ITPA Topical Group on Diagnostics
Report on Activities in the period June 2007 – June 2008

The coordinated, activities on diagnostics in the period from June 2007 until June 2008 were continued with emphasis being placed on the designated high priority topics. There were two meetings of the ITPA Topical Group (TG) on Diagnostics.

1. Meetings of the Topical Group on Diagnostics

The 13th Meeting was held at SWIP, Chengdu, China, from 30 October – 2 November 2007. The meeting was combined with a Progress Meeting on ITER relevant diagnostic developments in China, which took place on 29 October. The meeting was attended by 46 participants drawn from China (19), EU (12), Japan (4), Russia (4), South-Korea (1), USA (2), and the ITER IT (4). Special sessions were devoted to the ITER diagnostic design review and the overall assessment of the measurement capability with respect to the measurement requirements, as well as to neutron diagnostics.

The 14th Meeting was held at CRPP/EPFL, Lausanne, Switzerland, from 14 to 18 April 2008. The meeting was combined with a Progress Meeting on ITER relevant diagnostic developments in Europe, which took place on 14 April. The meeting was attended by 63 participants drawn from China (2), EU (42), Japan (9), Russia (1), South-Korea (1), USA (2), and the ITER IO (6). Special sessions were devoted to the effect of straylight and wall reflections on optical diagnostics, and on the proposed changes to the requirements for plasma measurements on ITER and the ITER diagnostic system following the design review in 2007.

In addition to the special sessions, the key topics reviewed and discussed at the TG meetings were:

- the progress and plans in meeting the goals of the Physics Voluntary R&D tasks in Diagnostics in especially the high priority topics;
- developments in the ITER measurement requirements and justifications of these measurements;
- the diagnostic capability in the light of ITER measurement requirements;
- review of critical areas of ITER diagnostic design and integration;
- the recent progress in ITER relevant diagnostic development and application in the Parties;
- review the status of the International Diagnostic Database and plan future development;
- review the responses to the action items from the 13th meeting of the ITPA Diagnostic TG and plan future actions;
- review progress by the Specialist Working Groups in Diagnostics;
- discussion on the date and location of the 16th meeting of the TG;
- planned future activities.

2. High Priority Topics

Good progress has been made in the tasks designated as high priority:

2.1. Development of methods of measuring the energy and density distribution of confined and escaping α-particles

2.1.1. Confined α-particles

The design status of the ITER fast ion Collective Thomson scattering system was discussed. As part of the changes arising from the design review process, the in-port components of this system are included in the revised ITER diagnostic system. Two options for the receiving system (with 1 and with 2 mirrors) are presently being explored. A mock-up of a candidate 4-mirror receiver system for the high field side (hfs)

of ITER has been developed to demonstrate that there could be an engineering solution for such a system. However, the impact of the hfs system on other systems, for example, the blanket modules, and the enhanced, localised, nuclear heat load on the central solenoid have not yet been determined. Neutronics calculations have, however, been performed to study the heat loads on the first mirror.

In the gamma spectroscopy system at JET a ^{6}LiH filter has been tested in one of the channels to study its usefulness for ITER. The filter reduces the DD neutron background by two orders of magnitude, while it reduces the gamma signal by only a factor of two.

In Japan a full-size strongly focusing He^{+}-source has been developed for use in a proof-of-principle double charge-exchange diagnostic for measuring confined alpha particles. A beam current of > 2 A was obtained at a beam energy of 20 keV, which is meeting the requirements. Additionally, a proof of principle lithium cell for production of a ground-state He^{0} beam was constructed with an efficiency >1% for conversion of He^{+} to He^{-}.

A survey diagnostic for fast ions based on charge exchange recombination spectroscopy on the heating neutral beam was proposed, with the aim to detect fast spatial redistributions of alpha particles due to interactions with Alfvén waves.

The effect of RF and NB-driven fast ions on ITER plasmas, and the capability of various diagnostics (fast ion collective Thomson scattering, neutron cameras, gamma tomography and neutron spectroscopy) to measure those effects, has been studied with a package of simulation codes. The number of fast ions driven by RF and NBI is relatively small in ITER, compared to a machine such as JET. The difference between the thermal and total neutron emission for the scenarios studies is not more than 3% and at this level will not be noticeable in tomographic reconstructions using both the neutron cameras. It would be useful to quantify the effect of other sources of fast ions, such as instabilities, and in addition to see whether there are synergistic effects between RF and NB.

2.1.2. Escaping α-particles

New results with the recently installed Faraday cups in JET for the detection of escaping fast particles, showed a very clear correlation between the fast ion losses and the occurrence of Edge Localized Modes (ELMs). The poloidal distribution of the losses has been observed to depend on the triangularity of the plasma and on the toroidal field ripple.

