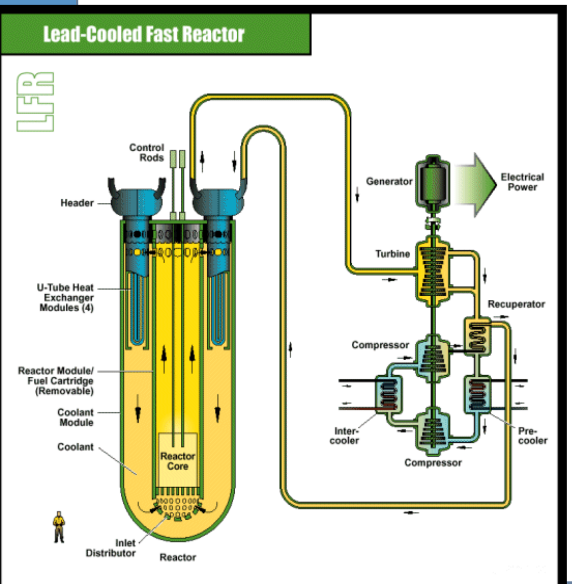
IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

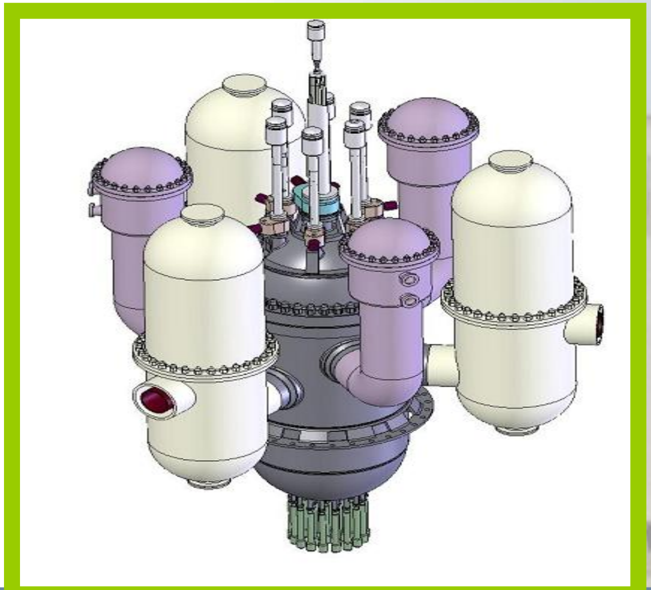
Faire avancer la sûreté nucléaire

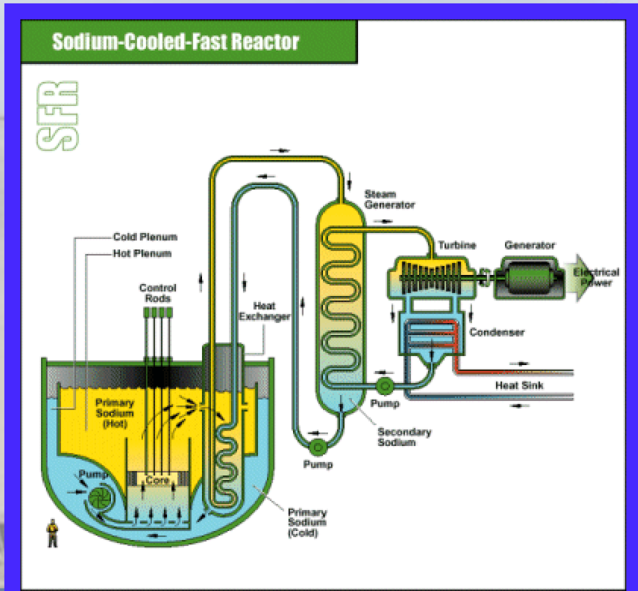
CN-199 FR13 Conference

Safety Design Criteria

G.B. BRUNA







Objectives for the GEN-IV Systems

Economic competitiveness	➢ Competitiveness of the nuclear KWh cost, vs. fossil energies
Sustainability	➢ Increased reactor lifetime (over 60 years) ➢ Optimization of fissile material inventory ➢ Decrease of the waste volume and storage costs
Safety	➢ **Very low probability of severe damage of the core** ➢ **No technical need for off-site emergency plan for severe accidents**
Resistance to proliferation and to acts of malicious damage	➢ Fuel cycle minimizing the production of weapon-grade materials ➢ Efficient protection against internal and external hazards

ESNII

The European Sustainable Nuclear Industrial Initiative (ESNII) was launched in November 2010 for sustainability purpose, to anticipate the development inside the European Union of a fleet of fast reactors with closed cycle i.e.

- **Sodium cooled Fast Reactors (SFR),**
- **Lead cooled Fast Reactors (LFR) and**
- **Gas cooled Fast Reactors (GFR).**

- **ESNII also includes some support infrastructures with, in particular, the FAst Spectrum Transmutation Experimental Facility (FASTEF) able to test both the LFR technology and the Accelerator Driven System (ADS) technology.**

SARGEN_IV

Safety methodologies are available which can be applied to the ESNII prototypes, pilot plants and demonstrators, such as:

- **Methodologies issued by the GIF Reactor Safety Working Group (RSWG) and the IAEA such as the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO)**
- **National safety approaches (France, Germany, Spain, Finland, Belgium) and the associated experience feedback in particular for the SFRs built in France and Germany, as well as for the European Pressurized Reactor (EPR™)**
- **Guidelines from International Organizations such as WENRA**

The SARGEN_IV project is aimed at preparing the safety assessment for the future innovative reactors through harmonized safety assessment practices and the EURATOM contribution to GIF.

