The plan is to combine □* scans from different machines to form a continuous path to an ITER target discharge having the same shape, □, collisionality and safety factor. The large range in □* from C-Mod to JET (~5) will then enable the □* scaling to be accurately determined.

Device	Period	Local Key Person
JET		D.C. McDonald
DIII-D		C.C. Petty
C-Mod		M. Greenwald
AUG		A.Staebler

Outline of Experiment

A series of similarity □* scans will be performed on several machines with matched, ITER relevant, □$_N$, □*, plasma shape and safety factor. As well as the baseline □$_N$=1.8 ELMy H-mode, a higher □$_N$ =2.5 value will be attempted using the hybrid mode. Although the precise configuration has not yet been agreed between the four devices it is expected that a high shape C-Mod like scenario will be used.

Status April 2005

AUG: No experiment planned for 2005, will be considered for 2006
JET: Experiments planned for late 2005 or early 2006
DIII-D: Experiments will be considered for 2006 campaign
C-Mod: Experiments planned for 2005
NSTX would like to participate (S.Kaye). Experiments to be performed preferably in 2005 than after

Task 3: MHD, Disruptions and Control

MHD physics tasks proposed by the ITPA and implemented under the IEA LTA have been conducted in a range of areas.

Resistive Wall Modes: Experiments were conducted between DIII-D and JET with matched plasmas (shape, q and pressure profile) to measure resonant field amplification (RFA) from externally applied error fields. When geometric differences are taken into account there seems to be relatively good agreement. This work was presented at the 2004 EPS and APS conferences.

Low β error fields: A non-dimensional error field scaling experiment has been completed on Alcator C-MOD, DIII-D and JET, with identity matched plasmas and a good match of the error field spectra. The error field thresholds on C-MOD and JET agree rather well, while DIII-D has a somewhat larger threshold. The origin of this discrepancy is under investigation. This work was presented at the 2004 IAEA and APS conferences. Studies are also on-going to resolve the influence of aspect ratio on the error field threshold using MAST and NSTX data.

NTM physics and error fields at high β: Cross-machine experiments have been completed on JET, DIII-D and ASDEX Upgrade, to study the critical β below which the 2/1 and 3/2 NTM are unconditionally stable. Results were presented at the 2004 EPS and IAEA conferences. A further influence on 2/1 NTM thresholds originates from error fields. On JET and DIII-D, deliberately applied error fields lowered 2/1 NTM β_N thresholds significantly. Data from DIII-D (subsequently supplemented by data from ASDEX Upgrade, JT-60U and JET) was used to predict the coefficients in the modified Rutherford equation, which are needed for predictions of ECCD feedback power in ITER. The results show that the proposed 20MW ITER system is adequate to substantially control the 2/1 NTM and that precise alignment and modulation would leave sufficient power for 3/2 NTM control too. Equivalent fitting for JT-60U alone gives a somewhat higher estimated power for 3/2 and 2/1 NTM stabilisation in ITER, but this can be reduced to 12MW by optimisation of the injection angle. Extended ECCD feedback of 2/1 NTMs has recently been successfully demonstrated on DIII-D. Also NTMs have been suppressed, at high β_N (~3), by early ECCD injection in JT-60U.

Disruption Mitigation: Recent DIII-D experiments used a directed jet, which has the advantage of being aimed more at the plasma centre. It is found that an instability appears to be involved in transporting the ionized impurities to the centre and/or heat from the centre towards the edge. In ASDEX Upgrade, disruption mitigation by gas injection is developed to the point of being used for machine protection. Reduced runaway signatures using mixed-species gas injection was observed in JT-60U, with Kr showing the best performance. This work was reported at the 2004 IAEA conference. Experiments on TEXTOR have shown pre-existing runaway electrons are suppressed within 0.5ms of the fast gas valve activation.

With regard to future plans from June 2005 to May 2006, it is expected that joint experiments on Disruption Mitigation, Neoclassical Tearing Modes, Resistive Wall Modes and Error Fields will continue, together with the related personnel exchanges.

Task 4: Edge and Pedestal Physics

Coordinated experimental activities/exchange of personnel took place during the period June 2004 - May 2005 in the following ITPA pedestal and edge topics:

PEP 1 & 3: JET/JT-60U pedestal identity experiments and modelling;
PEP 12: Comparison between C-MOD EDA and JFT-2M HRS regimes;
PEP 13: Comparison of small ELM regimes in JT-60U, ASDEX Upgrade and JET; and
PEP 14: QH/QDB comparison in JT-60U and DIII-D.

PEP1 & 3 (September 2004): New experiments in JT-60U with the JET identity shape were carried out. The scope was to understand the mechanism for the improvement of pedestal performance and change of ELM characteristics observed when perpendicular Positive-NBI was replaced by tangential Negative-NBI, in particular regarding the role of rotation and ripple loss on the pedestal and ELMs. Due to non-optimal wall conditioning, only marginal H-modes were obtained, without clear Type I ELM phases. Never-the-less, the general results of the previous experiments were confirmed, although the aim of producing data to distinguish the effect of rotation and ripple losses on pedestal parameters was not achieved. A. Loarte, G. Saibene and J. Lonnroth participated to the experiments. J. Lonnroth also carried out numerical modelling of the pedestal identity plasmas, as well as initiating collaboration between JET and JT-60U for ripple loss analysis using JAERI expertise and the OFMC code. The numerical modelling reinforced the earlier understanding that the differences in pedestal performance between JET and JT-60U is apparently not explained by differences in MHD stability (rotation effects), whereas large ripple losses of thermal ions in JT-60U seem to play a major role. These results indicate that a ripple experiment in JET, in collaboration with the JT-60U team, could provide unique information on pedestal physics and ELM control.

PEP 12: On both C-MOD and JFT-2M, boronization has been found operationally to be necessary for steady EDA or HRS regimes. However, the corresponding physics reason is not well understood, since both experiments use this conditioning technique routinely. This may be important for small ELM regimes on ITER. During the recent opening, C-MOD cleaned the boron coating from its metal plasma-facing surfaces and removed boron nitride components. H-mode experiments with the JFT-2M shape have been repeated, with on-site participation by K. Kamiya and N. Oyama of JAERI. As expected, the global character of the discharge was different, and a steady EDA regime was not achieved, although some quasi-coherent modes were seen. Comparison of pedestal parameters with

2004 experiments is ongoing. Further post-boronization experiments are planned later in the current C-MOD campaign to complete this inter-machine activity.

