Chengdu, IAEA meeting 2006

ITER, Safety and Licensing – One year after site decision

J.-Ph. Girard on behalf of the ITER international team and its partners

Joint Work Site Cadarache, 13108 Saint Paul lez Durance France

jean-philippe.girard@iter.org

The safe design of ITER has been paramount since the beginning of the ITER studies and the safety analysis was included in the *Generic Site Safety Report* produced in July 2001 together with the Final Design Requirements Report (FDR2001). On June, 28th 2005 it was decided to implement the experimental fusion facility in Europe, close to Marseilles, south of France. The design now needs to be checked according to the local legal requirements and the licensing will have to comply with the French regulations. This is the so-called undergoing ongoing site adaptation process. The safety analysis will be presented to the regulator and public hearings should lead to the "license". Construction will then start.

From January to May 2006 a public debate was launched to present the facility during a set of 16 meetings mostly in the locality. This process is the French implementation of the European Aarhus convention, signed on June, 25th 1998 which whose purpose is more transparency with the population on major investments.

The French safety regulations are mostly non-prescriptive and request that design provisions be taken according to the level of risk. Nevertheless a few areas must follow prescriptive design rules. Fire prevention thus requires putting in place fire and confinement sectors; pressure vessels and equipment must comply with a European directive and with a French order in case of nuclear inventory. Building design and construction have to comply with European rules. The ITER designers, in close contact with the Participant Teams, are proceeding with the upgrading of the design to comply with these requirements. The codes and standards for all equipment are also under revision in order to fit with the expected requirements, taking into account the procurement sharing agreement and the above regulation

Finally, and may be primarily, the QA system of the future organization will have to comply with a French order for nuclear facilities set in 1984 and close to the IAEA 50-C/SG-Q. The responsibility of the future ITER operator for procurements dealing with safety is emphasized in this order and will lead to the necessity for a close contact between the central team and the providers.

These three topics, *Quality assurance* of the safety- related procurements, *Codes and Standards*, *Safety and licensing* according to the local requirements, are the key challenges for the coming 18 months and any mismatch could have high impact on the project performances, cost and planning.

We review the current status of preparations, and highlight those areas requiring maximum effort in the immediate future.

1. Introduction, ITER, site decision

Seventeen years after the start of the *Conceptual Design Activities* (1988-1991), thirteen after the beginning of the *Engineering Design Activities* (1992-2001) the ITER partners have decided in Moscow on June 28, 2005 the implementation of the facility in Cadarache. In 2001 the 4 first partners (EU, Japan, Russian Federation, USA) have endorsed the design. Three more partners joined since (China, South Korea, India) and ratification of the ITER agreement is expected in 2007. The *Agreement* was initialised in Brussels (24 May 2006) and should be signed in November 2006. The ITER organization will be the designer, the responsible for construction and the operator of ITER, a nuclear facility in the Host state, France.

The partners, co-called parties of the ITER agreement will first set in place a **council;** this board will control the work performed by the ITER organization.

The **ITER organization** is now working under an interim agreement and designation of DG (Director general), PDDG (Principal Deputy DG) and DDG (Six Deputy DG) nominees has been gradually done since December 2005. Other staff members are seconded from research and development associations of the ITER's partners until full ITER employment can be achieved.

Each party will set in place in each of their territory territories a **Domestic Agency** (DA) to procure in-kind components to the organization for assembly.

The **host state** will take care of site preparation, welcome of ITER staff new comers, schools and road modifications for the transportation of heavy loads from the harbour on the Mediterranean Sea close to Marseilles to the site.

Finally to support the project and maintain their skills for the future of fusion power plants individual contributions of the partners' research associations, based on self-contribution, are leading research to help the project. The work agreements are called and detailed in "**ITER task agreements**" (ITA). These contributions, to support the safety studies and the licensing of ITER, are performed by all the partners, nevertheless the recent choice of Cadarache in Europe gives European associations a leading position to support the licensing issues.

