Point sur le WP1 (Integral safety approach and system integration) du projet SAMOFAR

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H2020 call: NFRP3

NFRP 3 – 2014: New innovative approaches to reactor safety

Specific challenge: Some very innovative reactor safety concepts are investigated, which could become breakthrough options if their scientific and practical maturity is demonstrated. The Euratom research, with its focus on safety and reliability and optimal waste management, should also consider such possible breakthrough options.

Scope: The aim will be to allow promising designs to move from the Technology Readiness Level (TRL) 1 to TRL 3, or from TRL 2 to TRL 3 as defined in Annex to this work programme. Focus will be on the proof of concept regarding safety (e.g. passive safety systems and new approaches to severe accidents management), reliability and quality assurance (e.g. industrial standards). Advanced experimental and numerical simulation tools to evaluate the viability and performance should support this research. It should be undertaken in close cooperation with industry and regulators whose involvement is indispensable at an early stage of design. International cooperation could be beneficial in this area.

Expected impact: This action will offer top-level scientists a level playing field for highly innovative ideas enabling them to demonstrate the feasibility of advanced safety concepts. It will open-up new avenues towards reactor safety design. In the medium / long term, this action should lead to new orientation and breakthrough in nuclear safety.

Type of action: Research and innovation actions.

Additional information: The Commission considers that proposals requesting a contribution from the Euratom of between EUR 2 and 4 million would allow this specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts.

The conditions related to this topic are provided at the end of this call and in the Annex 1.

H2020 call: NFRP3

Challenge: Very innovative reactor safety concepts that could become breakthrough options

Aim: TRL 1→3 or TRL 2→3

Focus: Proof of concept regarding safety, reliability and quality assurance

Should include:

- Support by advanced experimental and numerical simulation tools
- Cooperation with industry and regulators

Could include: International cooperation

Impact:

- New avenues towards reactor safety design
- New orientation and breakthrough in nuclear safety

Budget: 2-4 million €

H2020 call: Technology readiness levels

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept

NFRP-03-2014 New innovative approaches to reactor safety
TRL 1 to 3, or from 2 to 3

- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment
- TRL 6 – technology demonstrated in relevant environment
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Projet SAMOFAR – Safety Assessment of a MOlten salt FAst Reactor

« A Paradigm Shift in Nuclear Reactor Safety with the Molten Salt Fast Reactor »

Soumission 09/2014 - si accepté : durée de 4 ans (2015-2019)

Partenaires : TU-Delft (leader), CNRS, JRC-ITU, CIRTEN (POLIMI, POLITO), IRSN, AREVA, CEA, EDF, KIT + PSI + CINVESTAV

5 work-packages techniques :

WP1 Integral safety approach and system integration

WP2 Physical and chemical properties required for safety analysis

WP3 Experimental proof of i) shut-down concept and ii) natural circulation dynamics for internally heated molten salt

WP4 Accident analysis

WP5 Safety evaluation of the chemical plant

SAMOFAR : WP1 Integral Safety Approach and System Integration

WP1 is leading the integral safety assessment and coordinating the two-way data exchange with the other work packages delivering data and requests, and receiving data and recommendations. The strong involvement of the TSO and industry lays a sound base for the exploitation and dissemination of the safety methodology and for the acceptance of the safety principles of the MSFR by other TSO's and the nuclear safety authorities.

SAMOFAR : WP1 Integral Safety Approach and System Integration

Task 1.1 Description of initial reference design and identification of safety aspects (CNRS, TU Delft, CIRTEN, JRC)

A reference design of the fluid fuel circuit, the salt draining system, and the chemical plant will be given, together with the interaction phenomena between the reactor and the chemical plant, as previously defined by the EVOL project. CNRS and the other partners will first describe the initial reference design of the MSFR and identify all relevant safety aspects. During the project, this description will be continuously updated by including all improvements and recommendations from the other work packages.

Task 1.2 Identifying safety related physico-chemical and material data (JRC, TU Delft, CNRS, CIRTEN)

TU Delft together with the other partners will identify the missing safety-related data required for the safety studies and transient analyses, and transfer these requests to WP2 and WP3 for further evaluation. The updated figures will be used in the integral safety assessment of the MSFR (WP1) and in the numerical assessment of all transient and accident scenarios (WP4).