PEP 13: Collaborative experiments between JT-60U and ASDEX-Upgrade were carried out in June 2004. Part of the experiment was aimed at the verification in ASDEX Upgrade of the □ scaling of pedestal width found in JT-60U. Data analysis is not yet complete, but first indication is that pedestal widths in ASDEX Upgrade do not follow a □ scaling. High $□_p$ H-mode plasmas were also established in ASDEX Upgrade, to investigate the JT-60U grassy ELM regime. Small ELMs at high pedestal pressure were obtained in ASDEX Upgrade by operating at high q_{95} (~6), high □ □0.4) and high $□_p$ (1.8-2.0), following the JT-60U recipe. However, these small ELMs were obtained only when operating in a QDN shape. In SN, Type I ELM activity persisted, although sparse. External participants in the experiments were N. Oyama (JAERI), and A. Loarte and G. Saibene (EFDA, for the small ELM experiments).

PEP 14: The aim of these experiments was to compare the pedestal parameters by matching the plasma shape of JT-60U and DIII-D QH-modes. The experiments took place in January 2005 in DIII-D, with the participation of the JT-60U scientists Y. Sakamoto and H. Urano. Based on scans of squareness and triangularity, responses of the QH-mode on the plasma shape were studied. The detailed data analysis is in progress.

Task 5: SOL and Divertor Physics

Some of the particularly active SOL and divertor physics tasks proposed by the ITPA and implemented under the IEA LTA agreement are described. DSOL Task No. 7 (Study on separatrix density and edge density profiles): one of the most important tasks of this topical group is projecting the ITER SOL power width and separatrix density from existing machines - an ongoing activity whose latest update has been published in the Proceedings of the 16th PSI Conference "Multi-machine comparisons of H-mode separatrix densities and edge profile behavior in the ITPA SOL and Divertor Physics Topical Group", A. Kallenbach (AUG), with 6 co-authors contributing data from JT-60U, MAST, JET, DIII-D and C-MOD, J Nucl Mater 337-339 (2005) 381. This new data base exploits the general availability of main-SOL n_e and T_e radial profiles from Thomson scattering (power width λ_q ~ 2/7 λ_{Te}, assuming parallel power transport is largely due to electron heat conduction). This new database, in contrast with earlier ones, finds a quite simple scaling relation, specifically λ_{Te} ~ 0.003R, with only weak dependencies on other parameters such as density and field. This projects to λ_{Te} ~20 mm and λ_q ~6 mm for ITER. The separatrix density is also found to follow rather simple scaling: $n_{e.ped}/n_{e,sep}$ decreases from ~3 to ~1 as $n_{e,sep}/n_{Greenwld}$ is raised from 0.1 to 0.6; this curve falls slightly below the previously projected ITER operating point. This important database will continue to evolve along with the process of identifying all the controlling parameters of the edge – as needed to improve projections to ITER.

Tritium retention by co-deposition with carbon is a serious issue for ITER. O_2-baking is a potential solution; it may be able to recover tritium from all types and locations of co-deposit within the vessel. A new DSOL Task No. 12 (Oxygen wall cleaning) has been undertaken, initiated by the encouraging results of the accidental air-bakes on JET over past years, which occur when loss of vacuum can allow air to enter the heated vessel: plasma operation has been quickly recovered and no long term damage has been found. The JET findings lead to dedicated O_2-bake experiments on TEXTOR, 1999/continuing, on HT-7, 2004/continuing, and on DIII-D, initially with *ex situ* O_2-

baking of removed tiles – ones on which measured ^{13}C co-deposits have been formed under controlled and measured plasma conditions. The latter ^{13}C-tracer studies were also initiated through collaboration with JET and TEXTOR. JET tiles, loaded with measured ^{13}C co-deposits, will also be assessed and compared using the same *ex situ* O_2-baking analysis (Toronto). These *ex situ* data will be used to optimize *in situ* tests.

Recently discovered fast parallel flow was unsuspected, particularly at locations far from the divertor. A theoretical explanation is still sought. Such fast flow has major implications for co-deposition tritium retention and presumably also for impurity screening and power transport. Under DSOL Tasks No. 6 (Parallel transport in the SOL) and No. 9 (^{13}C injection to understand C migration) a database is being assembled on parallel flows based on data from Mach probes (JET, JT-60U, C-MOD, AUG and DIII-D), on plume shapes from impurity injection (DIII-D, C-MOD) and on ^{13}C deposition patterns (DIII-D, JET, TEXTOR, AUG).

Task 6: Steady State Operation

International collaborative experiments coordinated through IEA IAs have made significant progress and expanded multi-machine data sets for further analysis in view of steady state operation development. It should be noted that in this period no experiment had been carried out because of machine shutdown.

Preparation of ITER steady-state scenario; On JT-60U, study of ITER steady-state operation relevant discharges, which have a weak shear q profile, has been carried out in a framework of IEA/ITPA joint experiments (SSOEP-1). A nearly full non-inductive current drive state with a large fraction of bootstrap current (f_{BS} ~ 45%) with q_{min} ~ 1.5 was sustained for 5.8 s in a high $\square_p$ plasma without any neo-classical tearing mode.

Preparation of ITER hybrid scenario; For the development of hybrid scenario demonstration discharges, which have a flat q profile with q_{min}>~1, sustainment of $\square_N$ = 2.3 for 22.3 s with such a q profile was successfully demonstrated on JT-60U in a framework of IEA/ITPA joint experiments (SSOEP-2). In the discharge a figure of merit for fusion performance ($\square_N \cdot H_{89p}/q_{95}^2$) maintained > 0.4. On DIII-D development of the hybrid operation relevant plasmas in collaboration with JET, sustainment of high performance ($\square_N$ = 2.8, $\square_N \cdot H_{89p}/q_{95}^2$ ~ 0.6) for 9.5 s was obtained at q_{95} = 3.2. Even at higher q95 = 4.4, which is more suitable for the hybrid scenario, sustainment of $\square_N$ = 2.7 and $\square_N \cdot H_{89p}/q_{95}^2$ ~ 0.4 is demonstrated for ~5 s.

As for the future plan from June 2005 to May 2006, the research on steady state operation will be continued. The ITPA "SSO" TG is proposing researches on the ITER steady state relevant plasmas and hybrid operation relevant ones in more depth.

Task 7: Tritium and Remote Handling

De-tritiation of plasma facing component: Laser de-tritiation via layer ablation is a very promising technique for in-situ de-tritiation, since ablation of 50µm of deposited layer was obtained in laboratory studies using a 20W (2J/cm^2) 1052nm high frequency laser on samples originating in TEXTOR. In 2004, a surface of 10x10mm^2 was automatically ablated at 0.2m^2/hour, without damaging the graphite substrate. Extrapolation of these results to 100W power laser leads to a

removal efficiency of $1m^2$/hour for a 50μm co-deposited layer in air. Based on the above-mentioned experimental results, an optimised system is under design and will be constructed by the end of 2005 for in-vessel de-tritiation by laser ablation using Remote Handling capabilities. This new system will be ready at the beginning of 2006 for tests on JET tritiated tiles in the JET beryllium handling facility.
Tritium concentration in the near-surface region of a TFTR D-T tile was measured by BIXS (β-ray-induced X-ray spectrometry) at JAERI TPL. The results showed that the maximum tritium concentration appeared at the depth of a few microns from the surface. This agreed well with that obtained previously by Eximer laser ablation.

