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Proposed Joint GIF IAEA project on mHTGR Safety Design Criteria:

Joint IAEA–GIF Technical Meeting on the Safety of High Temperature Gas Cooled Reactors
9-12 December 2019

Frederik Reitsma
Team leader: SMR Technology Development

Nuclear Power Technology Development Section
Division of Nuclear Power | Department of Nuclear Energy

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CRP I1026 on Modular High Temperature Gas cooled Reactor Safety Design

… contributing to the development of modular HTGR appropriate safety design requirements

A key lesson learned for FSV and THTR…
cannot be licensed under LWR rules

Also the experience in the PBMR project and a key difference in the approach followed in the HTR-10 and HTR-PM licensing.

Recent pre-license discussions with the Canadian Regulator and US NRC publication of HTR specific approach

Background

In the TWG-GCR a clear need has been identified by the MS to develop mHTGR Safety Design Criteria

The development and implementation of comprehensive safety design criteria (SDC) that take HTGR-specific characteristics into account would provide a high level of assurance that modular HTGRs are consistently designed, constructed, and operated in a manner that takes advantage of these intrinsic properties, while also avoiding unintended compromises in plant safety.

CRP: Modular High Temperature Gas-cooled Reactor Safety Design

Cooperative Research Project

Objective:

- To develop a process for establishing Safety Design Criteria at the plant and major Structure, System, and Component (SSC) level for modular HTGRs.
- To Implement the process for representative modular designs;
- To establish the Safety Design Criteria for the representative designs with associated technical background.
- Serve as the technical basis for a future development of IAEA Safety Standards for HTGRs by the department of Nuclear Safety and Security of the IAEA.

"*Safety Terrain*" of modular HTGRs

Modular HTGRs

result in a **safety terrain that is fundamentally much gentler and more forgiving**:

- **Fuel failure mechanisms of CP fuel are decoupled and totally independent**

  ➔ **One coated particle failure cannot lead to the failure of a neighbouring CP**, as it is driven by the maximum fuel temperature.

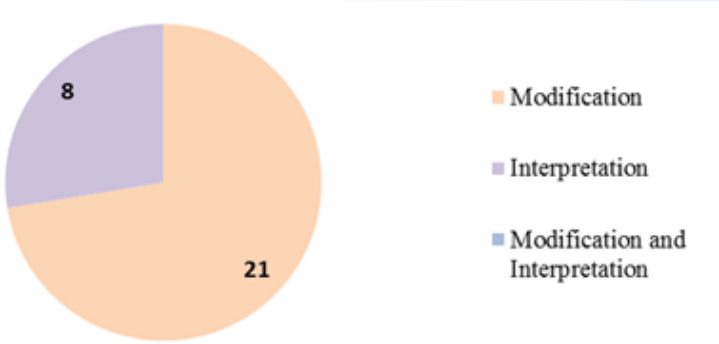
  ➔ **Failure also has no effect on the cool-ability of the fuel** as a failure will not change the heat removal path**.**

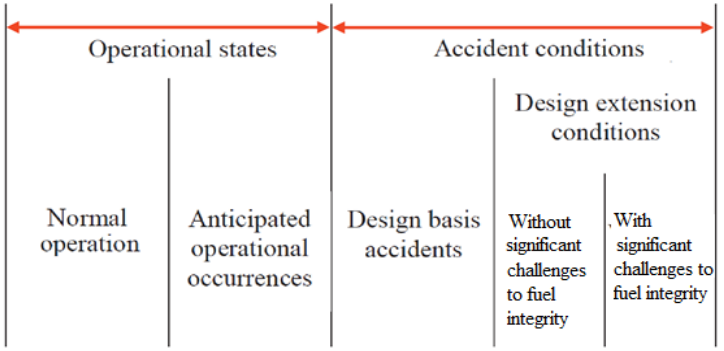
  ➔ **CP failure will release miniscule amount of FPs -** many CP will need to fail to be of any consequence.

Based on inherent and passive safety features, there is no cliff-edge effects or large releases even in extremely rare events far beyond the design basis.

Significant chances is required to SSR 2/1

- In a separate activity an NSNI project, home based assignments and consultancy meetings (in 2017) clearly identify the need
- More than 30% of the requirements require modifications or interpretation (many of the rest is generic high level requirements)
- Some additional requirements were also identified (chemical attack)
- Many of concepts need considerable rethinking such as DiD, the huge emphasis on the coolant and cooling systems, containment, post accident design features and management, and in particular design extension conditions with a postulated core melt….





