Priorities for JET Fusion Technology Activities in the 2010 Work Programme

Fusion Technology activity at JET, launched in April 2000, is providing relevant contributions to JET operation and to the design of ITER in the following areas:

- Plasma Facing Components and Tritium in the Tokamak
- Tritium Process and Waste Management
- Neutronics and Safety
- Licensing Issues

Based on discussions with experts from the Associations, members of the European Plasma Wall Interaction Task Force and of the JET Task Forces and in liaison with Fusion for Energy, this work programme for 2010 has been drafted for consideration by the STAC and for subsequent approval by the EFDA Steering Committee. The following topics have been recognised as crucial issues to be assigned the highest priority:

- Development of the in-situ detritiation of plasma facing components (PFCs);
- Analysis of selected PFC samples in order to support particle transport studies and in-situ detritiation activities;
- Development of the in-situ diagnostics for the characterisation of deposited layers and/or coatings;
- Characterisation of dust and assessment of in-vessel dust diagnostics and removal methods;
- R&D on mixed materials with a view to the ITER-like Wall Project;
- Development of detritiation methods for JET waste; and
- Lessons to be learned from JET for ITER licensing.

More detail on some of these priority areas is given below. Information about present and past JET Fusion Technology activities is available at:
http://users.jet.efda.org/pages/ft-task-force/index.html

In addition to the topics discussed below, new ideas and proposals may be submitted for consideration by EFDA-JET.

1. Plasma Facing Components

In situ treatment of PFCs:

Due to the maximum tritium inventory allowed inside the ITER machine, removal of trapped tritium will be regularly necessary to continue operation. In the past JET FT activities, flash lamp, laser and plasma torch detritiation methods have been developed and studied, essentially in a laboratory environment.

The ongoing activity using the laser method as an in-situ detritiation technique has to be continued. The technique needs to be optimised for the various PFC materials (especially for controlling the substrate integrity during treatment). Furthermore the assessment of the efficiency of the detritation by analysis of the cleaned tiles needs to be investigated.

Using the laser detritiation method to treat mixed materials such as Be/C, C/W or Be/W, needs to be investigated, particularly with the perspective of the ITER-Like Wall (ILW) project and for ITER. Therefore, the determination and optimisation of the operating parameters of the laser detritiation device on Be, W or Be and W coated CFC and their potential combinations is of paramount importance and need to be investigated.

The tests of Inside Gap Plasma Generator (IGPG) and of an N_2 or Ar plasma torch need to be continued. This task would be a continuation of a previous activity, which demonstrated at a laboratory scale the capability of the technique to remove deposits accumulated between gaps. However, the method needs to be demonstrated using JET samples treated in a facility able to handle Be and tritium contaminated tiles. In addition, the removal of metallic dust from gaps and castellated structures needs also to be addressed.

Several tasks aiming to characterise detritiated materials need to be pursued to analyse samples treated by the laser irradiation, IGPG and plasma torch. A comparison of the related efficiencies needs to be made.

Other techniques, such as in-situ heating detritiation that can be used for metal, need to be explored and tested.

Vessel Conditioning

During the last campaign at JET, some methods for wall conditioning have been tested such as ICRH discharges. However, it appeared that this technique was not very efficient and compared to the He glow discharge did not provide satisfactory results. This was attributed to the fact that ICRH was probably not properly optimised. Therefore, the assessment of its efficiency, as well as modelling of the operating parameters, especially in view of the ILW-project, needs to be investigated as well as its extrapolation to ITER.

Moreover, the evaluation of potential damages on plasma exposed metallic surfaces (blistering) after helium and other gas trapping in the tungsten during glow discharges needs to be investigated. If important amounts of hydrogen isotopes are trapped by the plasma exposed metallic surfaces, the restitution of good surfaces must be studied as well as the consequences of potential dust production. Tiles retrieved from the vacuum vessel during the EP2 shutdown will be available for such an analysis.

Dust Issues

The assessment of the various processes leading to dust production, such as wall conditioning, ELMs and disruptions occurring during “off-normal” operation, needs to be examined. Moreover, the effect of unipolar arcs needs to be investigated in a dedicated device especially on metallic surfaces such as W or/and Be.

The evaluation of the dust amount production, as well as the development of a reliable method for dust recovery, needs to be continued.

During the 2009 JET shutdown, collection of loose dust and flakes from various areas of the vacuum vessel (particularly the divertor) is planned. Samples can also be taken once the inner and outer divertor carriers have been removed, as well as from the inner and outer louver regions (separately). The chemical analysis and characterisation of such material needs to be undertaken and therefore, an appropriate experimental facility needs to be prepared in order to allow the handling and analysis of such toxic and tritiated material. The analysis should include weighing and various physico-chemical measurements such as Specific Surface Analysis, density and size distributions, elemental analysis and chemical composition, thermal desorption analysis, etc.