A new type of scintillator material (TG-Green) for the diagnosis of escaping fast ions has been tested at ASDEX-UG. Measurements with the new scintillator gave evidence that the fast ion losses from the tail of the ICRH particle distribution are related to MHD instabilities in the plasma core. Progress was also reported in the field of radiation hard ceramic scintillator materials developed in Japan. However, it was concluded that neither the new European nor the Japanese scintillators would survive the neutron and gamma radiation in ITER environment for long enough a time.

2.1.3. Requirements for α-particle and fast ion measurements

The measurement requirements for fast ions (including alpha particles) have been further developed, and more comprehensive and demanding requirements on measurements for fast ions and the electron distribution function have been proposed. The supporting argument for the proposed changes is that the interactions of fast ions with Alfvén Eigenmodes and with RF waves could have a significant impact on the confined alpha population.

2.2. Assessment of the various options for the Vertical Neutron Camera to measure the 2D n/α source profile and asymmetries in this quantity, and assessment of the calibration strategy and calibration source strength needed

2.2.1. Vertical Neutron Camera

Two options for the Vertical Neutron Camera (VNC) have been studied in detail by the Russian Federation and the ITER Organization: the Lower VNC looking up from the divertor and the Upper VNC, mounted in an upper port. The work has concentrated on the physics assessment of the measurement capability and on the integration aspects of the two options. The value of the LVNC and UVNC for tomographic reconstruction of the neutron emission profile has been assessed by means of simulations, taking into account the background. If the neutron emissivity is constant on a magnetic flux surfaces then the Radial Neutron Camera (RNC) plus equilibrium measurements will be sufficient, but if this is not the case, measurements in another direction will be needed for the tomographic reconstruction. The LVNC and UVNC are implementation options for the VNC to provide these measurements. The simulation results with the LVNC give a higher signal/background than with the UVNC, but the UVNC still provides useful information and generally clearly improves RNC-only reconstructions. A good knowledge of the scattered and background neutrons is needed. The LVNC and UVNC have also been compared from the engineering point of view. Both systems have difficult interface issues. As part of the changes coming from the ITER design review, it has been decided to adopt the option of the camera installed in the divertor port (LVNC). Therefore, the first part of this HP Topic is now concluded.

2.2.2. Calibration strategy of neutron diagnostics

The Neutron Working Group has further developed the calibration strategy and begun to specify the needed source strength of the calibration source. Also the necessity and location of the neutron test area have been further evaluated. Calibrations with a neutron source mounted in the vacuum vessel are thought to be needed but the determination of the optimum number of calibration points requires detailed numerical simulations. Even with the best calibration strategy that can be envisaged, extensive modelling by neutronics codes will be needed to correct for the heavy support structure of the neutron generator that needs to be moved through the vessel and, additionally, for any changes to the machine structure that occur after the calibration.

2.3. Assessment of the integrated measurement capability of the diagnostic systems relative to the specified measurement requirements.

This action was originally defined in support of the Diagnostic Design Review (DDR) that took place in July 2007. In the DDR a detailed comparison has been made between the level 0 measurement requirements specified in the ITER Project Integration Document and the integrated measurement capability of the various diagnostic systems. To aid this process a comprehensive diagnostic database has been developed, containing both the measurement requirements and the measurement capabilities of the various diagnostics. The outcome of the DDR was presented and discussed. The DDR has led to three Design Change Requests: DCR-125: Changes to the measurement requirements; DCR-126: Changes to the ITER Diagnostic System and DCR-127: Requirement for an on-site port plug test facility. As a result of the changes incorporated by the diagnostic design review, and the follow up activity of the cross party Diagnostic Working Group, the overall technical performance of the ITER diagnostic system has been improved. All former non-credited systems have either been properly included in the diagnostics system and allocated to a Party or dropped so that all the components of the baseline diagnostic system are now credited. In some cases, only the interfaces or the front end of systems are included but the systems concerned, for example the high resolution neutron spectrometer, will not be needed until several years

into the operational programme and so can be installed cost effectively later if required. This High Priority item has been successfully concluded and can be taken off the list of HP topics for 2008/2009.

2.4. Determination of life-time of plasma facing mirrors used in optical system

The report of the Specialist Working Group on First Mirrors gave an overview of all activities in the field of first mirrors. Much ITER-diagnostic specific research is in progress at many laboratories worldwide, but in general more solution-oriented research is needed. More refined geometries are being introduced for predictive modelling. The effort in this field should be intensified and accelerated to serve the rising needs. Further progress was reported in the field of deposition mitigation (e.g. by flowing gas in front of the mirror) and mirror cleaning, coated mirrors, mirror manufacturing and irradiation testing of mirrors. Reviewing the progress so far, it was agreed that more emphasis needs to put on the development of mitigation methods especially for Be deposition.

