Some Thoughts on Safety

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Presented at the APEX meeting
January 12-14, 1998

Operating Principles for the Safety Group

Find something that works from an engineering/physics standpoint, if we have the luxury of choices (e.g., materials), check with safety group for input

Design to optimize safety comes later

allowable decay heat depends on design

optimum material choice (from a safety point of view) can depend on design (certain materials may be better than others if temperature rise is high in accident—chemical reactivity and mobilization of materials is temperature dependent)

No materials will be ruled out (even materials such as 316SS may be acceptable from a disposal standpoint if the neutrons are absorbed elsewhere)

Tools for Safety Analyses (and R&D supporting development of tools) have improved dramatically over the last five years

Codes for analysis have been updated

- ATHENA - thermal hydraulics
- MACCS - dose code
- MELCOR - thermal transient code

MELCOR is a thermal transient code originally developed for fission; it has undergone extensive verification and validation (V&V) by the fission community

- several upgrades have been made to MELCOR to enable analysis of fusion-specific scenarios
  - cryogen/water interaction
  - LiPb, Pb, Sn, Ga, Li interactions with water and air
  - some V&V for fusion has been done, more is planned

More on Improvements in Safety Analyses

These tools have been used for ITER resulting in the most sophisticated safety analyses done for fusion to date (ITER meets the no-evacuation criteria)

We have learned much from the ITER safety analyses

- Oxidation-driven mobilization is not a significant safety issue for ITER
- Dust issues are particularly important for ITER (hydrogen production, transport of activated material)
- Tritium mobilization is an important safety issue for ITER

Disruptions and Safety

Disruptions can be initiator for accident sequences (e.g., runaway electrons cause of Loss of Coolant Accident, or LOCA, when they slice open the first wall)

However, the number/frequency of disruptions is generally limited by erosion limits rather than safety

The accident in ITER with the highest consequences was an ex-vessel LOCA leading to an in-vessel LOCA

> In this sequence, the plasma stays on until the first wall heats up enough that it fails, causing a disruption; once the disruption occurs, the first wall cools down quickly

Disruptions produce "dust" (chemical reactivity, activation product, toxicity), however, rather than limiting the number of disruptions, this dictates the safety requirements for dust removal

As designs evolve, keep safety group in the loop

Preliminary safety analyses can provide useful input to design

Results of safety analyses generally improve as design detail increases

> this is evidenced by the evolution of the ITER safety case as the design evolved (CDA to EDA)
>
> very conservative assumptions must be made in the absence of design information

Some Things to Keep in Mind

Passive safety is desirable; this must be shown through analysis

Keep the rest of the machine in mind (e.g., if water will be necessary in the machine to improve shielding, avoid the use of lithium)

Reducing the volume of material that must be disposed of is desirable

> recycle
> material choice

ITER has taught us that we can "design around" many accident issues

> we can live with materials that in the past were "safety forbidden," such as tungsten, if the design is optimized

It is very difficult to "design around" waste issues