Task 1.3 Development of a power plant simulator (CNRS, CIRTEN, EDF)

CNRS and CIRTEN will design and build a software simulator to assess the dynamic behavior of the overall plant, to define the operation procedures of the reactor (start-up, shut-down and load following), and to determine the associated controls and safety margins. The object-oriented modeling approach will be applied using open-software like Modelica and Java. This simulator will allow the analysis of the dynamic behavior of the overall plant, by assembling specifically developed component models and libraries, which involve not only the primary circuit, but also the Balance of Plant and the electrical grid connection. The simulator will also be used to develop and test the main control strategies of the reactor. EDF will contribute to the development of the simulator, and will review the code models and the architecture.

Task 1.4 Safety issues of normal operation conditions, including start, shut-down and load-following (CIRTEN, CNRS, TU Delft, EDF, PSI)

The software simulator developed in the task 1.3 will first be used to evaluate the normal operation procedures and the associated control strategies, and subsequently to identify the corresponding safety issues. In particular, it will be used to define and simulate the safe start-up and shut-down procedures, by exploiting the Petri net approach for the adequate formalization of the sequence of control actions to be performed during these transients. The formalized procedure will be implemented in a "supervisory system", which will combine the capabilities of the object-oriented modelling approach to perform continuous time simulations with those of the Petri net approach, which coordinates and manages the transitions taking place in Discrete Event Systems.
CNRS will contribute to the definition of the normal operation transients (start, shut-down, draining and load-following) and the identification of the corresponding safety issues. CIRTEN, CNRS and TU Delft will contribute to the evaluation of the normal operating conditions and the transient initiators. PSI and EDF will model the primary and secondary circuits using TRACE (-PARCS) to benchmark the 1D software and to asses some major transients. This analysis includes the capability to establish a natural circulation regime.

Task 1.5 Development on an integral safety assessment methodology for MSR (IRSN, AREVA, CNRS, CIRTEN, EDF, IRSN)

An integral safety assessment methodology will be developed for a fast neutron spectrum reactor with a liquid fuel. This methodology shall firstly take into account the Generation-IV safety requirements, the international safety standards and the peculiarities of this kind of reactor with the help of available risk analysis tools. Secondly, the assessment of a fast neutron spectrum reactor with a liquid circulation fuel requires a clear identification of the zones where the fuel is located. The following will be considered:

- Application of relevant safety objectives and standards from international sources (IAEA, WENRA).
- Identification of the ‘hot’ zones containing nuclear materials, and of the fissile distribution inside the molten fuel salt, during transients (including normal operation procedures) and accidents.
- Identification of the fundamental safety functions of all ‘hot’ zones with regard to:
  - ✓ Reactivity control (including the definition of the necessary measurements).
  - ✓ Decay heat removal (including diversity and redundancy).
  - ✓ Containment of the radiological and chemical products with the definition of the barriers.
- Postulation of initiating events and their classification, including those relevant to Organizational and Human Factors.
- Identification of i) all hazards for this kind of reactor, ii) all severe accidents, and iii) all events usually practically eliminated.

The results and analyses of this section will be iterated with tasks 1.4 and 1.6.

SAMOFAR : WP1 Integral Safety Approach and System Integration

Task 1.6 Identification of risks and phenomena involved, identification of accident initiators and accident scenarios (CIRTEN, TU Delft, CNRS, AREVA, EDF, IRSN, PSI)

A preliminary risk assessment will be performed based on the integral safety assessment methodology. The reference accidents will be identified together with their initiators and follow-up scenarios. An extension of the tool delivered in Task 1.3 will be made to select the relevant accident scenarios and to calculate some preliminary outcomes. AREVA, IRSN and EDF will develop the methodology to identify accident initiators and scenarios by identifying all risks and phenomena involved. CIRTEN will contribute to the definition of the accident initiators, considering the results delivered in Task 1.5 on the relevant components for safety assessment, and will participate in the evaluation of expected consequences. CIRTEN will extend current level 1 and 2 PSA approaches to risk analysis of liquid fuel systems and PSI will accomplished simplified level-3 PSA. PSI will provide a detailed analysis of the Fission Products (FPs) behaviour relevant to the safety analysis of the MSFR. The safety assessment methodology developed in task 1.5 will be applied to extend the analysis performed in task 1.4 to the accident regime for the selection of relevant accident initiators and scenarios. Results will be transferred to WP4 for further evaluation.