A roadmap to direct the international R&D in the field of first mirrors has been prepared and has been further detailed and evolved in special break-out sessions during both TG meetings. It is urgent to develop the road map into a tool that can be actively used to direct the international research in this field. As a first step it is proposed to cluster the various diagnostic mirrors in groups with approximately the same functional requirements and operational environment in order to recommend baseline solutions for each group on the basis of present knowledge. Furthermore, it was agreed that candidate mitigation methods against deposition need to be reviewed to identify the most promising ones for further development.

Also attention was paid to the effect of blistering on mirrors. In an overview talk on the likelihood of blistering in ITER it was shown that the surfaces exposed to single-ion species might suffer from blistering under some conditions, while these surfaces did not exhibit any apparent blistering when exposed to multiple-ion species under exactly the same conditions. In addition, the occurrence and degree of blistering seems to depend on the manufacturing method of the material, as well as on the history of the conditions to which the surface is exposed. The analysis of present knowledge on blistering has led to the conclusion that there are enough tools to effectively suppress and prevent the occurrence of blistering in ITER.

2.5. Development of measurement requirements for measurements of dust, and assessment of techniques for measurement of dust and erosion (with a special emphasis on dust measurements).

Recent studies and discussions within the ITER Organization reached the conclusion that the inventories for dust and tritium are expected to reach their maximum limits on a timescale comparable to the target erosion lifetime. Based on this, a control strategy for dust and tritium has been formulated. Dust will be removed during the scheduled divertor replacements (approximately every 4 years). Additionally the dust will be monitored during and before shutdowns. Local measurements will be benchmarked versus the tritium and dust recovered during the replacement of the divertor cassettes. The first benchmarking will be done in the hydrogen phase.

Various diagnostic methods for the measurement of dust and erosion have been proposed and tested (optical radar measurements, capacitive diaphragm microbalance, laser desorption) but need to be further developed. The possibility of including one or more of these systems in the ITER diagnostic system is being considered as part of the on-going Design Change Requests that are dealing with the topics of dust and tritium retention.

The TEXTOR team is presently developing a multi-purpose Nd:YAG laser-based diagnostics system that combines laser-induced breakdown, ablation and desorption spectroscopy with Mie/Rayleigh scattering and quartz microbalances for measuring tritium retention, material deposition and dust. The system is aimed to be applicable to ITER conditions. Since the precise requirements for the measurement of these quantities are under development in ITER, it was recommended that the researchers working in this field should follow these developments carefully in order to make sure that their methods are optimized for the ITER requirements.

2.6. Summary on High Priority Issues

The progress in all five high priority areas is good. Nevertheless, more and dedicated work is needed on four of the high priority issues and work on these needs to be continued in 2008/2009. The assessment of the integrated measuring capability of the ITER diagnostic systems has been completed and therefore it is proposed to take HP topic #3 off the list. Furthermore, it is proposed to fully focus HP#2 on the calibration strategy, since a decision has been taken on the favoured option for the Vertical Neutron Camera.

In addition to reviewing the progress with the high priority topics, progress with the intermediate and long-term tasks has also been reviewed. The progress is summarized in tabular form in Attachment 1.

3. Party Reports

During the Progress Meetings on ITER relevant diagnostic developments in China (combined with the 13th meeting) and in Europe (combined with the 14th meeting) Chinese and European scientists, respectively, presented their work on a large variety of diagnostic systems in preparation for ITER. Many of these presentations were directly related to the high priority research topics of the TG.

Representatives of the ITPA Party Teams (PTs) reported steady progress for many diagnostic techniques that are ITER relevant. It is clearly evident that many scientists working on diagnostics in the various PTs are becoming more aware of the problems and challenges of implementing diagnostics on ITER. This is again demonstrated by the large attendance to both meetings.

4. Specialists Working Groups

The seven Specialist Working Groups (SWGs) continue to work in a focussed manner in their specific fields (beam-aided spectroscopy, spectroscopy, reflectometry, Thomson scattering, neutron diagnostics, first mirrors and radiation effects). Good progress was reported by the SWGs for many of the outstanding action items. Most of the work described above under the high priority issues has been the result of the coordinated effort within the various SWGs. The work on many action items has been completed and a number of new action items were formulated at the meetings. Figure 1 shows the evolution of the action items. The 1/e-lifetime of the action items has dropped from 1.5-2 years (3-4 meetings) during the first five ITPA meetings, to approximately 1 year (2 meetings) during the more recent meetings.

