QA, Safety, and Licensing Related Codes and Standards Issues

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ITER QA Program

- French regulator will require a quality assurance program for ITER activities including TBM
  - ITER will be regulated as an experimental nuclear device not a fission power reactor
  - Quality Order of August 10, 1984 “Concerning Basic Nuclear Installation design, construction and operation quality”-OFFICIAL GAZETTE OF THE FRENCH REPUBLIC SPECIAL ISSUE September 22, 1984, page 8652
  - ITER is currently assembling QA requirements
  - To facilitate regulatory approval for TBMs, the TBM projects should adopt the ITER QA program to the extent possible
    - Must recognize the experimental nature of the TBMs (e.g. high temperature design rules)

Why does ITER need a QA program?

- A good QA program will provide a quality product that will pass regulatory muster
  - Establish overall umbrella of project controls and requirements
  - Establish uniform mechanism for vendor qualification
  - Produce documented pedigree of the component/system/item
  - Increases confidence that components/systems will function as anticipated
  - Reduces technical risk
  - Overall benefit to the project given complexity of ITER and the number of institutions involved
- Provides a structured framework to perform ITER-related design activities in the areas of
  - Design control, inputs and changes
  - Formal design review and configuration control
  - Design verification and validation
  - Data/testing needed to validate design
  - Safety analysis
  - Records/documentation
- ITER is drawing upon QA requirements from other well established standards

Licensing/Regulatory Approval

- ITER is a “nuclear” machine (kg level of tritium and Megacuries of activated material) and will need to obtain regulatory approval from the host site
- The license from the safety aspect is in large part focused around providing an adequate safety case (e.g. acceptably low risk to the public and to workers)
- Many of the licensing activities are related to safety issues/concerns
  - Safety analysis (source term, accident identification and consequences)
  - Validation of safety methods
- Some of the licensing activities are related to design verification
  - Commissioning tests of the facility to verify behavior of key components and interaction among components
  - Surveillance program to verify shielding
  - QA
  - Different than current tokamaks and different than fission reactors
- Depth and rigor of the regulatory approval and design verification processes will depend on French regulator

Equipment Qualification

- Components and systems are qualified in all engineering endeavors
- In nuclear systems, the activities that comprise the qualification have two parts:
  - Design/operational validation: Establishment of the operating window and associated operating margins, for the system, ensuring it will function as designed (e.g. heat extraction, tritium behavior,magnetic confinement, reliability, temperatures, stresses, etc) - *more of an investment protection flavor*
  - Licensing aspects: Providing information needed to support safety analysis or licensing basis for the facility
    - Source terms, failure mechanisms if important, failure rates
    - System behavior under off-normal conditions

Qualification/Licensing: Fission vs. Fusion

- Important differences exist in the objectives for qualification and licensing for fission compared to fusion
  - Risks of the two systems
  - Safety strategy of the two systems. ITER is more like an experimental fission reactor than a nuclear power plant
- The US has always argued that what needs to be qualified, how you qualify it (depth and rigor), and why you qualify it are very different for these two systems

Basic ITER Safety Strategy

- Implements project objectives "to operate safely and to demonstrate safety and environmental potential of fusion power"
- Recognizes ITER is an *experimental fusion nuclear* facility
- Must tolerate uncertainties associated with entering a new plasma physics regime and use of materials with 14 MeV neutron damage
- Must allow maximum design and operational flexibility

ITER Safety Approach

- Minimize safety burden on plasma physics, plasma control, diagnostics, divertor, first wall shield/blanket, and magnets
- Shift safety burden to vacuum vessel, cryostat, heat transport systems, and tritium plant which are known verifiable technologies
- Makes safety case more demonstrable because safety is implemented using proven technology with operating experience

ITER as an Experimental Machine and Its Impact on Regulatory Approval

- A key aspect for obtaining regulatory approval is the depth and rigor of the safety analysis. French regulators will expect a fair amount of depth and rigor in the analysis
- Experimental fusion machines like ITER will be hampered compared to fission because regulators expect:
  - Well developed computer codes used for analysis
  - Codes validated with data different from that used to develop the codes/models
  - Quantified uncertainties in calculations
  - Current fusion database is probably inadequate. The lack of rigor in safety analysis will probably lead to a conservative phased approval process by the regulator
- There will be more emphasis on “demonstration by test” during R&D and commissioning than with proven nuclear technologies
- ITER regulatory approval and operation will set a *fusion* precedent for qualifying many of the non-nuclear systems (e.g.,pellet injection, pumping, heating, diagnostics) in the plant that still have some safety role (e.g. confinement)

Qualification requirements for non-safety or experimental fusion components

- Regulators will not have a "cut and dry" set of rules for fusion. The ITER designers need to develop what makes sense
  - Need to demonstrate that rules used for ITER components are prudent; identify exceptions and justify them
  - This has been done for many of the major components in ITER including the critical safety components
  - Developing such rules for fusion in a prudent manner with strong technical arguments will help the regulator make the most informed decision possible
  - Regulator may use experts or peer review as a means of acceptance
- Key items that need to be examined/re-visited include:
  - Load cases
  - Reliability requirements
  - Acceptance criteria (TBMs cannot use existing rules)
  - Safety margins implicit in acceptance criteria
  - Materials and welding approaches
- Simple rules may not work for the complicated stress state in some components like the TBMs and magnets. In some cases more sophisticated design by analysis techniques may be needed
- My experience in developing the fusion safety standard is that this is hard work

Phased Approach to Regulatory Approval

- Phased approach during facility commissioning is expected
- Verification of design and assumptions in safety analysis during initial startup if data were not available prior to facility operation
- The approach basically starts with restrictive/conservative operating and safety envelopes that are gradually relaxed as more confidence is gained by regulators and facility operators about the performance of ITER
- Precedence for this approach in light water reactors and other DOE nuclear facilities.
- This approach will place a greater burden on the commissioning phase of the project for systems that play a role in the safety of the machine, especially radiological confinement around the tokamak and decay heat removal. Greater attention to detail and documentation should be expected.

Summary

- Qualification of ITER design will be required as part of obtaining an regulatory approval to operate.
- Qualification has both design verification and safety aspects.
- Fusion is not the same as fission and thus the approach to qualification should be different.
- ITER is a “nuclear” machine and thus different than current tokamaks in terms of safety and environmental issues.
- Given the experimental nature of ITER, a phased approach to regulatory approval is anticipated. Commissioning and demonstration by test will be very important.
- Given the lower risk of a fusion facility, it is not clear that nuclear grade design codes must be used in design of components. Non-nuclear grade codes may be acceptable. There are many aspects to consider when selecting a design code beyond safety (reliability, margin, design complexity, inspectability)
- Designers/fusion researchers need to be involved in development of rules that make sense for fusion. The ultimate decision will be made by the ITER host but strong technical arguments about appropriate rules/approaches can help guide the regulator to make prudent informed decisions.
- ITER will provide an important fusion precedent for the safety strategy outlined here, the approach to regulatory approval and qualification of many fusion components.