IAEA Coordinated Research Project (CRP)

CRP Approach

- CRP collaborators have chosen to develop and assess two approaches to SDC development for modular HTGRs

- Results will be assessed for key strengths and weaknesses, and will then be evaluated for integration into a common set of SDC

"Approach 1" to SDC Development

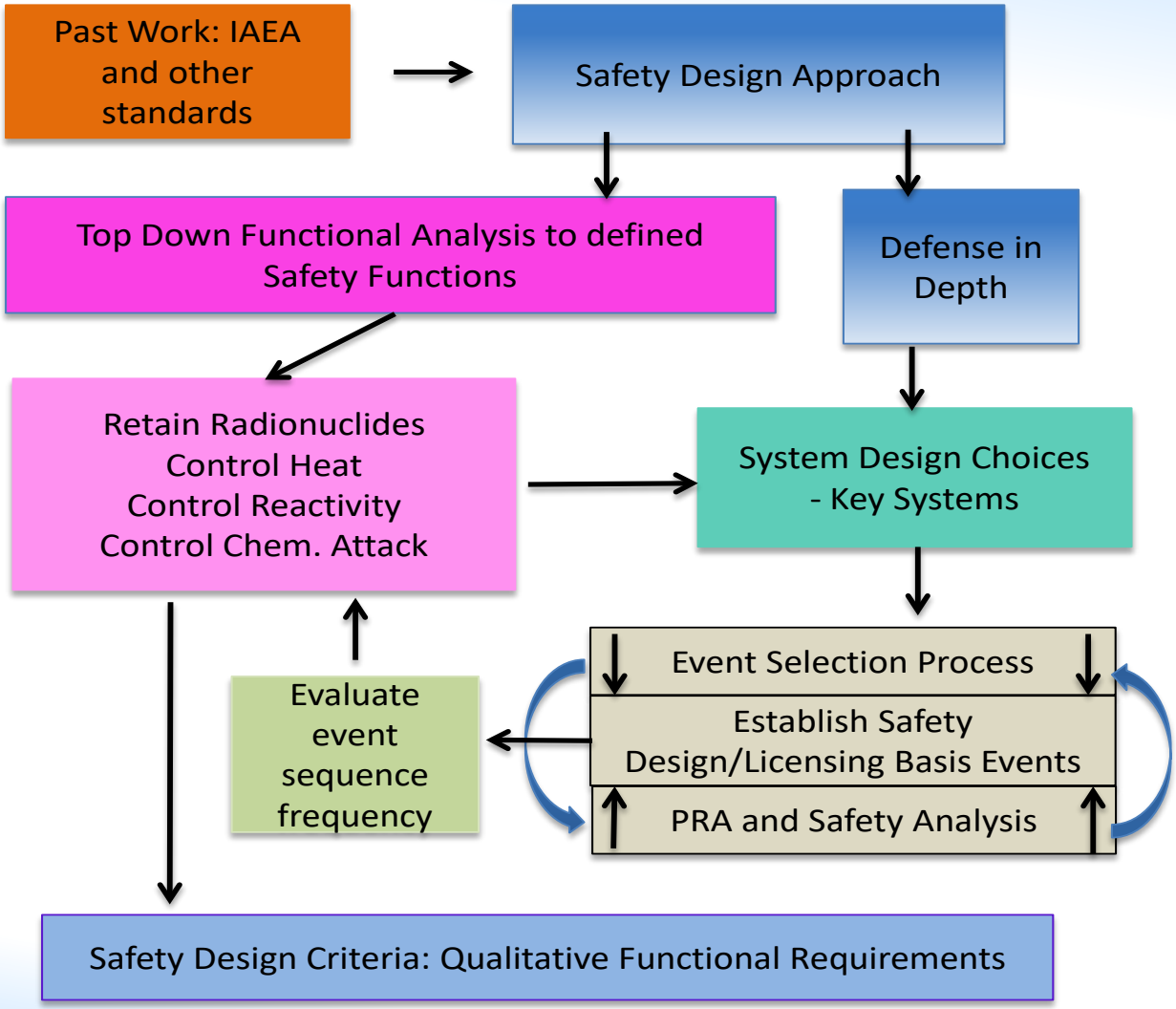
Establish a structured, risk-informed approach for selecting and categorizing licensing basis events as they may occur over a broad spectrum from normal operation to rare, off-normal events.