2. ITER generic safety features, design, safety reports

The purpose of ITER is to demonstrate the possible operation of a tokamak with long deuterium-tritium plasma pulses with net balance of energy and the qualification of technological components for future fusion power plants.

The facility is mainly the assembly of three sub-systems:

- the **tokamak** with its vacuum vessel (the plasma chamber) and cryostat and super-conducting magnets, gas injection and pumping systems, plasma heating systems and diagnostics, heat rejection systems collecting the heat from the slowing down of neutrons in the first wall and blanket inside the vessel

- the **tritium plant** for tritium regeneration, purification and storage, it includes all rooms and glove boxes detritiation systems working either on full-time or stand-by basis

- the **hot cells**, neutron neutral beam hot cells[1], maintenance hot cells and **waste facility**

The tokamak, the diagnostics and the tritium plant are in a common building called the tokamak complex building set on aseismic pads.

ITER is the first true fusion nuclear facility. It is both important both for the experimental one-of-a-kind reactor, ITER, and for the future of fusion power plants to well understand the key safety issues of this new type of energy production device, though some differences will be highlighted to present the specificities of ITER.

The main original feature of this type of nuclear facility is the plasma, using, as fuel, nuclei of deuterium and tritium. The tritium is a radioactive material,.

The output of the fusion reaction are:

- a nuclei of helium (which is not radioactive) and whose energy will be used to partially heat-up the plasma and
- a neutron bearing the energy expected to produce heat by collisions in the blanket. This slowing-down process has the side effect that when the neutron is captured or interacts with atoms, it can activate the material by transmutation of specific atoms, mainly of the first wall. On the other hand this neutron can interact with lithium in order to produce the tritium needed to feed the fusion (though this process will not be full scale tested in ITER, test demonstration of breeding capabilities will be done in test modules provided by the partners under ITER-IT quality control).

2.1. The plasma power control

In contrast with fission reactors the neutron produced by the fusion of deuterium and tritium cannot sustain the reaction: there is no possibility of chain reaction. Moreover in a fission reactor all the fuel needed for months of energy production is present in the pool all the time. In a fusion plant only the amount of fuel for the instantaneous production of energy is fed in the tokamak at one time. In ITER the amount of tritium nuclei inside the tokamak plasma at one time is a fraction of gram.

The plasma fusion rate is mainly dominated by:

- the injection flow rate of tritium and exchange of tritium with the first wall
- the temperature controlled by the heat balance between auto alpha heating and other heating systems controlled from outside of the plasma (neutral beam, pellets injectors…) and
- the density of the plasma monitored controlled by the magnetic field.

Any deviation from the nominal parameters will lead either to a quick stop of the deuterium-tritium fusion or to a small possible increase of power and in any case a limited amount of possible released energy. Any pollution from the first wall (dust) will impair the operation of the plasma.

Power control is only requested to maintain the confinement barriers in the specified temperature conditions to avoid leakage of the tritium and other contaminants as dust

[1] In the design the NB hot cell is in the tokamak complex

produced in the tokamak and corrosion products in the cooling system (note that in a fusion power plant the wording “cooling system” will be replaced by “heat extraction system” to produced the electricity). The power will be automatically shut down in case of an abnormal situation in the cooling systems to prevent overheating of the first wall.

2.2. Decay heat removal

The heat removal, during plasma operation, is performed through cooling systems of the first wall, blanket and divertor. Most of the neutron energy and other radiation from the plasma is collected by these components.

As soon as the fusion process will stop the heat power to remove is only the energy deposition in the structures arising from decay of the neutron activation products. There is no inherent power in the fuel that would need attention.

The design is such that either one of two 100% cooling systems of the vacuum vessel (VV), circulated by passive convection, can remove this heat and maintain low temperatures of in-vessel componentsprevent any degradation of the primary barrier thus maintaining the integrity of the confinement of the radioactive inventory.

2.3. Inventories at risk and confinement

As a result of these two first comments the prevention of the release and dispersion of radiotoxic material is the main safety function of ITER.