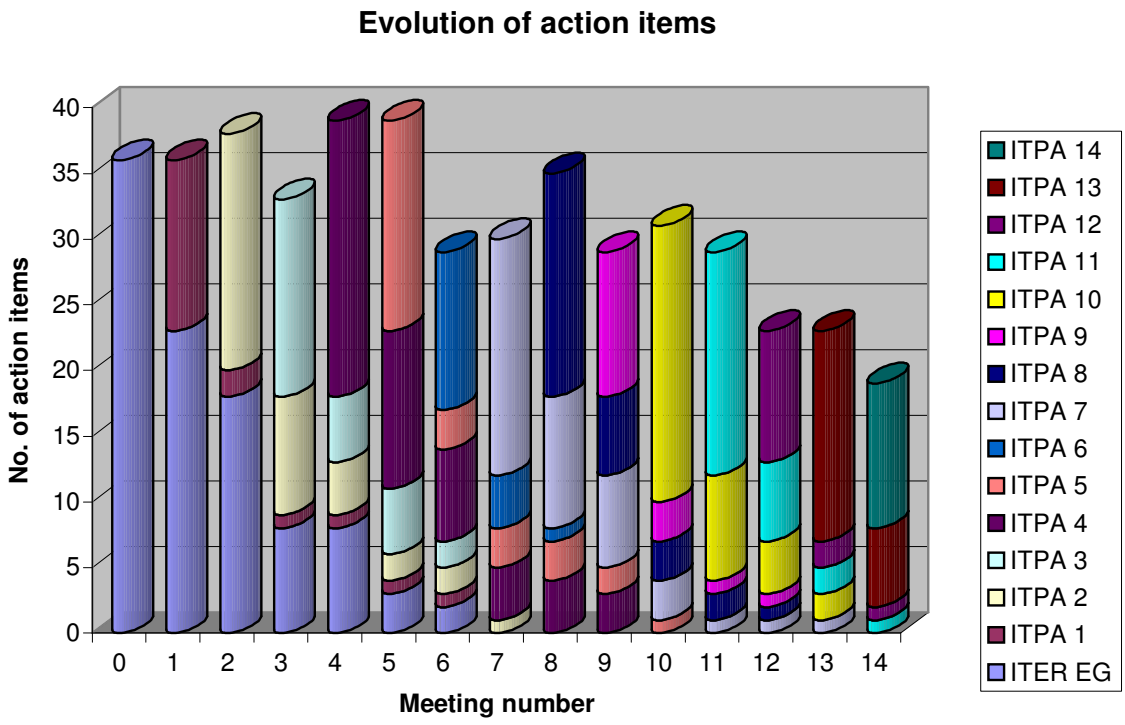

Figure 1. Evolution of the action items from meeting to meeting. The colours refer to a specific meeting in which action items were defined. Meeting #0 refers to the action items that were inherited from the former ITER Expert Group Meetings (<2001). Numbers for meeting #14 are still provisional.

5. Progress in other areas

5.1. Measurement requirements

The ITER requirements have been updated as part of the ITER design review and accepted into the ITER baseline. In parallel the measurement requirements have been reviewed by the ITPA Divertor & SOL TG at their meeting in January '08. This has resulted in a number of proposals for changes to the measurement requirements that now need to be reviewed by the ITPA Diagnostics TG and, if supported, be incorporated in the level 1 measurement requirements and put forward to the IO for consideration for inclusion in the ITER Requirements documentation.

5.2. Neutron diagnostics

A special session at the 13th meeting was devoted to neutron diagnostics. Partly this has been already summarized under high priority topics Sections 2.1 and 2.2. Design details of the neutron flux monitor and of the neutron generator required for in-situ calibration were presented. The interfacing issues for a high resolution neutron spectrometer on ITER have been studied and indicate that implementation of such an instrument is technically possible. The interface for such an instrument is now included in the baseline and will enable a cost effective installation later. Modelling of the neutron emission for a number of ITER scenarios has been performed, demonstrating that information on fast fuel ions and alphas can be obtained, albeit with a low signal-to-background ratio. Neutron spectroscopy potentially gives, amongst others, information on T_i, toroidal rotation, fusion power, heating efficiency, $Q_{non\text{-}thermal}$, and fast ions including alpha particles. A multi-spectrometer system would be needed to cover D and DT operations, as well as the full DT neutron yield range

5.3. Effect of straylight and wall reflections

A special session at the 14th TG meeting was devoted to the effect of straylight and wall reflections on optical diagnostics. One presentation focused on the effects of wall reflections on the operation of the Tore Supra MSE system. The reflections lead to a reduced signal/noise ratio and parasitic lines in the spectrum. The best chords are the ones that look into another port. Various methods are being tested in order to reduce the effect of the reflections including modal decomposition techniques and neutral beam modulation. Although the results are positive more effort is needed. Another presentation argued in favour of using the bidirectional reflectance distribution function (BRDF), widely used in other fields, for standardization of reflection coefficients. The specular reflectance lobe is the most difficult part of the reflectance behaviour to characterise. Using model functions established in the rendering community (i.e. virtual reality models used in computer games), it appears that this lobe is not very important for extended sources such as bremsstrahlung, but for edge sources it is. The modelling calculations remain to be confirmed by measurements on at least one set of completely characterised tiles in order to study whether or not in-situ checks of the evolution of the reflectance with exposure to plasma discharges are possible. Since the wavelength dependence of the reflectance is different from that for bremsstrahlung, measuring at several wavelengths should help to assess the impact in the experiment. For edge emission, imaging should be supported by Zeeman spectroscopy to localise the true source of the emission.