In this objective SARGEN_IV gathers European designers, TSOs, research organizations and utilities already involved (or to be involved) in the field.

Critical safety features of GEN IV Systems 1/3

- **Document available on the public IRSN website in French and English**
- **INTERNET link: http://www.irsn.fr/FR/Larecherche/publications-documentation/collection-ouvrages-IRSN/Pages/documents-reference.aspx**

Critical safety features of GEN IV Systems 2/3

- **Coolant boiling temperature**
  - High for LFR (about 1700°C) and FASTEF* (about 1670°C)
  - Medium for SFR (about 800°C)
  - Not relevant for GFR

Coolant void effect on reactivity

High for SFR according to previous core designs

- Medium for LFR
- Low for GFR
- Negative for FASTEF

- **Chemical risk** from specific materials (Pb, Na...)

High for LFR and FASTEF

- Medium for SFR
- Low for GFR

- LFR, SFR, GFR = Lead, Sodium, Gas Fast Reactor
- FASTEF = FAst Spectrum Transmutation Experimental Facility

Critical safety features of GEN IV Systems 3/3

- **Corrosion risk (Compatibility coolant/structures,...)**
  - High for LFR and FASTEF
  - Medium for SFR
  - Low for GFR

- **Need for specific mitigation measures in case of core melting (e.g. core catcher)**
  - Yes for SFR
  - No for LFR and FASTEF
  - Dubious for GFR (depends of the behavior of the materials in case of a core melt down)

- **Sensitivity of power density to SA blockage**

- **Reactivity increase due the core compaction (e.g. under earthquake)**

Before Fukushima: safety practices for GEN-IV reactors 1/4

- **Ambitious safety objectives are targeted in GEN-IV current studies & designs,** **even though the safety goals of GIF are not prescriptive when specifying objectives for GEN-IV nuclear power plants.**

- **The main goal is to reduce the potential consequences and impact of the operation of nuclear power plants** **on public, workers and environment as well as the occurrence/frequency of failures, incidental and accidental situations.**

Before Fukushima: safety practices for GEN-IV reactors 2/4

- **Safety assessment should be performed for both reactor and fuel storage, in all plant states and conditions - including maintenance - over the whole lifetime of the installation, including decommissioning.**

- **Waste management and workers radiological protection should be taken into account.**

- **Human and organizational factors and man-induced situations are a part of the safety demonstration.**

- **Natural phenomena should be considered.**

- **Security/safeguard aspects should be dealt comprehensively from the design phase.**

- **Chemical effects could be a challenging issue with regard to designs of current GEN-IV reactor designs.**

Before Fukushima: safety practices for GEN-IV reactors 3/4

Defense-In-Depth (DiD) principle remains fundamental.

- An overall reinforcement of DiD is expected for GEN-IV NPP, including an improved independence among all levels of DiD.
- A specific issue for GEN-IV should be identifying severe accidents in level 4 (in particular for MSR and V/HTR).
- Another specific issue should be clearly establishing the list of events not dealt with (large break on main vessels...).

Other topics should also be carefully addressed, such as:

- The definition of barriers,
- The application of the As Low As Reasonable Achievable & Practicable (ALARA & ALARP) principles.

Before Fukushima: safety practices for GEN-IV reactors 4/4

- **Adoption of passive systems, with adequate balance between active and passive systems**

- **An inherent approach should reinforce the fulfillment of the fundamental safety functions through:**

  - **Mitigation (the consequences of transients should be reduced),**

  - **Enlargement of grace periods,**

- **The *practical elimination* should be adopted for a limited number of events relying on comprehensive in-depth analyses. (inherent safety vs. probabilistic demonstration).**

- **Complementarily and integration between deterministic and the probabilistic approaches is to be enhanced.**

After Fukushima: how safe is safe enough? 1/2

- **… We thought we were getting close to regulatory equilibrium... Fukushima brings a host of new questions, even beyond the "simple" issue of internal and external events, and the role of the design basis.**

- **Should society require addressing rare yet credible events with potentially severe consequences, limited by the appropriate risk considerations?**

- **If so, which are the best stable solutions and the operator's initiatives?**

- **- Pre-Fukushima: stable regulatory frameworks, stirred only by specific issues; global convergence on safety principles; focused on adequate protection**

- **- Post-Fukushima: ensuring that protection of public health and safety are consistent with know-how, and that socio-political and economic impacts are addressed in the proper perspective (What does Residual risk mean? What is acceptable about it?)**

(DOES THE ACCIDENT IN JAPAN CALL FOR A MAJOR OVERHAUL OF NUCLEAR SAFETY REGULATIONS?, Dr. Nils J. Diaz Embedded Topical Meeting: Fukushima 2012 ANS Winter Meeting San Diego, November 12-14, 2012)

After Fukushima: complements to the harmonization of safety practices for GEN-IV reactors 2/2

- Hazards would be a major challenge for GEN-IV reactor designs.
- They should be comprehensively addressed accounting for the outcomes of post-Fukushima investigations, also including the European stress tests.
- Investigation on specific GEN IV issues (identified by SARGEN IV) should include:

  The total loss of power sources,
  The total loss of the ultimate heat sink(s)
  The combination of both losses
  The management of a severe accident engendered by these losses.
  Provisions allotted to improve the grace period before cliff-edge effects
  Hardened equipments.

Thank you for attention