The specific ITER inventories at risk are the tritium and the dust produced by plasma wall interaction in the VV. The activation activated corrosion products in the cooling system are less significant even though the cooling systems are more exposed to the neutron flux than the secondary loops of a fission reactor.

The tritium-gas inventory of ITER is mainly in the tritium fuel cycle including fuelling, pumping and tritium processing. As a result of the choice of carbon and beryllium for the in vessel plasma-facing component a significant trapped tritium inventory is also expected to accumulate in these components. As a whole, a few kilograms of tritium can be present at a time.

The dust inventory is also expected to build up during operation and it will be an experimental objective of ITER to study this accumulation process. As a safety provision it is taken into account in the design that a few hundreds of kilograms of carbon, beryllium and tungsten dust can be present in the VV. Dust inventory measurements and dust removal systems are under consideration to be available before tritium plasma operation.

Both the accumulation of tritium in the first wall and the build up of dust are ITER material dependant and cannot be considered as future fusion facility issues.

To prevent any significant tritium releases, ITER will be the first tritium facility with full detritiation and recycling capabilities. Very low gaseous and liquid releases are expected in normal operation, less than 10µSv as impact on the first nearest inhabitants.

A first confinement system will prevent releases. In case this system will fail, a second mitigation system will prevent expansion of events and/or moderate the releases in order to maintain their consequences at a level that will prevent in any case the need to take counter-measures on populations.

The first system is the process wall (VV, cooling system, tritium process, cell and waste confinement). The second system includes cells, vault and building areas with ventilation that can be turned to a depression system, filters and detritiation systems in case a leak will occur.

2.4. Main incidental/accidental sequences and design assumptions

The facility is designed to withstand a failure of a first wall components facing the plasma. In such a case the coolant from the blanket or the divertor would be spilled in the vacuum vessel causing an immediate inherent shut down of the plasma. The VV pressure will increase due to the water/steam ingress. Such overpressure will be easily accommodated inside the 1000 m^3 VV and extension; would the leak be bigger a bleed line and a drain line will accommodate and allow collection and condensation of steam; finally would the collapse of the cooling system be large and sudden, a rupture disk will passively open and a specific device called the VVPSS (VV Pressure Suppression System), full of cold water, will condensate the steam and allow to maintain the VV under the design pressure; the sky atmosphere of the VVPSS is linked to the detritiation system. The VV and window design takes into account such overpressure as well as other loads (1kW/cm^2 as order of magnitude of the divertor thermal load, magnetic field load).

The confinement of inventories at risk is in such a way guarantied as long as no energy could be mobilized that could challenge the integrity of the first confinement system. Such energy could be mobilized in case of magnetic arcs (energy in the plasma and magnets could be from 1 to 50GJ, although this energy is spread over a relatively wide area) or by double breaks of the cooling circuits in between the atmosphere outside of the VV and the inside of the VV that could lead to air ingress and reaction with the dust.

Special care of the design and quality control of the VV, the windows and the cooling system procurements, in- service monitoring of magnets deficiencies as well as an automatic fusion plasma termination system will prevent double break and air ingress in the vacuum vessel.

The safety of the tritium plant, the hot cells and the waste storage will rely on standard defence in depth and barriers as for any such facilities already being operated, Candu reactors or other defence facilities.

2.5. Operator radiological exposure

The specific experimental nature of ITER including replacement of in-vessel components leads to the necessity of development of devoted remote handling and machining robots. The mean overall yearly doses on operator is expected to be less than 0.5 man.Sv with the target of an individual dose lower than 10 mSv over twelve consecutive months. Careful check of doses on operators during maintenance will allow a better monitoring and improvement as lessons learnt from other nuclear activities have shown it.