Approach 1 is intended to address:

- Adequate protection through an appropriate balance between risk and deterministic considerations.
- Issues with uncertainties and the probabilistic risk assessment (PRA),
- Calculation methodologies to be employed (conservative vs. best estimate)

Approach recommended in IAEA's: *Accident Analysis for Nuclear Power Plants with Modular High Temperature Gas Cooled Reactors (IAEA SRS No. 54).*

Two-Approaches: I



Approach 1
"Bottom-Up" approach:

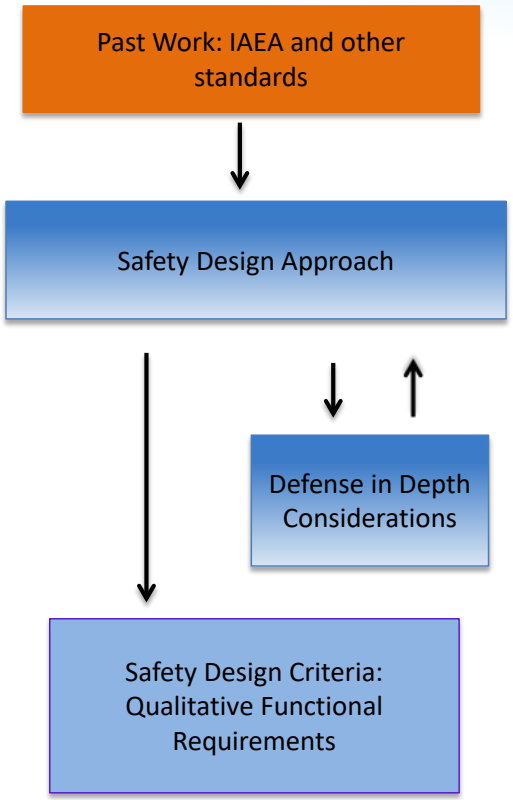
"Approach 2" to SDC Development

Approach 2 adapts the prescriptive and deterministic requirements for light water reactors that are contained in the IAEA's: *Safety of Nuclear Power Plants: Design, IAEA Safety Standards Series No. SSR-2/1*

"Approach 2" involves a requirement-by-requirement modification to the IAEA LWR criteria reflected in SSR-2/1 based on technical insights and expert judgment

