GEN IV International Forum℠
Expertise | Collaboration | Excellence

Safety of Generation IV Reactors

Summary / Objectives:

Excellence in safety and reliability is among the goals identified in the technology roadmap for Generation IV nuclear reactors. This webinar will give an overview of the activities of the GIF Risk and Safety Working Group done in support of the six Generation IV nuclear energy systems towards the fulfilment of this goal. Topics include a presentation of the safety philosophy for Generation IV systems, the current safety framework for advanced reactors, and the methodology developed by the group for the safety assessment of Generation IV designs. Other ongoing activities between the group and the designers of Generation IV systems will be also highlighted.

Meet the Presenter:

Dr. Luca Ammirabile works at the European Commission (EC), Joint Research Centre in Petten, the Netherlands, where he is Group Leader of the NUclear Reactor Accident Modelling (NURAM) team of the Nuclear Reactor Safety and Emergency Preparedness Unit. His group deals with Nuclear Reactor Safety assessment for current and innovative reactors, focusing on the safety issues related to the prevention and mitigation of Severe Accident conditions and Source Term estimation. His current research activities are core thermal-hydraulic analyses, deterministic code application and development, and safety assessment of advanced reactors. Since 2014, he has been co-chairman of the working group on Risk and Safety of the Generation IV International Forum. He is also the EC representative on the OECD/NEA Working Group for the Analysis and Management of Accidents (WGAMA) and the Working Group for the Safety of Advanced Reactors (WGSAR). Prior to joining the European Commission in 2007, Luca worked at Tractebel Engineering (now Tractebel Engie) in Belgium in the Thermal-hydraulics and Severe Accident Section, where he was engaged, among other projects, in the development of innovative methodologies in support of the safety assessment of the Belgian Nuclear Power Plants.

Luca received his doctorate from the Imperial College London in 2003 and his master’s degree in nuclear engineering from the University of Pisa, Italy in 1999.

Risk and Safety Working Group :

The primary objective of GIF Risk and Safety Working Group (RSWG) is "Promote a consistent approach on safety, risk, and regulatory issues between Generation IV systems".

For this purpose, RSWG developed and have promoted a technology-neutral Integrated Safety Assessment Methodology (ISAM).

System	Neutron Spectrum	Coolant	Pressure (MPa)	Temperature (°C)	Fuel Cycle	Size (MW)
GFR	Fast	Helium	~9	850	Closed	1200
LFR	Fast	Lead	0.1+ (atm.	480–800	Closed	45-1500
MSR	Fast or Thermal	Fluoride or hloride salts	0.1+ (atm.	700–800	Closed	1000-1500
SFR	Fast	Sodium	0.1+ (atm.	550	Closed	50–1500
ScWR	Thermal or fast	Water	~25	510–625	Once-through or Closed	10–over 1000
VHTR	Thermal	Helium	~5.5	900–1000	Once-through	250–300

Explanation of Safety & Reliability Goals (Defence in Depth) :

GIF Safety & Reliability Goals are corresponding with the concept of Defence in Depth.

- Excel in Operational Safety and Reliability
  - ➢ DiD Level 1-2 [N.O., AOO]
- Very low likelihood & degree of reactor core damage
  - ➢ DiD Level 2-3 [Design for severe accident prevention]
- Eliminate the need for offsite emergency response
  - ➢ DiD Level 4 [Design for severe accident mitigation]

Defense-in-Depth Levels				
Level 1	Level 2	Level 3	Level 4	Level 5
Operational states		Accident conditions		EP&R
Normal Operation	Anticipated Operational Occurrences	Design Basis Accidents	Design Extension Conditions	Residual risk and practically eliminated accidents
			Severe accidents	

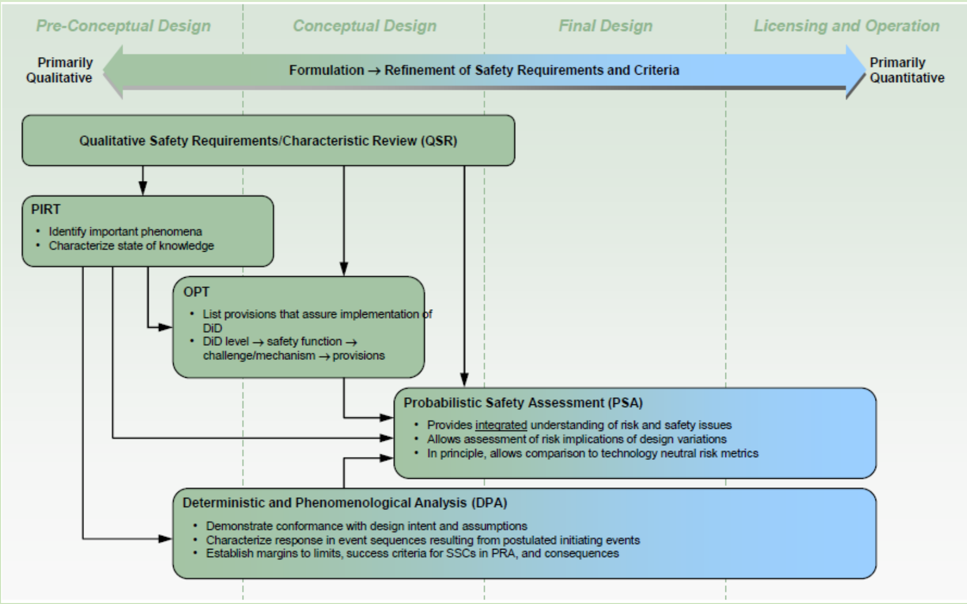
Plant states considered in design
(safety analyses)

Out of the design
(addressed in level-5 of DiD)

Integrated Safety Assessment Methodology (ISAM):

The ISAM consists of five distinct analytical tools.