3. Inputs from the host country, France. Regulation, Codes and Standards

ITER will be operated in EU/France. As agreed in the JIA (*Join ITER Agreement*), ITER organization, as operator of a nuclear facility, in France, will comply with the French regulations. Regulation applies to safety important components, pressure equipments, buildings, handling devices, electric networks… Main regulations concern licensing, quality, transposition of European recommendations in the French law[2]. Most of the documentation

[2] -Order from 2006: law on **transparency** for nuclear facilities
-Order from 1984: **Quality** in nuclear facilities, close to the IAEA 50C-QA guide

for design and operation comes from IAEA or ICPR international standards. This regulation together with the experimental requirements, including the safety inputs, is the basis of the essential requirements for the design. Generally, from the safety and licensing point of view, in France, any International Code and Standards is accepted for the design, fabrication and operation of mechanical components. Assessment of the conformity of the facility with the regulation and the safety provisions will have to be done and proven to the regulator.

3.1 Example of site adaptation – prevention of fire

Except in case where no fire load would be present in a given room, the French regulation recommends that all rooms with nuclear a radioactive inventory would be protected to prevent impact of fire. The fire is postulated, then fire sectors or fire sectors and confinement sectors are implemented to limit the impact on the environment in the event that the postulated fire would happen. This should induce some modifications in the tritium plant, mainly to be able to operate the ventilation and these fire sectors and confinement sectors during the fire. Stability, depression, confinement, and detritiation performance will have to be assessed.

3.2. Pressure equipments

The generic project postulated, as a reference, that it would/could be designed, built and operated according to US C&S. This assumption was done even though completeness of the set of codes proposed was not fully demonstrated.

Ad-hoc modifications were expected (code cases) in the detailed design phase as well as site adaptations to local regulations. As far as pressure equipments are concerned the Pressure Equipment Directive, PED, (97/23/EC) is in force in the EU member states since May 29, 2002. The directive provides an adequate legislative framework on at the European level for equipment subject to a pressure hazard. It has been introduced in France by a set of decrees[3] The Directive applies to the design, manufacture and conformity assessment of pressure equipments and assemblies of pressure equipments with maximum allowable pressure greater than 0.5 bar above atmospheric pressure (i.e. 1.5 bar of absolute pressure). The manufacturer needs to classify the equipment into categories and subject to this classification performs an appropriate conformity assessment under the control of a Notified Body.

The Directive and associated French decrees states that nuclear pressure equipments should comply with a specific home state order[4]. This order provides the requirements for design, manufacture and operation of equipments that may induce releases of radioactivity in case of

---

-Order from 1963 amended: what is a nuclear facility, **licensing process** and public hearing
-Order from 1995 upgraded: **releases and water intakes** (public hearing)•Order from 199 upgraded: **design prescriptions**
-Order from 2006: application of CEE rules on **pressure vessels**
-Order from 2006: application of CEE rules for **radiological zoning** and workers Operational Radioactive Exposure

[3] The PED is in force in France by the following Decrees:
-French Decree dated 13 December 1999 concerning pressure equipment (Amended by Decree No. 2003-1249, 22 December 2003 and by Decree No. 2003-126, 23 December 2003);
-French Decree dated 21 December 1999 concerning the classification and evaluation of the conformity of pressure equipment;
-French Order dated 15 March 2000 concerning pressure equipment operation (Amended by Order dated 30 March 2005).

[4] French Order dated 12 December 2005 concerning nuclear pressure equipment (ESPN).

failure. Nuclear Pressure Equipment (ESPN in French) are equipments which are pressure equipment as defined in PED, are used in a nuclear facility, have a direct role in confining radioactivity in normal operating conditions and would lead to the release of over 370 MBq in case of failure (370 GBq for tritium). ESPN follows the pressure hazard classification and conformity assessment procedure in many cases based on PED requirements. In addition, each pressure equipment is classified into one of the three levels N1, N2 and N3 related to the nuclear hazard. Ministry in charge of nuclear safety shall approve notified Body for equipment under level N1 and N2.

The classification of equipments, the choice of the code to apply, the material standards to specify, and the conformity assessment are under way. The work will need careful checking against safety function of equipment, safety requirements – such as pressure specification according to abnormal sequence analysis – and clever choice of codes according to procurement sharing and interface management for a given component or between two components.