Same as GIF approach to SDC development for sodium fast reactors

Two-Approaches: II

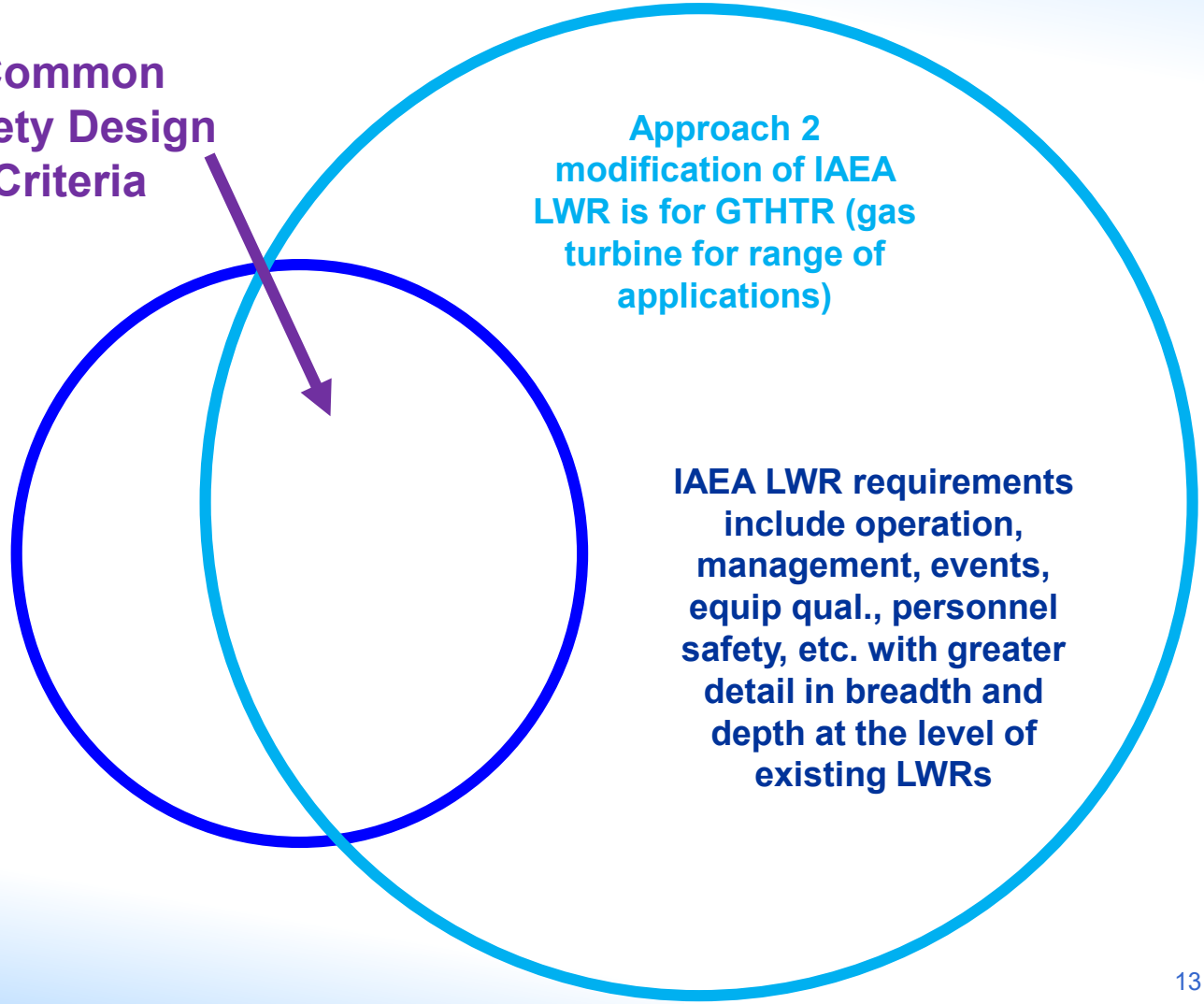


Approach 2
"Top-down" approach:
From IAEA SSR-2/1 to HTGR requirements through expert judgement and review.

Limited Scope Safety Design Criteria of Approach 1 for MHTGR Example

1. Retain Radionuclides in Fuel Particles
2. Remove Core Heat
3. Conduct Heat from Core to Vessel Wall
4. Radiate Heat from Vessel Wall
5. Maintain Geometry for Conduction and Radiation
6. Transfer Heat to Ultimate Heat Sink
7. Control Core Heat Generation
8. Control with Movable Poisons
9. Shutdown Reactor
10. Maintain Geometry for Insertion of Movable Poisons
11. Shutdown Reactor Diversely
12. Maintain Geometry for Insertion of Diverse Movable Poisons
13. Control Chemical Attack
14. Limit Fuel Particle Hydrolysis
15. Limit Fuel Core Oxidation

Scope, Breadth, Depth, and Terms of Two Approaches Vary



CRP: Modular High Temperature Gas-cooled Reactor Safety Design

Implementation started December 2014

Good support for the CRP

10 participating organizations from 9 member states: China, Germany , Indonesia, Kazakhstan, Korea (Republic of), Japan , UK, Ukraine, USA

- 1st RCM took place 9-12 June 2015
- 2nd RCM took place 13-17 June 2016
- 3rd RCM took place 19-23 June 2017
- 4th RCM took place 11-14 June 2018
- Consultancy planned June 2019
- Possible future cooperation with GIF to continue SDC development

Planned outcomes:

- NE series report: Modular High Temperature Gas-cooled Reactor Safety Design Criteria
- TECDOC: Modular High Temperature Gas-cooled Reactor Safety Design Methodology and Implementation Examples

Concluding remarks …

- SUMMARY
  - DRAFT CRP reports to be ready (to be shared informally with GIF) early Q3 2019
  - NE and NS results on activities related to Approach 2 possibly to be integrated / harmonized
  - The GIF proposed Approach 1 activity has also been accepted within the workplan of OECD-NEA GSAR (proposed October 2018, further detailed proposal being made in the April 2019 meeting)

- PROPOSAL:
  - GIF-IAEA initiate cooperation at the 1st Joint IAEA-GIF Technical Meeting on Safety of High Temperature Gas Cooled Reactors (9-11 Dec 2019)
  - Consider possibility of cooperation with the OECD-NEA GSAR activities (to be investigated)

- Important to coordinate (and not duplicate) activities with other international organizations
- Stakeholders are different – but the IAEA HTGR community and the GEN-IV VHTR system members represents a substantial overlap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Thank you!