5.4. International Diagnostic Database

The activity in the International Diagnostic Database has been relatively low. Only a few diagnostics have been added. The IN PT has started an analysis of the data in the IDD for a number of different diagnostics. First results of the analysis were shown at the 13th meeting, and a special session on the analysis of the International Diagnostic Database is planned for the 15th meeting.

5.5. Joint ITPA/IEA Experiments

The Joint ITPA/IEA experiments in the field of diagnostics were discussed. Multiple experiments on first mirrors are in progress and are reported in Sec 2.4. A new joint experiment to resolve the discrepancy between measurements made by ECE and Thomson scattering that occurs at high temperature under some conditions was launched by the end of 2007. First results of this activity were reported at the EC-15 workshop in March 2008 in Yosemite, USA.

6. Publications

Three papers co-ordinated by either the TG or by the SWGs have been accepted for poster presentation at the IAEA Conference on the following topics: progress in HP issues, first mirrors, and on Thomson scattering. Also a paper from the IO on the implementation of diagnostics systems on ITER has been accepted. A paper on the neutron calibration strategy was presented at the 2008 EPS Conference.

An overview of other publications by the ITPA TG on Diagnostics is included as Attachment 2.

7. Plans for Future Meetings

The 15th meeting of the Diagnostics TG has been approved and will be held in Ghandinagar, India from 17 - 21 November 2008. The Institute for Plasma Research has kindly offered their support to act as host. Candidate topics for special sessions are: x-ray systems; active beam diagnostics; real time control capabilities for plasma control and an analysis of the International Diagnostics Database (presentation, extended discussion). The meeting will be combined with a one-day Progress Meeting on ITER Relevant Diagnostic Developments on-going in India. The 16th Meeting will be scheduled in the spring of 2009 in Russia.

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ATTACHMENT 1 - PROGRESS WITH PHYSICS TASKS

