Perspectives on the Final Design Review process from the US ITER Diagnostic Residual Gas Analyzer team.

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Motivation for this talk

• The ITER Diagnostic Residual Gas Analyzer system (PA 5.5.P1.US.01) was presented at a Final Design Review (part 1) on July 29-30, 2014 at the ITER building in France.

• This was the “first US-credited diagnostic to reach FDR.”
  – Provisionally passed; Cat. 1 Chits currently being resolved.

• This was the “second diagnostic system to reach FDR of all DA’s.”
  – First was the Rogowski Coil System (EU)

• Motojima: “Please complete the DRGA design as quickly as possible.”

Thanks to ITER DRGA team

• ITER International Organization
  – Philip Andrew (Technical Responsible Officer)

• US ITER (Domestic Agency of the US)
  – Dave Johnson (WBS manager), Bill DeVan, Emil Nassar

• ORNL F&MNS Division (subcontract to US ITER)
  – Ted Biewer, Chris Klepper, Van Graves, Chris Marcus, Tim Younkin

• National Resource Management (subcontract to ORNL, engineering analysis & design)
  – Chris Bett, et al.

• DeNuke Inc. (subcontract to ORNL, scheduling)
  – Mike Morris
Outline

• Admittedly, a RGA is a relatively simple diagnostic to implement, technologically.
  – Send a simple system down the path (of implementation) to find where the landmines/potholes are.
  – Path to implementation is still steep for subsequent (more complicated) systems, but it may be less rocky.

• Nothing is easy in a nuclear environment; technologically or procedurally.
  – Technical: radiation, magnetic field, stress (baking), etc.
  – Procedural: documents, traceability, RAMI, seismic, etc.

• Recognize and respond to “dynamical nature of constraints” on the system design.
  – Being early in the schedule leads to more susceptibility to changing constraints.
Measurement Requirements of the DRGA Systems

- DRGA measurements **during pulse**
  - Group 1a2 measurements needed for basic machine control.
  - **Goal**: measure fuel ratios, He (ash), and impurity concentrations
  - 1-100 amu range, with 0.5 amu or better
  - Time response: <1 s in divertor, <10 s at midplane
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• Nuclear-qualified environment drives the design
  - Particularly challenging to be robust against “off-normal” loads, conditions, and events.
The process of diagnostic delivery

General Milestones

• CDR – Conceptual Design
• PDR – Preliminary Design
• FDR – Final Design Review
• MRR – Manufacturing Readiness Review
• FAT – Factory Acceptance Test
• SAT – Site Acceptance Test
• Installation & Commissioning
• Operation
The process of diagnostic delivery

General Milestones
- CDR – Conceptual Design
- PDR – Preliminary Design
- FDR – Final Design
- MRR – Manufacturing Readiness Review
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- Installation & Commissioning
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Dates for DRGA System
- CDR – July 2010 ✔
- PDR – April 2013 ✔
- FDR1 – July 2014 ✔
- FDR2 – →Fall 2016
- MRR – →Fall 2017
- FAT – →Spring 2019
- SAT – →Fall 2019
- Installation (advisory)
- Commissioning (advisory)
- Operation (not in scope)
  - 1st plasma ~2023?

“ITER is a construction project, not a research program.”

- Technical solutions [i.e. new diagnostics] (if identified today) would still require ~10 years as an engineering design Project to be installed on ITER.

- ITER (like NASA) will be “flying missions” with (somewhat) obsolete, but qualified, technologies.
  - Instrumentation choice is proven technology but “state-of-the-art” is a moving target.

- ITER IO recognizes that splitting FDR’s can allow for the design of front-end components (necessary for integration), while allowing instrumentation to evolve and be designed later.
Dynamical nature of design constraints

- Simultaneous construction and design of interfacing systems creates challenges
  - E.g. location of embedded plates in floors/walls.
  - E.g. estimation of severity of off-normal events (engineering loads) continues to evolve.

- ITER has prescribed environmental parameters, but actual (predicted) values have not been calculated in some instances.
  - E.g. DRGA FDR1 design sought to minimize the moments and forces on elements whose allowable limits have not been established.

- Integration activities will drive the DRGA milestones going forward.
Summary and Conclusions

• The ITER DRGA system is the first US-credited diagnostic to reach the FDR milestone.

• The process of achieving the split FDR1 milestone has been educational to ORNL, US ITER, and ITER IO.

• As more sophisticated diagnostics systems strive for implementation on ITER, the challenges will grow.

• Hopefully, some pitfalls have been identified and removed as a result of lessons learned from the DRGA project.

• Rigor of the design process (when applied to all systems, plus their integration) gives the DRGA team confidence that ITER will be a technical success.
Thanks for your attention
Example: Cryostat Pass-through & IGP

Compliance with ASME – Results

- Node points of interest are:
  - Node 10, Vacuum Vessel
  - Node 68, Elbow at Node 70 …worst case for thermal stress in-port
  - Node 90, Elbow …worst case for primary stress in-port
Example: CP-t & Inner Guard Pipe

Compliance with ASME – Results

- Dyn14 – VDE4

```
**** B31.3 -2010, March 31, 2011
**** CODE STRESS CHECK FAILED

HIGHEST STRESSES: (  KPa  )

CODE STRESS %:  246.7  @NODE 10
STRESS:     269919.7 ALLOWABLE: 109434.
BENDING STRESS: 268516.6  @NODE 10
TORSIONAL STRESS:  23795.8  @NODE 79
AXIAL STRESS:   2925.0  @NODE 80
3D MAX INTENSITY:  271087.2  @NODE 10
```

- Results for piping in scope are 99% of 189 MPa allowable at Node 68.
- Node 10 is located on the out-of-scope inner guard pipe.
- The allowable limits are adjusted by hand to correspond to B31E.