Trials of flash lamp photonic cleaning have been conducted in 2004-2005 both inside the JET vessel and in the JET Beryllium Handling Facility using inner divertor and outboard poloidal limiter tiles. The results demonstrated clear co-deposit removal, and appear to confirm the $2.5J/cm^2$ cleaning threshold observed in laboratory studies. First rough estimates show that the removal rate is between $2.5\text{-}10m^2$/hr for a 10□m thick co-deposit using a single flash-lamp at 250J per pulse. In the absence of co-deposit removal, de-tritiation via heating appeared to be limited to only the surface <1□m layers due to the short pulse length of the flash-lamp discharge.

Exhaust gas from the JT-60 tokamak was analyzed to understand the behavior of fuel and impurity elements in the vacuum vessel. In the tokamak discharge, various hydrocarbons such as CD_4, C_2D_6, C_2D_4 and C_2D_2 were detected and possible relation with formation of codeposit is suggested. Introduction of 0.1% oxygen with Helium into the vessel and glow discharge cleaning with it was found to enhance the carbon removal. No effect of oxygen onto tokamak discharge was observed.

Diagnostics studies: Optical fibres offer an attractive practical solution to transport light through the complicated geometry surrounding a fusion reactor. However, they can suffer from serious radiation-induced optical absorption and radio-luminescence. Special fabrication and glass hardening techniques must be used to deploy suitable radiation-resistance fibre in tokamak ITER-like machine. Studies have been undertaken at JET to demonstrate the feasibility of using optical fibres in diagnostics systems during reactor operation and, in particular, the possibility of using large diameter fibres, i.e. with a core diameter of 600μm, acrylate coating and suitable hydrogen treatment to enhance radiation tolerance. As a result, a small but detectable loss in optical transmission (6% at maximum) was observed. When the radiation activity decreases, the fibre recovers totally its transmission capabilities, suggesting that no permanent damage has taken place. Direct measurements carried out in luminescence mode revealed the presence of radio-luminescence during the plasma pulse. Consequently, an increase of the optical transmission following the shape of the pulse is observed in all the pulse. However, no correlation was found between the radiation conditions and the luminescence intensity. This probably results from the non-uniformity of the irradiation conditions.

Cryopanel studies: The design of the ITER high vacuum system is based on a number of supercritical helium cooled cryosorption pumps providing a high pumping speed and capacity, and fast on-line regeneration. To pump helium, which cannot be condensed at the 5°K cooling conditions available, and to help hydrogen pumping, the pumping cryopanels (PCP) are coated with activated charcoal granules. This new PCP was first operated during the JET Trace Tritium Campaign of Autumn 2003, pumping gas from the torus and neutral beam injectors. PCP worked well according to the design specifications. Pumping efficiency is very high (estimated for D_2 to 23mbar-l/cm^2) leading to a high gas amount pumped: 140bar-l of D_2 in 245litres of PCP volume. Several tests with pre-defined gas feed from external supply in agreement with the ITER gas exhaust tritium concentration have also been performed. These tests have shown that the pumping mechanism for tritium is condensation. Tests will continue in 2005 in order to better characterise the competing behaviour between tritium and helium. In 2006, PCP will be dismantled and analysed to determine the tritium levels in the cryopanels. Specific de-tritiation methods will be also developed.

Surfece alalysis of plasma facing component: Tritium and deuterium distribution in the plasma facing material has been investigated in JT-60U in collaboration with Japanese universities. Deuterium concentrations and depth profiles in graphite tiles used in the divertor were investigated by nuclear reaction analysis (NRA) with a deuterium accelerator of Fusion Neutronics Source (JAERI-FNS). The highest deuterium concentration of $D/^{12}C$ of 0.053 was found in the outer dome wing tile, which is much less than those observed in other tokamaks.
Two reports of the JT-60U carbon dust analysis were presented at the 16th International conference on PSI (Portland Maine, USA, 2004), which had been collected and analysed in collaboration with INEEL in 2003.

Task 8: Others

The A key activity in this category was the successful completion of workshop W61 titled “Heating and Control for Long Pulse Operation in Large Tokamaks”. As the name implies, the workshop focused on the main technical challenges for developing reliable heating and control systems tokamaks. Significant technical progress was report from all three parties; Japan, US and the EU. From JT-60U, a major accomplishment was the operation of a gyrotron for 16 s at 0.4 MW by controlling the anode voltage through the discharge. The US reported on developments in the prototype of the "JET ITER-like antenna" and the Alcator C-MOD LHCD antenna. The EU participants reported that enhancements on JET have produced the following long pulse performance figures: 12MW-20s NBI, 8MW-20s ICRF, 3MW-20s LHCD. In 2005 a new ITER-like, ELM tolerant antenna will be installed.

Dr. Larry Grisham (PPPL) has for many years maintained a collaboration with the JT-60U tokamak in Naka, Japan to understand the physical processes which limited the performance of the first generation of high power negative ion neutral beam systems, and to use this knowledge to improve the performance of these systems, while enhancing the performance and reliability of future generations of neutral beam systems for such devices as ITER. During the past year, the JT-60U negative ion neutral beam system injected into the machine many shots of about 1.5 megawatts at about 356 keV with a duration of 10 – 20 second, and one pulse of variable power lasting 25 seconds. This marked a major extension of the pulse length capability, which in the early years was only a fraction of a second. This improvement was a result of many improvements suggested by both parties over the years, including recent changes to the cathode operation and grid extraction area.

A general problem for steady state tokamak research is the high heat loads that must be endured by plasma facing components. Dr. M.Seki visited JET to discuss the generic issue of excessive heat loads on LHCD launchers with Drs. Alan Kaye, Mark Nigtingale and Joelle Mailloux. Specific points of discussion related to the PAM launcher design for JET, which can be effectively cooled, and the newly developed LHCD launcher with eight 12-divided multi-junction modules made of carbon materials for JT-60U. Dr. M.Seki proposed that an arc monitor on JET would be helpful to protect the launcher from sudden heat loads due to RF break down.

Appendix A2

The Status and Plans of Three Parties

<EFDA-JET>

The last year has seen extension of JET's scientific capabilities, preparation of JET's Experimental Campaigns for late 2005/early 2006, continuation of JET's Fusion Technology activities, and establishment of a longer term perspective (2007-2010) for JET to further develop operating scenarios in conditions closest to ITER and to optimise ITER auxiliaries.