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
HIGH		
1 Development of methods of measuring the energy and density distribution of confined and escaping alpha-particles	The measurement of the energy and density distribution of confined alpha particles will be important on a BPX. Currently there are no established techniques for this measurement. One possible technique is Collective Scattering. There are two possible implementations: CO_2 (10 μm) extreme forward scattering and near backscattering at mm wavelengths. Proof of principle demonstration on an existing tokamak is required, including measurements on confined fast ions. Similarly, an alternative technique, Knock-on Tail Neutron Spectrometry, requires demonstration on an existing tokamak. 1) Carry out proof-of-principle studies, including physics modelling, of collective scattering on fast-ion populations in a tokamak, a) at CO_2 wavelength, b) at mm wavelength; 2) Carry out proof-of-principle studies of knock-on tail neutron spectrometry on a D-T tokamak; investigate feasibility of pulsed bubble chambers to achieve time resolution < 1 s; 3) Propose and develop concept for other techniques. The measurement of the number and energy of escaping alpha particles will be an important measurement. Currently there are no established techniques for this measurement that are feasible for implementing in a BPX environment. Possible techniques include Faraday cup energy analyser, scintillator or diamond-detector energy/pitch angle and IR imaging. The investigations required are: 1) Carry out proof-of-principle test of Faraday cup analyser in D-T device; 2) Evaluate scintillators for least neutron sensitivity with sufficient light intensity for a reflecting optics system; 3) Carry out proof-of-principle test of diamond detector "array" using a fast-ion population; 4) Carry out a proof-of-principle of IR-imaging in a D-T device; 5) Propose and develop concept for other techniques.	See Section 2.1 of main document. HP topic needs to be continued.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
HIGH		
2 Assessment of the various options for the Vertical Neutron Camera to measure the 2D n/α source profile and asymmetries in this quantity, and assessment of the calibration strategy and calibration source strength needed	The requirements for measurements of the neutron/alpha source profile along with the related justification for the measurements have to be urgently assessed. The principal technique for measuring the alpha source profile is 2D neutron tomography. Conventionally this measurement is made with a radial and a vertical view neutron camera, but on ITER the coverage of the radial camera has been limited and severe interface difficulties have been experienced in the implementation of a camera viewing from above the machine.	See Section 2.2 of main document. First part of the HP topic is concluded. The second part on the assessment of the calibration strategy needs to be continued
3. Assessment of the overall measurement perfor-mance of all diagnostics (credited and uncredited) with respect to the ITER measurement requirements	The capabilities of most individual diagnostics systems (credited and uncredited) have been compared with the detailed ITER measurement requirements. However, to get an understanding of the overall performance of the ITER diagnostics, it is needed to make a detailed assessment which diagnostic techniques can be used in measuring the various ITER requirements and whether the combination of the various techniques can fully cope with the measurement requirements for certain parameters. This will then give immediate insights which of the parameters are adequately diagnosed, and which parameters are underdiagnosed. On its turn this can be used to focus the R&D in the field of diagnostics to the most problematic areas.	See Section 2.3 of main document. This HP Topic has been completed.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
HIGH		
4 Determination of life-time of plasma facing mirrors used in optical systems	The plasma-facing component of all optical systems will be a mirror. The mirror will be subject to erosion and deposition. Systematic measurements of the effect on reflectivity and on mirror lifetime of potentially damaging effects are required especially erosion due to CX sputtering and deposition due to evaporation of first wall and divertor target plates. Lifetime studies of laser mirrors for large numbers of pulses are also required. 1) investigation of the impact of high neutral particle fluxes on metallic mirrors; 2) investigations of material deposited on plasma facing surfaces (e.g. windows) in existing machines; 3) identification of the mechanisms of contaminants deposition and development of models; 4) extrapolation to BPX conditions if possible 5) experience with protective measures, such as shutters and baffles on existing machines; 6) tests of TS laser mirrors up to ITER lifetime are required.	See Section 2.4 of the main document. HP topic needs to be continued.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
HIGH		
5. Development of measurement requirements for measurements of dust, and assessment of techniques for measurement of dust and erosion	Measurements of dust are required to ensure that excessive dust has not accumulated and become a potential safety hazard. Measurements can only be made of the dust in specific locations but the safety inventory limits are set on the total amount of dust on the hot and cold surfaces. Techniques for measuring dust that can be implemented on a BPX such as ITER are required along with a method for extrapolating the local measurements to give estimates of the required global quantities. Techniques are required which are capable of measuring erosion of the target plates in real time. A possible technique under study on current devices is Speckle Interferometry. Another technique used on TFTR is optical radar. Analyse possible techniques; carry out proof of principle tests including real-time in a tokamak.	See Section 2.5 of the main document. HP topic needs to be continued.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
6. Development of new methods to measure steady state magnetic fields accurately in a nuclear environment and assessment of thermal EMF on irradiated coils used for magnetic field measurements	Experiments with a prototype magnetic coil in a neutron and gamma radiation field in a fission reactor gave unexpected results, which have been attributed to Radiation Induced Electro Motive Force (RIEMF). A simple extrapolation of the results shows that problems would occur in the magnetic equilibrium measurements for pulse lengths over several seconds. However, the results are inconsistent with the large body of data on RIEMF in the cable employed (MI cable) and further tests must be carried out.	In Europe new miniature micromechanical sensors have been developed for steady state magnetic field measurements and have been tested in a radiation field. Also new sensors based on the colossal magneto-resistive effects are being considered after a very promising feasibility study. Measuring instrumentation for steady-state magnetic fields in ITER ex-vessel locations is under development at the Magnetic Sensor Laboratory in the Ukraine. The sensors are based on radiation-hard 3D Hall probes, with integrated Hall transducers, electronic unit, interface and the software. These intelligent measuring devices are equipped with tools for self-diagnostics, periodic calibration and correction of the sensors' signal drift. Owing to these functions, the instrumentation provides a high accuracy of magnetic field measurement of 0.3% in ITER-relevant conditions without need for probe replacement during the ITER life time. Prototype sensors were successfully tested in the JET, Tore Supra and CASTOR tokamaks.