As far as the choice of codes are is concerned, investigation on an addendum to the EU RCC-MR (code for fast breeder reactor) is under consideration for the vacuum vessel, either ASME/ASTM or EU standards will be specified for other parts of the facility according to the requirement and the country which will procure the component.

4. Licensing process, public debate, public hearings

The licensing of ITER, in France, has been started by the host state in the candidature phase where a safety review took place with the French regulator in November 2002 on the basis of the generic design. Based on a so-called “Dossier d’Options de Sûreté” (DOS), the French Nuclear Safety Authority (NSA) has issued advices related to activation of components by the high energy neutron flux, inventories at risk, reliability of cooling systems, the list of incidents and accidents and waste management.

As soon as the site decision was taken (June 28, 2005) the host state organized a public debate to present and explain the objectives of the ITER project and surrounding aspects to the public (both locally and on a broader scale, Paris and Nice). Meeting were held from January to May 2006. There were 16 meetings, 2500 attendants, and a dedicated website (http://www.debatpublic-iter.org/). Technical questions were asked during these meetings and on the web site. Nevertheless the debate did not introduce new technical issues. Most of the questions dealt with understanding of releases (both radioactive and chemical), seismic hazard and waste management. “Non-fusion” aspects such as load transportation, schools and cost increase of lodging took most of the discussion session time.

Both the first safety review and the conclusion of the public debate will be inputs for the next steps that is the public hearings. In parallel to the final design, and taking into account the local regulations, the Preliminary Safety Report (RPrS) will be drafted with support of the European partner and others in the framework of ITER Task Agreements. Together with the license application, the RPrS will be forwarded to the regulatory bodies, which will launch public hearings and a safety review. Both processes must succeed in order to start the nuclear buildings construction. In parallel, France, responsible for site preparation will also launch authorisation requests to enable standard constructions, electric supply, site clearance and road upgrades for heavy load transportation, which are not safety-related permits but have to follow an administrative procedure. It is expected to be able to launch the public hearing in 2008, together with the safety review. The process will take from 12 to 18 months after the

ITER international organization will have officially forwarded the documents to the State ministers and to the regulator. This will make possible the start of the on-site construction -on site- during 2009. During the construction a continuous dialogue with the regulator and a careful survey of the component fabrication done under the responsibility of the partners shall insure ensure a trouble-free continuation of the project. This should lead to the first plasma in 2016. Before the start-up of ITER with deuterium and deuterium-tritium plasma a final safety report (as-built) will be reviewed by the regulator to authorize the operation with radioactive material.

5. . Status, milestones, lessons learnt

ITER is a large project. As such the work breakdown structure, configuration management as well as interface management is a key issue of the project. Education and communication of all the partners in close contact with the project (for instance the regulator, support teams, even contractors) is also a major issue for its success.

The site-specific safety report (RPrS) is under preparation together with final design changes and site adaptations. In parallel the new management has launched a technical design review. Both processes should lead to the final procurement specification early 2007. The safety and licensing files should be ready by the end of next year in order to meet the target of the start of nuclear building construction beginning of 20082009.

Codes and standards is also a key issue to solve, before procurement can be launched. The unique and specific nature of ITER will require ad-hoc adaptation of available C&S to meet both the design specifications requested by the experimental nature of the facility and essential safety requirements of the regulation.

Acknowledgement

This report was prepared as an account of work undertaken within the framework of ITER Transitional Activities (ITA). These are conducted by the Participants: the European Atomic Energy Community, Japan, the People’s Republic of China, the Republic of Korea, the Russian Federation, and the United States of America, under the auspices of the International Atomic Energy Agency. The views and opinions expressed herein do not necessarily reflect those of the Participants to the ITA, the IAEA or any agency thereof. Dissemination of the information in this paper is governed by the applicable terms of the former ITER EDA Agreement. Note that India now joined the project and will be part of the ITER-IT.