A new divertor target for high power, high triangularity operation and 14 new/upgraded diagnostics/systems (including 4 with significant US involvement) have been installed during the shutdown which is due to finish in July 2005 with closure of the vacuum vessel. Following a period of restart and high-level commissioning, the experimental campaigns of late 2005/early 2006 will concentrate on bringing the new systems to full performance, critical issues for ITER, preparation of ITER operating scenarios, and specific physics issues for ITER. A programme based on the 372 proposals for experiments and modelling received (49 of which involve international collaborators) and 80 two-shift experiment days has been prepared. If necessary, this will be revised before the beginning of the Campaigns in November 2005, following a review of the ITER-like ICRH antenna project (7MW power capability and ELM-resilient coupling; High Power Prototype support tests being conducted at ORNL) which is scheduled for installation in Spring 2006.

While the present EFDA-related agreements extend up to the end of 2006, a longer-term JET programme, which includes major enhancements of high scientific value and strategic importance, has also been developed vigorously over the last year. Two major strategic goals have been identified: the test of a tungsten divertor with a beryllium wall and the development of ITER scenarios. A project aimed at installing on JET an ITER-like combination of first wall and divertor materials has been approved. All first wall materials components in contact with the plasma will be replaced by beryllium tiles, whilst tungsten will be used in the divertor. Installation is planned for a year-long shutdown in 2008. The aim is to address a number of critical issues in preparation of ITER operation, which include the minimisation of T-retention, material erosion and migration, mixed materials effects, melt layer behaviour, impurity control etc. A most important goal is the development of operational scenarios fully compatible with a Be/W material mix, thereby offering a serious alternative to the use of carbon in ITER. A second major project which has been approved is an increase of the neutral beam heating power to 35MW for 20s. This will allow plasma scenarios to be developed in the relevant range of parameters (high current, high beta) at high densities. A high frequency pellet injector will allow ELM-pacing, as developed successfully on ASDEX Upgrade. A programme of machine refurbishments has also been launched, and a package of upgraded and new diagnostics is being finalised. Further enhancements (LHCD PAM, power supply upgrade, and ergodisation coils) are also being studied, with a view to their possible implementation. Finally, the exploitation of JET during the period up to 2010 is foreseen within the Seventh Framework Programme proposal of the European Commission.

Also during the last year, Poland and Slovenia became parties to the EFDA Agreements, collaborations with Japan and the US concentrated on ITPA ITER high priority coordinated experiments conducted through IEA Implementing Agreements, and collaborations with the Russian Federation and the People's Republic of China continued. VIP visits to JET included the Portuguese Secretary of State for Science and Innovation, the new European Commissioner for Science and Research, the Chinese Ambassador, the Brazilian Ambassador, the President of the National Commission for Nuclear Energy of Brazil, and the President of the European Physical Society.

Sixty-eight JET FT tasks have been launched since 2000, concentrating recently on de-tritiation of plasma facing components, feasibility of using optical fibres in diagnostics systems under fusion reactor conditions, and pumping cryopanels (PCP) coated with active charcoal granules to allow both helium and tritium pumping. For 2006, JET FT will continue to focus on issues relevant to ITER licensing.

<JT-60>

1) Facility status: Due to the trouble of motor generator for plasma heating (H-MG) on February 2004, energy to heating and current drive system was provided from motor generator for toroidal field (T-MG). This forces us to reduce toroidal field less than 3.2T from 4T since energy was supplied from line grid only. So the 2004 JT-60 run was done with reduced toroidal field capability. The H-MG was repaired and tested in March 2005. So the full toroidal field will be available for 2005-2006 experimental campaign. After the 2004 operations completed in November, JT-60 team is making effort to reduce toroidal filed ripple by the insertion of ferritic steel in May-July. Operation will be resumed in November, 2005.

2) Experiments: Since 19th Ex-Co meeting, JT-60 operates 6 weeks of conditioning operation and 8 weeks of experiments from July to November 2004. Key subjects of the experimental campaign are stationary sustainment of high β_N plasma, high beta full non-inductive current drive, long sustainment of high bootstrap current fraction discharges, long pulse high recycling H-mode, high density RS and high βp plasma, density limit, ITB with electron heating, transient heat transport, burning plasma simulation experiment, runaway electron control, current hole, CS less operation, ELM and pedestal, NTM stabilization with ECCD, real time control of q profile, and SOL plasma fluctuation studies. Most of these experimental results were reported in 20th IAEA Fusion Energy Conference at Vilamoura.

Among these, long sustainment of ITER relevant high β_N (=2.3) up to 22.3s (~13τ_R), demonstration of steady J profile at β_N=2.5 for 15.5s, confirmation of saturated wall with 30s discharge, progress of understanding current hole, investigation of QH mode, significant difference with JET in hydrogen retention in the divertor tile are particularly interesting.

3) Joint Experiments: As for the ITPA/IEA joint experiments, we had 5 visitor from JET for PEP1+3, sent 2 scientists to DIII-D for TP-5&PEP14, 1 scientist to AUG for PEP-13, 2 scientists to C-MOD for PEP-12.

4) National Research Collaboration: Number of national collaborators was 163 in 2004 from 24 Universities and Institutes and becomes 170 in 2005. Number of papers published by collaborators was 37 in FY2004. For a new experimental period of 2005-2006, we have modified our structure of theme close to the ITPA topical areas.

5) NCT Program: Design study of JT-60U modification to a superconducting device is progressing with national discussion and international workshop (W59). Basic configuration was fixed in FY2004 to allow wide range of plasma shaping (kappa, delta and aspect ratio). We will start detailed design study from FY2005.

6) Theory and Simulation: Supercomputer system of JAERI was upgraded significantly from FY2005 whose peak performance, main memory and storage disk system are 13.1TFlops, 13TBites and 120TBites, respectively. This infrastructure will help to accelerate our plan to explore NEXT simulation based on first principle.

7) Management Items: The JAERI will be reorganized jointly with JNC as JAEA (Japan Atomic Energy Agency) from Oct. 1. Right and responsibility for IEA LT IA will be succeeded by JAEA. FY2004 and 2005 budget continued to be low to support only 2 cycles.

<U.S.>

DIII-D, C-MOD, and NSTX are the major U.S. participants in the IEA LT IA, as well as the U.S. collaborations on JET and JT-60U. In FY 2004 (ended on 9/30/04), the three facilities completed a high facility utilization factor, running for 18, 19, and 21 weeks, respectively. In FY 2005, this trend will continue with planned run weeks of 14/17/17 weeks, respectively. DIII-D completed its FY runs in mid April, thus achieving 33 weeks of experimental operations in a span of 13 months. In addition, theory support and computer simulations also make substantial contributions to the exchange programs.

The research emphasis in all three programs are optimization of toroidal concepts using high field in C-MOD and low aspect ratio in NSTX around the more conventional parameters of DIII-D. All three programs are extensively involved in IEA/ITPA joint experiments and they make major contributions to key physics issues relevant to burning plasmas and ITER physics. They are national programs with extensive collaborations from many universities and national laboratories.