Task 1.7 Improved Integral power plant design (reactor core and chemical plant) to maximize safety and proposal for safety demonstrator (CNRS, AREVA, EDF)

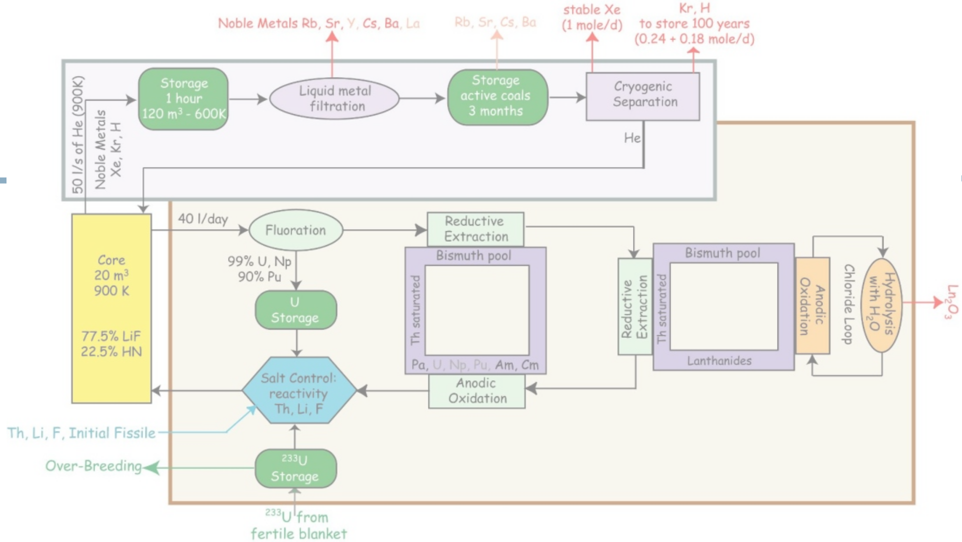
CNRS and its partners will make design changes to the MSFR reference design according to the recommendations from the safety assessment in WP1 and the calculations / measurements in WP2 to WP5. AREVA will provide recommendations, including safety and industrial views, on the overall plant architecture and design. EDF will review and analyse the design changes.

SAMOFAR : WP1 Integral Safety Approach and System Integration

WP1 is leading the integral safety assessment and coordinating the two-way data exchange with the other work packages delivering data and requests, and receiving data and recommendations. The strong involvement of the TSO and industry lays a sound base for the exploitation and dissemination of the safety methodology and for the acceptance of the safety principles of the MSFR by other TSO's and the nuclear safety authorities.

Livrables du WP1 :

D1.1 (T0+6) Description of initial reference design and identification of safety aspects
D1.2 (T0+6) Identifying missing data and material issues
D1.3 (T0+24) Development of a power plant simulator
D1.4 (T0+30) Safety issues of normal operation conditions
D1.5 (T0+36) Development on an integral safety assessment methodology for MSR
D1.6 (T0+36) Identification of accident initiators and scenarios and preliminary PSA analysis
D1.7 (T0+48) Improved Integral power plant design (reactor core and chemical plant) to maximize safety and proposal for safety demonstrator