Diagnostics in Tokamaks with metal walls (Surface temperature evaluation):

The surface temperature of the plasma facing components is usually measured using infrared cameras. This method requires a precise knowledge not only of the emissivity of the material, but also of the reflected and parasitic fluxes. For carbon, the emissivity is known and constant over the detection wavelength and the temperature range encountered in tokamaks. However, for materials like Beryllium and Tungsten, the emissivity is lower and varies with surface temperature and condition and in this regard, the reflected flux could contribute significantly to the collected flux. This effect should be taken into account when estimating the surface temperature. Pulsed photo-thermal techniques are under assessment at the laboratory scale. In the next WP, a task could be launched in order to select the most suitable technique for JET and the ITER tokamak. An assessment of the practical and available active IR methods and their implementation in JET could be included in this task. The potential methods could be:

- Lock-in laser tests (continuation of ongoing tasks)
- Assessment and test of a diagnostic based on a pulsed photothermal method and/or on a pyro-reflectometry technique

Moreover, several important activities such as diagnostics for fuel in-situ inventory evaluation (e.g. LIBS) as well as modelling of IR experiments from Tokamak or test bed activities could also be foreseen in 2010.

Post-mortem analysis and simulation:

As a contribution to the impurity transport and erosion/re-deposition studies and to complete the picture on tritium trapping, further analyses of PFCs, mirrors and dust are needed. In addition, a system able to provide in-situ mapping of erosion/re-deposition and capable of estimating the characteristics of co-deposited layers such as thickness, chemical and physical properties would be highly relevant. Many new issues in this area will also be raised by the installation of the ITER-like wall in JET (which is configured specifically to have direct relevance to ITER PFC). This would also include development of modelling for the erosion, dust production and plasma contamination occurring after off-normal operation events such as ELMs, VDE, disruptions, etc...

Moreover, analysis of mixed deposited materials has been flagged by EFDA as a major topic of concern for ITER. JET provides a source of Be-C mixed materials, and in future will provide Be-W and Be-W-C films. Existing analytical methods such as IBA and SIMS will need to be supplemented by high resolution techniques such as SEM and Ion Microprobe and chemical analysis techniques such as XPS/AES. In addition, the development of thermal analytical (TA) methods such as Thermogravimetry or Differential Scanning Calorimetry need also to be developed. Combining TA with gas-analytical techniques could also be very helpful when investigating alloys (such as the mixed compounds that we may have when C, Be and W are present) by identifying the various phases that can be formed as a function of the temperature.

The commissioning of the new plasmatron installed at Mol in the frame of previous FT tasks and its further development towards using tritium plasmas needs to be continued. Such a device can now be used in laboratory scale, to study the behaviour of the plasma facing materials when exposed to plasmas especially in terms of retention, dust production, surface erosion and material re-deposition not only for the materials foreseen for ITER (W, C, Be) but also for the mixed materials such as beryllium carbides and tungsten beryllides, which are expected to be generated during plasma operation. This study is of particular interest for JET in view of the ILW-Project.

Typical post-mortem analyses will include:

- Samples analysis (continuation of ongoing tasks)
- ^{13}C transport analysis and modelling (JET 2008/2009 experiments)
- Analysis of tiles markers for ILW (W and Be)
- Structural determination (powder X-Ray, etc.) and bonding states of mixed material samples, thermal characterisation (TDS including species determination).
- Tritium profiling via coring technique and dissolution/combustion
- Assessment of detritiation techniques (see above)

Use of the Test Beds and other JET facilities

Two beam-lines are available for testing in J1C at JET.

1. Neutral Beam Test Bed fitted with numerous diagnostics and which have been used in the past to test tritiated components
2. Beryllium Rig II (BR2) is also available for handling large beryllium, or berylliated and/or tritiated components.

In the past these facilities have been used to test materials as well as the characteristics of the co-deposited layers. The evaluation included heat flux test, thermal conductivity measurements of the co-deposited layers, and interpretation of the IR thermography data.

Moreover the BR2 is the only facility that can handle contaminated JET tiles and deliver relevant heat loads. The understanding of the thermal properties of the JET tiles will not only allow us to model the heat loads in current JET experiments, but also it is an essential guidance for the operating limits in JET with Be and W components which will melt if the heat load limits are exceeded.

The NB Test Bed facilities could also be used for the development of Neutral Beam technologies relevant to JET and ITER.

2. Tritium in the Tokamak

Tritium compatible vacuum pumping

The lack of reliable large tritium compatible vacuum pumps presents a technical issue not only for future tritium campaigns on JET but also for ITER.