The DIII-D Program Advisory Committee has identified the following outstanding achievements in DIII-D during the past year:

- Impressive progress on the development of an advanced Plasma Control System (PCS), including a new NTM control algorithm that maintains island and ECCD alignment through real-time q-profile reconstruction;

- Achievement of discharge regimes demonstrating parameters that when projected to ITER could result in 1) fusion powers as high as 700 MW with the possibility of ignition, 2) a fusion gain of Q ~ 10 for a flattop time of 3900 s and 3) steady-state operation with Q ~ 5;

- Feedback stabilization of RWM’s in low rotation plasmas with internal control coils and high-bandwidth amplifiers;

- A vigorous reentry into the area of fast-particle physics with elegant diagnostics that allow clear identification of internal Alfvén Eigenmodes including the observation and interpretation of the “sea of AE’s” in AT plasmas;

- Continued progress in the theoretical and experimental identification of mechanisms of anomalous transport, and mitigation, with improved diagnostics spanning the range $0.1 \leq k_{\perp}\rho_s \leq 10$ for density fluctuations;

- ELM suppression using n=3 resonant magnetic perturbations;

- First measurements of the edge current density with the Lithium beam, permitting more detailed assessment of MHD stability in the vicinity of the pedestal;

- Measurements of the migration of C13 showing the poloidal flow of hydrocarbons and deposition near the divertor strike-point;

- Installation of 3 MW of high-harmonic fast wave power at 60, 110 and 115 Mhz together with two new antennas and successful coupling of 2.7 MW for ~ 1 s into an L-mode plasma with measurable increase in neutron emission, an impressive accomplishment at this early stage of operation.

In C-MOD, achievements during the past year include the following:

- Turbulent transport and SOL flows as related to topology and implications to L-H transition, co-deposition and core rotation;
- Test of all-metal, high Z machine environment by removing boron coating and boron-nitride limiter guards, and initiating a trial of tungsten brush divertor;
- Achieving 6 MW ICRF heating, and extending ITB operation using two frequency ICRF to higher power;
- Successful use of PCI diagnostics to validate mode conversion physics
- target plasma at 8T, 2MA has been demonstrated for future experiments.

NSTX operated for 21 weeks in FY 2004, making progress in broad scientific front.

Most of the accomplishments were in the areas

- Expanded parameter space via improved control, shaping & operation
- High beta-tau discharges with high bootsrap fraction with wall stabilization of strongly rotating plasma;
- RWM measurements at substantially above no-wall limit;
- Fluctuation studies and investigation of electron transport
- Investigation of AE's driven by supra-Alfvenic ions,
- Ion heating by HHFW and measurement of EBW emission from plasmas.

The details of these and other accomplishments and program plans of the three facilities can be found in the three separate presentations on these programs.

U.S. ITER Project Office was started in July 2004, as a joint activity between PPPL and ORN, with Ned Sauthoff as the Manager. The USIPO has been extensively engaged in getting approval for ITER as a Project in the U.S. system, conducted extensive cost estimates and management plans for the proposed U.S. contributions to ITER, and participated in the ITER International team activities.

The U.S. fusion community is establishing a Burning Plasma Program that will accompany the ITER Project activities. The purpose of the BPP is to coordinate activities among related programs, focus on ITER needs and plan for physics experiments and technology tests on ITER , advocate for BPP and train new scientific staff for ITER in the future.

The President's budget for the OFES program increases from $273.9 M in FY 2005 to $290.6 M in FY 2006. $ 55.6 M of this budget is for ITER (an increase of $ 50.6 M from FY 05), thus resulting in substantial decrease in the core program. DIII-D would operate for only 5 weeks, C-MOD for 12 weeks, and no operations for NSTX if this budget is approved by the Congress.

Appendix A3

IEA Large Tokamak Cooperation

REPORT FORM to Secretariat (Workshop) (Form C)

Workshop Number: W58

SUBJECT: Third Joint Workshop on Large Tokamak, Poloidal Divertor and TEXTOR IA's "Implementation of the ITPA Coordinated Research Recommendations"

Date: 8-10 December 2004
Place: Eynsham Hall, Near Oxford, UK.

Name (s) of attendees: (All names of attendees are listed in the attachment.)

Brief description of the activities in the Workshop W58

The Workshop was the third in the series and was held jointly by the three tokamak-related IEA IA's and ITPA. While recognizing that the ITPA is the most effective international body in place for generating coordinated experiment plans across a wide range of fusion research topics, the Workshop aimed to stimulate and facilitate increased multi-machine Joint Experiments amongst the various tokamak programmes.

The Workshop was attended by 25 participants, including the Chairs and additional ExCom members of the three tokamak-related IEA IA's, the Chair and additional members of the ITPA Coordinating Committee, the Chairs (or their representatives) of the six ITPA TG's, and the Programme Leaders representing 19 major world tokamaks (JET, JT-60U, DIII-D, ASDEX Upgrade, FTU, MAST, TCV, TEXTOR, Tore Supra, C-MOD, NSTX, JFT-2M, TRIAM-1M, CSTN, and the Russian tokamaks (T-10, T-11M, Globus-M, Tuman-3M, FT-2)). The representative of the Chinese tokamak programme (HL2A, HT-7) was unable to attend the Workshop, but subsequently submitted input.

Specifically, the Workshop:

- reviewed the status of implementation of the ITPA/IEA coordinated experiments among the major world tokamaks;
- discussed new proposals made by the ITPA and which would benefit from coordination of joint experiments among the major world tokamaks; and
- considered the implementation of these proposals on the major world tokamaks and through agreements such as the three tokamak-related IEA IA's.

Written documentation included a Report from the last Workshop (M. Kikuchi), a Report from the ITPA for Joint Experiments between the various tokamaks from 2004 (R. Stambaugh), and a Proposal from the ITPA for Joint Experiments between the various tokamaks for 2005 (R. Stambaugh). The ITPA Coordinating Committee Chair (R. Stambaugh) reviewed the status of the implementation of the Joint Experiments and summarised the new Joint Experiments proposed by the six ITPA TG's. The Programme Leaders then indicated their level of commitment to the new Joint Experiments. In addition, the Operation plans of the various Facilities were collated and presented by O. Gruber on behalf of the Programme Leaders.

The coordinated effort which resulted from this Workshop adds great value to the experiments on the individual Facilities, and will result in personnel and, possibly, some hardware exchanges. The commitments made by the various tokamak Programme Leaders were confirmed, and consolidated by R. Stambaugh, after the Workshop.

This report received by Secretariat on _ day mo __ y

No.