- Qualitative Safety-characteristics Review (QSR)
- Phenomena Identification and Ranking Table (PIRT)
- Objective Provision Tree (OPT)
- Deterministic and Phenomenological Analyses (DPA)
- Probabilistic Safety Analysis (PSA)



Qualitative Safety-characteristics Review (QSR):

QSR is "check-list" as systematic and qualitative means of ensuring that the design incorporates desired safety attributes (preparatory step).

Phenomena Identification and Ranking Table (PIRT):

PIRT is generated for the purpose of identifying system and component vulnerabilities, and relative contributions to safety and risk.

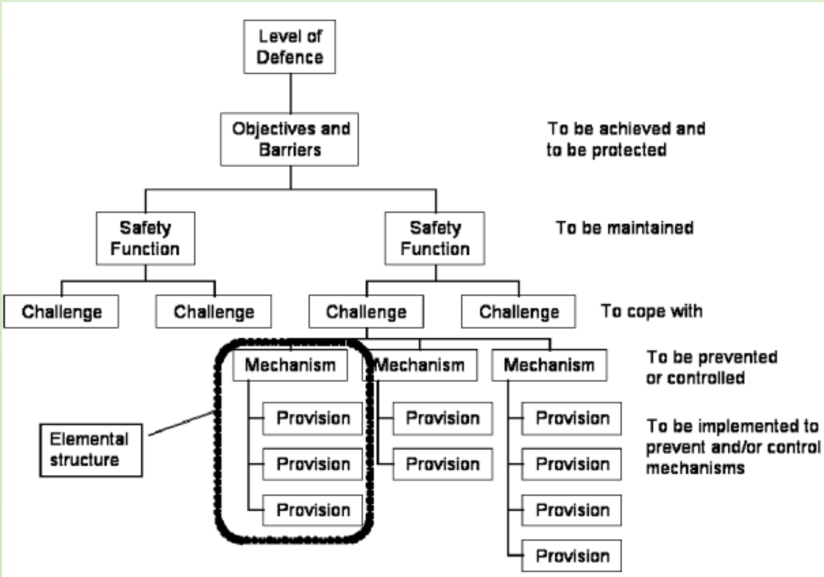
System	Component	Phenomena/Characteristics/State variables	IR		KL_1		KL_2	
			A	B	A	B	A	B
BRSS	SASS	SASS actuation temperature	H	H	1	2	3	4
Reactor	Upper core region around SASS	Coolant transport delay time from core outlet to around SASS	H	H	3	2	3	3
		Time constant of temperature response delay from coolant around SASS to SASS device	M	M	1	2	3	3
	Reactor core	Core outlet temperature of the coolant that flows to around SASS	H	H	3	3	3	3
		Doppler reactivity	M	M	4	4	4	4
		Fuel temperature reactivity	L	M	4	3	4	3
		Fuel cladding temperature reactivity	M	M	4	4	4	4
		Coolant temperature reactivity	H	H	4	4	4	4
		Coolant flow rate halving time	H	H	4	4	4	4
		Power distribution	M	M	4	4	4	4
		Flow rate distribution among core assemblies	M	M	4	4	4	4
		Coolant temperature at the core inlet and outlet	L	L	4	4	4	4
		Fuel pin gap heat transfer coefficient	M	M	4	3	4	3
		Fuel pellet thermal conductivity	I	I	4	4	4	4
		Thermal material property of fuel cladding and coolant	I	I	4	4	4	4
RPCS	Temperature I&C	Coolant temperature to be used reactor power control	M	L	4	4	4	4
PHTS	Pump	Pump rotating inertia	M	M	4	4	4	4
	-	Pressure loss in the reactor and PHTS	M	M	4	4	4	4

PIRT

Knowledge Base Gap Determination				
Adequacy of knowledge	Rank of Phenomenon			
	H	M	L	I
(4) Fully known; small uncertainty				
(3) Known; moderate uncertainty				
(2) Partially known; large uncertainty	GAP	GAP		
(1) Very limited knowledge; uncertainty cannot be characterized	GAP	GAP	GAP	

Objective Provision Tree (OPT):

OPT is a tool for identifying the provisions for prevention, or control and mitigation, of accidents that could potentially damage the reactor.



Deterministic and Phenomenological Analyses (DPA):

DPA is traditional safety analyses to assess the system's response to known challenges and guide concept/design development. Based on conventional safety analysis codes, DPA provides input to PSA.

Probabilistic Safety Analysis (PSA) :

PSA is performed in order to assure a broader coverage of the accident space. PSA is iterated from the late pre-conceptual design phase to the final design stages.