Four tritium compatible large scroll pumps have failed on JET after a short duty. A task attempting a comprehensive analysis of these failures is compulsory as a lack of understanding in this area may put ITER operational reliability at risk.

As JET has a number of possible real test applications it would be an excellent place to prove the reliability of such a pump. A task is required to continue the testing and development of such a pump.

Tritium permeation into the cryogenic coolant

Tritium permeation from the inter gap cryopump volume through the walls of the cryogenic piping into the cryogenic coolant needs to be examined. It is expected that such permeation (at least the diffusion contributing to it) is very much dependent on the temperature, and therefore the regeneration of the cryopump at 470K, as is foreseen to be the case in ITER, would constitute the worse case scenario which needs to be investigated.

3. Neutronics and safety:

In order to provide inputs from the JET experience to the ITER licensing process, data have been collected on JET. In this respect, a new activity should be started to provide the support of the JET facilities in evaluating and validating ITER relevant leak localisation techniques.

Moreover, the previous task on the scale and frequency of problems, failures and malfunctions of various components at JET needs to be continued. The task should also include the strategy adopted at JET for the repair of such malfunctions, as well as the possible extrapolation of these data to ITER. Such data collection should be fully examined and thoroughly evaluated.

Follow-up activities are required on the development of the code models for the shutdown dose rate prediction, in order to analyse the outcomes of the dedicated measurements performed in 2008 and 2009.

Conversion of CAD files

The conversion of the existing CAD files to the newest version of CATIA V5, which includes the material composition, is essential as it will allow an easy upgrade of the existing MCNP models. This work is ongoing but not yet complete and the intention is also to update the existing MCNP models to include the coming changes taking place at JET during 2009/2010 major shutdown, i.e. the implementation of the ITER-like ‘Be-wall’.

In this regard, it would also be worthwhile to compare the accuracy of the older MCNP models to the MCNP models produced separately “by software conversion”, using a full CATIA V5 file as input to the McCAD.

Furthermore, an uncertainty analysis should be carried out, probably for the important KN2 3U irradiation and activation coefficients. Repetitive runs of good statistical quality are required for each of many deliberate geometry /materials changes.

Research into activation products

To improve the confinement of fusion plasmas its accurate characteristics must be known at any rate. In this respect, measurements of charged particles and neutron emission at very close to the plasma locations can provide important data. The post-mortem analysis of the activation probes introduced into the vacuum vessel needs to be continued.

Such measurements provide important information not only related to the first wall erosion but also in terms of material transport across the Scrape-off-layer.

4. Waste management:

Safe and economic processing of the various waste streams at JET are important tasks also for ITER to make fusion viable.

The identification, quantification and characterisation of the various waste streams arising from JET operation and decommissioning have been addressed in a previous task. However, there are still missing data, in particular on the beryllium and tritium contamination of the waste material and its respective activation levels. Such a study would provide very useful data in the development of a JET and ITER waste management strategy.

Beryllium tiles are proposed for ITER and the ITER-like JET wall project. The development of detritiation / recycling methods for bulk beryllium and the definition of a strategy to reduce the constraints linked to the management of mixed waste containing beryllium should be addressed.

The assessment of the Tritium Method 3 technique involving the soak of housekeeping waste into water needs to be investigated. The analysis will involve the measurement of the tritium concentration in the soak water and will determine the relationship between leached tritium and total tritium. Initial results indicate that a soak at 80°C for a period of about one week may be sufficient to liberate all removable tritium. However, the optimum temperature and soak time should be determined.

Detritiation by dissolution of any metals containing tritium should be re-assessed in view of the potential hazard caused by the accumulation of explosive air mixtures (>4% hydrogen).

Finally, the tritium concentration found in drums containing compacted housekeeping waste, which was categorised as potential Intermediate level Waste (ILW) and stored on site for more than a decade, needs to be evaluated. The air in the top of a drum could be sampled through a small penetration and the tritium in the solid contents could be compared. If the scatter band from measuring several drums can be established, then the method can be used to infer the tritium inventory of other similar drums via a tritium sniffing method.

The waste management task could include the following subjects:

- Measurement of tritium content in waste packaging from JET waste materials
- Characterisation of tritium out-gassing from waste JET material (molecular species)
- Assessment and test of techniques such as diffusion barriers to limit degassing from JET waste samples
- Treatment (detritiation) of JET soft house keeping materials including study of an industrial route for detritiation of soft house keeping waste.
- Improving the knowledge of thermal detritiation process efficiency (increasing the temperature up to 1100°C, changing carrier gases, melting and gas bubbling), with a special focus on Be samples. Definition of an industrial route for Be and metal detritiation (including preliminary tests with 500g of Be and other metals, safety assessment and cost analysis)