AGENDA

Wednesday 8 December 2004

15:30 Afternoon Tea — Court Tea Bar

16:00 Workshop begins — Harcourt Room

(Ch: J Pamela)

1. Opening Remarks — Jerome Pamela
2. Report from Last Workshop — Mitsuru Kikuchi
3. Status of Documentation — Ron Stambaugh

20:00 Dinner — Oak/Red Restaurant

Thursday 9 December 2004

07:30 Breakfast — Harcourt Suite

09:00 Workshop Resumes — Harcourt Room

(Ch: J Pamela)

ITPA/IEA Multi-Machine Experiments — Ron Stambaugh

1. Status of Implementation of Joint Experiments
2. ITPA Views on Implemented Joint Experiments

   Discussion

10:30 Coffee Break — Court Tea Bar

10:45 ITPA Proposals on Implementation of Joint Experiments — Ron Stambaugh

1. ITB and Transport — (Ch: M Kikuchi)
2. Confinement Database and Modelling
3. Steady State Operations and EP
4. Divertor and SOL
5. Edge Physics and Pedestal
6. MHD

   Overall discussion

12:30 Lunch — Oak/Red Restaurant

14:00 Break-out Session for Programme Leaders

1. To discuss Proposed List of Joint Experiments
2. To discuss other ITPA Experiments, if any
3. To enter their responses regarding implementation, identifying those which are, might be or are not included in their plans
4. To present Programme Schedules for 2005 (Organiser: O Gruber)

   JET, ASDEX Upgrade, FTU, MAST, TCV, TEXTOR, Tore Supra

   DIII-D, CMOD & NSTX

   JT-60, JFT-2M, TRIAM-1M, CSTN

   Russian Tokamaks (T-10, T-11M, Globus-M, Tuman-3M, FT-2)

AGENDA (continued)

Thursday 9 December 2004 (continued)

15:30	Coffee Break	Court Tea Bar
15:45	Break-out Session for Programme Leaders (continued)	
18:00	Presentation of Status of Draft Responses Chair: E Oktay	Ron Stambaugh
18:30	Workshop Adjourns	
19:30	Dinner	Oak/Red Restaurant

Friday 10 December 2004

07:30	Breakfast	Oak/Red Restaurant
09:00	Finalise Implementation of Joint Experiments 1. Status of Implementation of New Joint Experiments	Chair: U Samm Ron Stambaugh
10:30	Coffee Break	Court Tea Bar
10:45	Finalise Implementation of Joint Experiments (continued) 1. Status of Implementation of New Joint Experiments	Chair: U Samm Ron Stambaugh
11:30	Concluding Discussion	Mitsuru Kikuchi
12:15	Concluding Remarks and Close of Meeting	Jerome Pamela
12:30	Lunch	Oak/Red Restaurant

LIST OF PARTICIPANTS

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IEA Large Tokamak Cooperation

REPORT FORM to Secretariat (Workshop) (Form C)

Workshop Number: W59
SUBJECT: Shape and Aspect Ratio Optimizaton fro High Beta, Steady-State Tokamak
Date: 14 – 15 February, 2005
Place: General Atomics, San Diego, CA

NAME (S) OF ATTENDEES:			Party
	M. KIKUCHI	JAERI	(JT-60)
	X. Litaudon	EFDA-JET	(JET)
	T. Taylor	General Atomics	(US)
	Etc. See attached list		

Brief description of the activities in the Workshop

Steady-state operation with high beta and high bootstrap current fraction is required in future tokamak DEMO reactor. Many present tokamaks are addressing such operation for ITER and DEMO. Shape and aspect ratio is particularly important for achieving high beta and also for the optimization of edge stability and edge pedestal performance. Therefore, this workshop addressed shape and aspect ratio optimization of high beta steady state tokamak including DEMO concept, stability and CD assessment of such operation, and the design of future tokamak devices addressing such experiments. The workshop focused on tokamaks, including low aspect ratio.

The first set of talks discussed the systems design of DEMO, and steady-state next step devices with emphasis on connection between the plasma shape and aspect ratio on the mission and goals of the devices. These designs are progressing toward (a) improved economics, (b) steady-state (low re-circulating power), and (c) more compact (higher power density). The requirement for both high bootstrap fraction and high power density lead to a physics optimization with high normalized beta, which favors strong shaping. It was generally thought that the optimization in aspect ratio is rather broad owing to the loss of toroidal field strength at low aspect ratio.

A number of papers dealt with the dependence of stability limits on the plasma shape and aspect ratio. On the major issues there was general agreement, normalized beta increased with, increasing elongation, increasing triangularity, decreasing aspect ratio, and broader pressure profiles. At very high elongations the stability limit saturates (beta_n does not continue to increase with elongation), and the value of elongation at which saturation begins increases with higher triangularity.

Several papers presented operational physics issues that depend rather strongly on the plasma shape and operation at high beta. One of these is the size of the ELMs as the shape is varied, and the impact on the survivability of the divertor. The need for ELM mitigation techniques (ELM pace making with pellets, stochastic fields, etc.) was discussed as essential elements of the next step devices.

The last set of talks focused on control aspects of steady state plasmas. The discussions included precise plasma cross-section shape control; the difficulty of controlling the plasma current profile in steady state discharges; and the controllability of instabilities, such as the resistive wall mode, in high beta plasmas. The workshop ended with two very lively discussion periods.

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No.

ATTENDEES

IEA WORKSHOP 59, FEBRUARY 14-15, 2005 - GENERAL ATOMICS

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AGENDA

IEA Workshop 59
Shape and Aspect Ratio Optimization for
High Beta, Steady-State Tokamak

Conference Room 07/217

Time	Speaker	Topic
MON. FEB. 14		
08:00 – 08:30		Coffee
		Session Chair – John Ferron
08:30 – 08:45	T. Taylor	Welcome and Introduction
08:45 – 09:30	K. Tobita	Concept development of compact DEMO reactor
09:30 – 10:15	F. Najmabadi D. Meade	Optimization of a Steady-State Tokamak-Based Power Plant Optimization of a High-beta Steady-State Tokamak Burning Plasma Experiment Based on a High-Beta Steady-State Power Plant
10:15 – 10:30		Break
10:30 – 11:15	Y. Miura	Mission and Design Requirements on National Centralized Tokamak (NCT)
11:15 – 12:00	A. Field	MAST Spherical Tokamak Developments: towards high-beta, steady-state Tokamak operation
12:00 – 13:30		Lunch
		Session Chair – Yukitoshi Miura
13:30 – 14:15	J. Ferron	Optimized Beta Limits in DIII-D Advanced Tokamak Discharges: Global & Edge
14:15 – 15:00	F. Rimini	Advanced Tokamak regimes at JET: what are the changes

		when operating at high triangularity
15:00 – 15:15		Break
15:15 – 15:45	G. Kurita	Stability calculations on NCT
15:45 – 16:30	C. Petty J. Menard	Stability and Transport Implications for Shape and Aspect Ratio of Steady-State, High-Performance Tokamaks Ideal MHD Stability Scaling with Aspect Ratio, Shaping & q
16:30 – 17:00	X. Litaudon	Scientific rationale for the power upgrade on JET: towardsSS operation at high bootstrap
17:00 – 17:30	G. Saibene	High Beta_p experiments on JET and access to type II ELMs