7. Establishment of a radiation effects database	During the ITER EDA and EDA Extension phases considerable R&D was devoted to irradiation testing of candidate materials for diagnostic construction (e.g. materials for windows, mirrors, fibres) and some specific components and sensors were tested. Much information is available in this field, but unfortunately it is not readily available in a form that is helpful to diagnostic designers. To aid the diagnostic design process it is proposed to gather the large amount of data on radiation effects into a single database – the Radiation Effects Database (REDB).	The long awaited "Ceramics Irradiation Database" (CDB) has now been prepared as a module within the existing EU Fusion Materials Database System (EUDBS). The initial step is to provide reference to the results of the EFDA Ceramic Irradiation Programme by recording all relevant information, provide a searchable repository of documents, provide a searchable database suitable for designer of diagnostics and H&CD systems to find the available information and facilitate design choices. The system is intended to be extended for full ITER partner use at a later date. The ITPA members will shortly be invited to test and comment on a restricted version. The problems of filling the data base with existing data, and access are now under discussion.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
8. Determination of the minimum target measurement requirement to support the 'advanced' tokamak operation	In view of the recommendations by a number of the other TG's for high resolution in the measurement of several key parameters to support the Advanced Tokamak type of operation, and the difficulty of providing these measurements under BPX conditions, it is proposed to define a new high priority investigation in this area. It is important to determine the minimum target measurement requirements to support these modes of operation.	All changes that have been proposed in recent years by the other TGs have been reviewed and assessed by the Diagnostics TG on a step-to-step basis. These include also the determination of the minimum target measurement requirement to support the 'advanced' tokamak operation.
9. Devise new concepts for measuring light in-core impurities (e.g. He-ash) that do not rely on a diagnostic neutral beam (DNB)	Measurements of light impurities in the plasma core of a BPX are in principle possible by CXRS using a DNB but a DNB that will provide sufficient neutral particles at the plasma core is a difficult and expensive development and installation. Alternative methods that are less demanding on port space and also are cheaper are highly desirable. Propose and develop concept for alternative techniques for measuring light in-core impurities.	No significant developments were reported in the field of He-ash measurements in the plasma core that do not rely on a DNB.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
10. Determination of measurement requirements in divertor region and recommendation of diagnostic techniques	Because of the restricted access and potential damage to diagnostic components during disruptions, diagnostics in the divertor region are very difficult to implement. It is necessary to determine the minimum measurements required for operation and evaluation of divertor performance. The requirements for plasma and target measurements in the ITER divertor region have been further developed in collaboration with the ITPA TG on Divertor and Scrape Off Layer Physics. The discussion on many of the issues has now closed with revised measurement requirements having been agreed and justified. System designs have also advanced and there is now a closer match between requirements and anticipated measurement capability for a number of divertor parameters although some significant discrepancies still remain. In particular the measurement of T_e in the divertor looks very difficult even in the outer leg, and presently there are no measurements of T_e and n_e in the inner leg. Measurements in the inner region are regarded as important, in particular for understanding and optimising the divertor performance.	The assessment of the measurement requirements in the divertor is part of the overall review of all requirements. Specific interactions with the Divertor & SOL TG on this are underway. A review of the measurement options for an inner leg Thomson scattering system has taken place and proposals for the integration of the associated measurement systems into ITER have been presented. Various changes in the divertor structure have made the engineering of this system very difficult. A solution has been proposed which uses the midplane-port in an imaging scattering mode. The scattering angle is about 170 degrees and a spatial scan would be achieved by a slight tilt of the laser with respect to the collection optics. Currently this system is not in the ITER baseline.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
11. Determination of the outgassing rates of mineral insulated cables and develop methods to reduce the outgassing rates.	In ITER up to 80 km of cable will be used, with 1-2 joints in primary vacuum. Potentially about 45 l of trapped gasses could be inside these coils. The coils cannot be sealed, and neither can they be left open. The out-gassing rate of 7.2 m length of coil with both ends open has been measured at DIII-D. The conclusion is that too long a time (in the order of months in ITER) is needed to evacuate the coils. It cannot be proven that leaks will not occur, and keeping the ends open is not sufficient. Therefore ways to reduce the out-gassing rates (e.g. by perforations) are being investigated.	No progress reported.
12. Devise new concepts for measuring j(r) that can be applied to a BPX with sufficient spatial resolution.	Techniques are required for measuring j(r) that can be realistically implemented on a BPX and will meet the measurement requirement. It is anticipated that measurement of j(r) will be required for real-time plasma control for advanced tokamak modes. Techniques that have been used include MSE and polarimetry. MSE requires the use of a current-drive beam with many optical sightlines for good spatial resolution (and, potentially, radial electric field correction) and many components, such as windows, are sensitive to the local magnetic field. The retro-reflectors used in the polarimeter are very vulnerable to erosion and deposition and can be a potential showstopper. Hence both are very difficult to implement on ITER.	Much work has been reported on the measurement of j(r) by MSE (US PT) and polarimetry (JA PT). Both techniques are thought to be feasible on ITER although have significant technical challenges. No specific reports have been presented on new concept techniques for the measurement of j(r).