TUES. FEB. 15		
08:00 – 08:15		Coffee
		Session Chair – Dave Humphreys
08:15 – 09:00	M. Matsukawa	Design study of NCT and its shape and aspect ratio controllability
09:00 – 09:30	S. Sabbagh	Aspect Ratio Considerations for Active RWM Control
09:30 – 10:00	A. Hubbard	Current profile control for high performance steady state tokamaks: Considerations from C-Mod LHCD program
10:00 – 10:30	D. Moreau	Plasma shape, profile and flux control for high-bootstrap steady-state tokamaks
10:30 – 10:45		Break
		Session Chair – Xavier Litaudon
10:45 – 11:15	D. Meade	Discussion --- Design considerations for next step and demo
11:15 – 12:00	Y. Miura	Discussion --- Stability, Transport, and Control

IEA Large Tokamak Cooperation

REPORT FORM to Secretariat (Workshop) (Form C)

Workshop Number: W61

SUBJECT: Satellite Workshop on "Heating and Control for Long Pulse Operation in Large Tokamaks"

Date: 23 Sept. 2004
Place: Giorgio Cini Foundation, Venice, Italy

			Party
Name (s) of attendees:	R. Callis	GA	(US)
	R. Felton	EFDA-JET	(JET)
	K. Kurihara	JAERI	(JT-60)

(All names of attendees are listed in the attachment.)

Brief description of the activities in the workshop W61

THE PURPOSE OF THE WORKSHOP IS TO REVIEW THE STATUS OF CONTROL AND HEATING SYSTEMS FOR LONG PULSE OPERATION IN THE MAJOR WORLD TOKAMAKS AND TO DISCUSS ON THEIR TECHNICAL ISSUES.

At first, the status and development of JT-60 power supplies, control, RF and NB systems for long pulse operation were presented by the participants from JA: For the power supplies and control systems, the major reconfigured points for 65-s long pulse discharge were reported that a new control function of the shot interval to avoid excessive heat load on the TF and PF coils, reduction of primary voltage applied to the PF-coil thyristor power supply from 18 kV to 11 kV, and a new integrator having a feature of low signal drift. For the ECH system, it was reported that a technique of anode voltage or heater control during a shot to keep the oscillation condition against the beam current decay has been established and 0.4MW, 16 sec by a gyrotron was attained. For the positive-ion-based NBI system, modifications of the power supply, control system and beam limiters were conducted. In negative ion NBI system, the modification of ion source, power supply, control system and beam limiters were conducted. In negative ion source, the grid heat load was reduced due to decreasing pressure in the accelerator and the pulse lengths of positive and negative NBI were extent up to 30 s and 25 s, respectively.

Second, the participants from US presented their research plans and developments: LHCD for Alcator C-mod is planned to develop and explore the potential of regimes with high fraction of bootstrap current and high confinement. A multi-element, 24 column waveguide array LH antenna for this experiment, which can launch 1.5 MW has been designed and tested. A high power load-tolerant prototype of the "JET ITER-like antenna" has been fabricated and tested. The high power test shows that an improvements are needed in several areas to improve the thermal handling characteristics of the antenna, with the flxipivot point of the current strap connection being the most important. The modified design shows good RF characteristics in calculation and the next high power test will be started in Jan. 2005. Electron temperature control by the real-time power control on gyrotron and NTM stabilization by the local ECCD has been demonstrated in DIII-D.

Third, the participant from EU presented their research plans and developments: The heating systems for JET attained the following numbers: 12MW-20s by NBI with a new power supply, 8MW-20s by ICRF, and 3MW-20s by LHRF. In 2005 a new ITER-like, ELM tolerant antenna will be installed. Many profile measurements are newly added to the real-time loop for various multivariable feedback controls.

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This report received by Secretariat on 19 day 10 mo ‘04 y

No.

AGENDA

Satellite Workshop W61 on "Heating and Control for Long Pulse Operation in Large Tokamaks"

Under the auspices of the IEA large tokamak implementing agreement
At Giorgio Cini Foundation, Venice, Italy

SEPTEMBER 23, THURSDAY, 2004

Organizer: R. Callis (US), R. Felton (EU), M. Kikuchi, K. Kurihara (JA)

Participants

US	Joel Hosea	(PPPL, Lower Hybrid)
US	David Swain	(ORNL, Ion Cyclotron)
US	Rich Callis	(GA, Electron Cyclotron)
EU	Robert Felton	(JET, Plasma Control System)
JA	Kenichi Kurihara	(JAERI, JT-60 Power Supply and Control Systems)
JA	Shinichi Moriyama	(JAERI, JT-60 RF System)
JA	Naotaka Umeda	(JAERI, JT-60 NBI System)
JA	Kenji Tobita	(JAERI, Reactor Systems)

16:50-	Opening Greetings	R. Felton
Session I: Status of JT-60		Chairman: R. Felton
16:55-	Status of JT-60 power supplies and control systems for long pulse operation	K. Kurihara
17:10-	Status of JT-60 RF H&CD system for long pulse operation	S. Moriyama
17:25-	Status of JT-60 NB H&CD system for long pulse operation	N. Umeda
Session II: Status of US Devices		Chairman: K. Kurihara
17:35-	Status of long pulse AT regime operations plans for Alcator C-Mod	J Hosea
17:50-	US R&D and plans for long-pulse ICRH antennas	D. Swain
18:05-	Status of the ECH System on DIII-D	R. Callis

Session III: Status of JET		Chairman: R. Callis
18:20-	JET machine status for long pulse (Presenting material from the NB, RF, LH and Chief Engineer groups of JET and from E.Joffrin (co-ordinator of the long pulse experiments))	R. Felton
19:35-	Closing Remarks	R. Callis

Appendix A4

IEA Cooperation Among Large Tokamak Facilities

Minutes of the 20th Executive Committee Meeting for the IEA Large Tokamak Cooperation Programme

9 – 10 May 2005

Attendees:

E. Oktay	(U.S.)	: Member
D. Meade	(U.S.)	: Member
R. Stambaugh	(U.S.)	: Alternate
E. Marmar	(U.S.)	: Alternate
M. Peng	(U.S.)	: Expert
P. Gohil	(U.S.)	: Expert
J. Paméla	(EU)	: Member
S. Clement-Lorenzo (EU)	: Member	
M. Watkins	(EU)	: Alternate
O. Gruber	(EU)	: Expert from PD
J. Jacquinot	(EU)	: Expert from PD
M. Kikuchi	(JAERI)	: Member
Y. Nakamura	(NIFS)	: Expert
J-H. Han (KBSI)	: Expert from PD	

Secretariat
K. Shinohara (JAERI)

The Twentieth Executive Committee Meeting for the IEA Implementing Agreement on Cooperation among Large Tokamak Facilities was held at PPPL, 9 -10 May 2005.

A. MEMBERSHIP AND CHAIR

The Committee elected E. Oktay as the chairman until the next meeting. It was announced that Dr. N. Sauthoff and Dr. J. Willis had been replaced by Dr. D. Meade as a member and Dr.

N. Sauthoff had been replaced by Dr. E. Marmar left as an alternative members, and Dr. D. Meade became a new member and Dr. E. Marmar became a new alternate member. The present members of the Executive Committee are shown in Appendix A.

B. ADOPTION OF AGENDA

The Committee adopted the agenda, which is attached as Appendix B.

C. REPORTS ON THE STATUS AND PLANS OF EACH PARTY

The status and plans of the fusion programs of JT-60, EFDA-JET, U.S. (DIIID, C-MOD, NSTX) were presented by Drs. M. Kikuchi, M. Watkins, E. Oktay, R. Stambaugh, E. Marmar and M. Peng. The status reports are also attached as Appendix C.

D. REPORTS ON THE COMPLETED WORKSHOPS AND PERSONNEL ASSIGNMENTS FOR JUNE 2004 – MAY 2005

Workshops and personnel assignments completed in the period of June 2004 - May 2005 are listed in Appendix D1. Three workshops of “Implementation of the ITPA Coordinated Research Recommendations” (W58), “Shape and Aspect ratio Optimization for High beta steady-state tokamak (Combined workshop with DOE/JAERI technical planning of Tokamak Experiments)” (W59), and “Heating and Control for long pulse operation in large tokamaks”(W61), were carried out. The total number of personnel assignments completed in the period was 24. 23 PAs were for review tours (less than 4 weeks) (see Appendix D2). Subjects are summarized as follows (see Appendix D3): 2 on Task1: Transport and ITB Physics (8%); 0 on Task 2: Confinement database and modeling (0%); 7 on Task 3: MHD, disruptions and control (19%); 5 on Task 4: Edge and pedestal physics (21%), 2 on Task 5: SOL and divertor physics (8%), 4 on Task 6: Steady State Operation (17%), 0 on Task 7: Tritium and RH Technologies (0%), and 4 on Task 8: Other (17%). The reports on the workshops (FORM C) , the short reports for review tours and a report for EU65 (FORMB) are attached as Appendices D4 and D5, respectively. To show other activities between the Parties, ., some information for other assignments from other agreements is added as a footnote.

Some of the exchanges were carried out through the remote participation. The committee encourages this form of collaboration, especially between JET and JT-60U.

E. PROPOSALS OF WORKSHOPS, PERSONNEL ASSIGNMENTS AND REMOTE PARTICIPATION FOR JUNE 2005 – May 2006

Proposed Workshops and Personnel Assignments for June 2005 - May 2006 are listed in Appendix E. These include two new Workshops (W60: “Burning Plasma Physics and Simulation”, W62: “Fourth Joint Workshop of Large Tokamak , Poloidal Divertor and TEXTOR IA’s on ,”Implementation of the ITPA Coordinated Research Recommedations””, W63: “Joint Workshop with PD IA on Real time control for steady state”) and 37 personnel assignments. The Committee discussed these proposals and authorized their implementation.

The loan agreement for JU97 was also discussed and accepted by members.

F. BRIEF REPORTS ON IEA LT TASK AREAS

There were 8 Task areas. The list of coordinators are appended in Appendix F1. The activities of tasks (submitted reports) are attached in Appendix F2.

G. GENERAL DISCUSSION OF EXCHANGE ACTIVITIES

Exchange activities were discussed, as also was the content of the task reports. A discussion on the way in which task coordinators executed their work and made their reports led to the formulation of guidelines which would assist task coordinators in the preparation of their task reports;

1. Task reports are required for the annual report and should cover ITPA joint experiments under the auspices of LT IA and also under the cooperation with other IA. It should also cover non-ITPA activities of LT IA.
2. For each JEX, Spokespersons provide reports to ITPA. Task coordinators will provide brief summary of LT related reports to the respective Ex-Co members consistent with report to ITPA [report should be compact including number of JEX(ex. PEP13), title of JEX, summary of results (a few lines), publication lists].
3. After the completion of each personal exchange (including. remote ones), brief report should be sent to the secretary to put on the Web so that task coordinators/ExCo members can look at the progress. Based on these reports, LT ExCo members will add non-ITPA related activities and send to the secretary based on this reports.
4. An intermediate report will be presented at each Executive Committee meeting to cover progress of the ITPA high priority coordinated experiments. Each Facility Leader will provide the Secretariat with condensed information prior to the meeting.

H. IEA LT HOMEPAGE STATUS AND REQUESTS TO PARTIES

The current LT homepage was briefly introduced briefly by the secretariat. It was decided that the annual report should be opened to the public, namely not password-protected, but should not include any personal information such as the list of e-mail addresses and personnel exchanges . Such information could be made available in the password-protected area.

The committee members expressed appreciation to JAERI staff for establishing an excellent web page for the Agreement. This which is very useful for this disseminating information on collaborative activitiesy.

I. SCHEDULE FOR ANNUAL REPORT FOR FPCC

Schedule and responsible persons for annual report for FPCC were discussed. The members agreed to returning to the calendar year as the basis for the contents will be returned to be based on theof the report calendar year. The deadline of for the submission will be at the end of November.

The committee expressed itss appreciation to Dr. M. Kikuchi for his excellent work in preparing EOT report. This report was accepted by FPCC for submission to CERT to extend the Agreement for another five years from Jan 15 ’06.

The committee completed “CERT Criteria for IEA” table for submission to CERT.

J. Amendment of IEA LT Agreement

Dr. S. Clement-Lorenzo reported on the Amendment of IEA LT Agreement.

K. NEXT MEETING

The next Executive Committee Meeting will be held in May 2006 in Garching. That's It will be a joint meeting with PD IA.

L. Joint session of the two Executive Committees

Joint session of two Executive Committees for IEA Implementing Agreements on Co-Operation on the Large Tokamak Facilities (LT) and Cooperative Program for the Investigation of Toroidal Physics in, and Plasma Technologies of Tokamaks with Poloidal Field Divertors (PD) was held.

Dr. O. Gruber presented the status report, including ITPA joint experiments, of ASDEX-U. Results and requests on ITPA Joint Experiments were also reported by ITPA Chair. Then, the status and plans for ITPA joint experiments was were reported by for all devices.

Reports from the last IEA FPCC meeting in March '05 was were presented. Members recognized the urgency of improving efficient communication between the ITER Iinternational Tteam and ITPA in with regard to increased focus in high priority research tasks.

In response to the discussion and steady-state issue at the FPCC meeting, the participants agree on the importance of physics and technology of steady-state and long-pulse operation. This topic is covered by many existing devices and IAs; this will be a focus of new super-conducting toroidal devices. There is a good opportunity for increased coordination among the different Agreement in this area.