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
13. Determination of impurities in divertor using only visible and UV spectroscopy	Presently some key impurities (heavy ions?) in the divertor region can only be measured using VUV spectroscopy but such measurements will be difficult/impossible to implement on a BPX. 1) Carry out appropriate atomic physics calculations to determine whether the information can be obtained from measurements in the visible and UV that are more easily made. 2) Evaluate agreement between measurements made now in current tokamak divertors in the visible and UV with model calculations.	Prototypes of the collection optics for the divertor impurity influx monitor have been built. These include a Cassegrain telescope and micro-lens array joined optical fibers. A computerized tomography reconstruction based on the maximum entropy method has been applied with two divertor viewing fans. The emission line intensity of carbon impurities in the divertor plasma has been estimated by means of the Eirene-B2 code including a collisional-radiative model. An in-situ calibration system using a micro retro-reflector array has been developed for the Impurity Influx Monitor. Ray-tracing analysis has shown that the optics has good enough performance, with sufficient signal to noise ratio in a wide wavelength range (200 nm ~ 1000 nm).

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
INTERMEDIATE		
14. Measurement of runaway electrons	While runaway electrons are already a problem on present-day machines, they pose a significant danger on ITER as the runaway current scales with plasma current, and must therefore be diagnosed. Techniques are required for measuring the runaway current and typical runaway energy and which are feasible for implementation on a BPX. Existing techniques, for example the measurement of the X-ray emission will be difficult/impossible to implement because of the intense gamma background. 1) A critical review of the possible techniques is required. The latter include, but are not limited to: I) synchrotron emission in the infrared; II) hard x-ray measurements; III) ECE at high harmonics. Extrapolation to possible runaway energies in ITER must be considered in the analyses. 2) Carry out measurements using these techniques for various non-thermal electron components in tokamaks.	No progress reported.

Measurement Requirement	Motivation and Required Investigation/Development	Progress since June 2007
LONG TERM		
15. Demonstration of direct measurement of local electric field	Techniques for measuring the E_r in the plasma core directly and which can be implemented on a BPX are required. 1) Propose and develop a technique for measuring E_r directly inside the plasma core. 2) Implement a test of the technique on an operating tokamak.	At ASDEX-UG it was demonstrated that high-resolution radial profiles of the perpendicular $\boldsymbol{E}\times\boldsymbol{B}$ rotation velocity can be diagnosed by means of Doppler reflectometry, from which the radial electric field E_r can be obtained, together with E_r-shear profiles showing enhanced negative shear in H-mode. Adding a second probing channel allows simultaneous E_r-shear and turbulence radial correlation measurements.
16. Measurement of core density fluctuations (reflectometry can only work from high-field side on the low frequency cut-off)	Measure the core density fluctuations on ITER cannot be made from the low field side because the density profile is expected to be flat. Hence, it is currently proposed to use reflectometry on the low frequency cut-off from the high field side but there is no experience of measuring fluctuations using this cut-off.	Adding a second probing channel to Doppler reflectometry allows simultaneous E_r-shear and turbulence radial correlation measurements. Numerical simulation results show that Doppler radial correlation is a more robust diagnostic technique than standard normal-incidence correlation reflectometry. By looking at fluctuations in the Doppler frequency shift, coherent flow perturbations such as GAMs can also be studied, as well as straightforward measurement of the turbulence k-spectra. Beam-emission spectroscopy (BES) can be used to characterize plasma turbulence and flow profiles, for which it is one of the few options. The key to success is to achieve high enough a signal-to-noise ratio to resolve sub-percent fluctuations in plasma density up to 1 MHz bandwidth. A first estimate of the measurement possibilities on ITER reveals that measurements on the DNB from the core CXRS system could resolve MHD waves with $m = 10$–60, and therefore could potentially detect fast-particle modes. With the BES optics planned for the equatorial port, turbulence measurement will be possible only at the edge.

Attachment 2
Publications by the ITPA TG on Diagnostics 2006-2007

Publications in peer-reviewed journals

- A. Litnovsky , V. S. Voitsenya , A. Costley and A.J.H..Donné for the SWG on First Mirrors of the ITPA Topical Group on Diagnostics, *First mirrors for diagnostic systems of ITER,* Nucl. Fusion **47** (2007) 833-838.

- F.P. Orsitto, J.-M. Noterdaeme , A.E. Costley, A J H Donné and the ITPA TG on Diagnostics, *Requirements for Fast Particle Measurements on ITER and Candidate Measurement Techniques,* Nucl. Fusion **47** (2007) 1311-1317.

Presented at the 2008 EPS Conference

- L. Bertalot et al., *A strategy for calibrating the Neutron Systems on ITER,* Proc. 35th EPS Plasma Physics Conference, Hersonissos, Greece (9-13 June 2008), Paper O-2.001

Accepted for the 2008 IAEA Fusion Energy Conference, Geneva, Switzerland

- A.J.H. Donné, A.E. Costley, for the ITPA Topical Group on Diagnostics*, Key R&D activities for ITER Diagnostics*

- M. J. Walsh, M. N. A. Beurskens, T. Hatae, D. Johnson, E.E. Mukhin, R. D. Scannell, G. Vayakis, *Performance evaluation of ITER Thomson scattering systems*

- A. Litnovsky, V. Voitsenya, T. Sugie, G. De Temmerman, A.E. Costley and A. Donné, *Progress in research and development of mirrors for ITER diagnostics*