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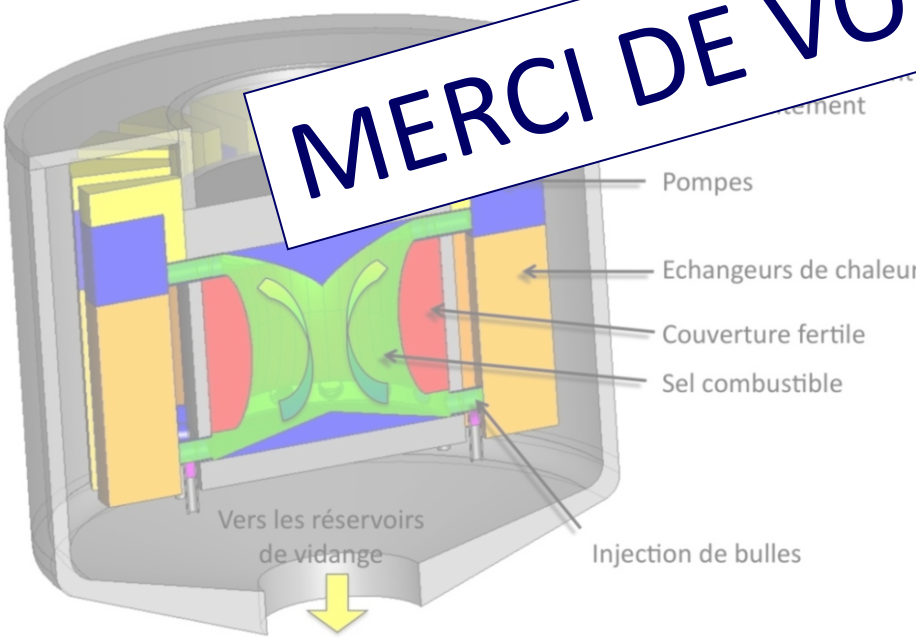
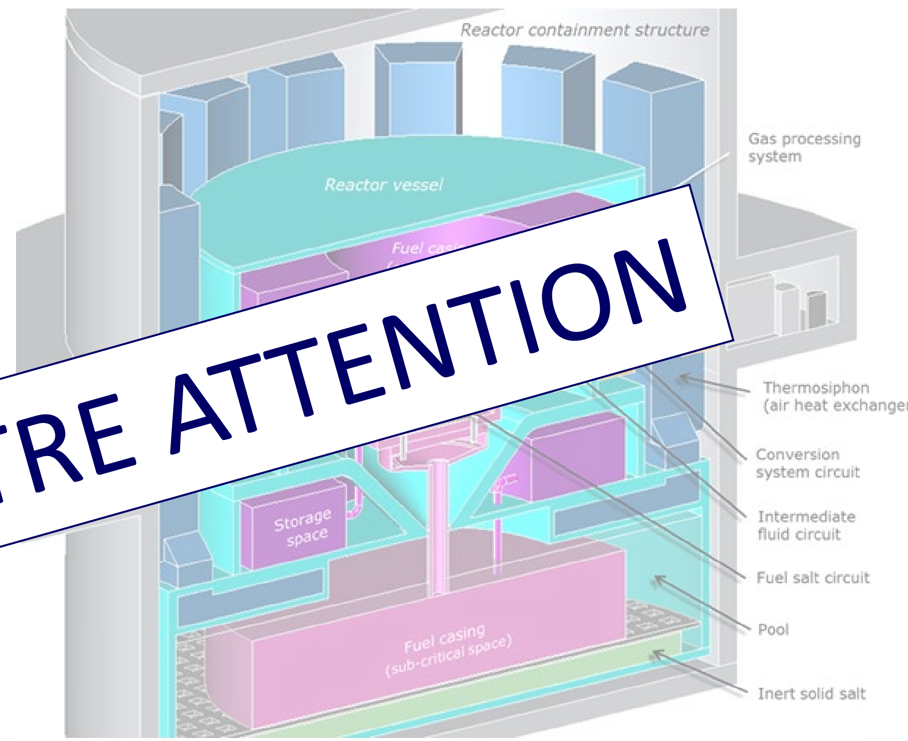


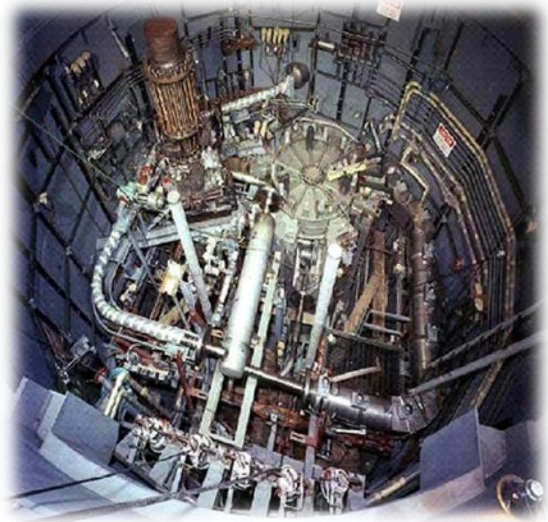


ANNEXES

Bref historique de la R&D RSF

Les projets de l'ORNL (Oak-Ridge National Labora

- L'Aircraft Reactor Experiment (ARE)
  - Il s'agissait de concevoir un réacteur embarqué dans un avi
    - Il a fonctionné une centaine d'heures à 2,5 MW_{th} en 1954
- Le Molten Salt Reactor Experiment (MSRE)
  - Démonstrateur de RSF
    - Il a fonctionné 5 ans à 8 MW_{th}
      - De 1965 à 1968 à l'Uranium enrichi à 30%
      - De 1968 à 1969 au Plutonium
      - En 1969 à l'Uranium 233
- Le Molten Salt Breeder Reactor (MSBR)
    - Projet de réacteur industriel en cycle Thorium de 2500 MW_{th}
    - Recherche d'une surgénération maximum
    - Arrêt du projet en 1976



Les projets sur les RSF ont ensuite repris

- Japon depuis les années 80
- France CEA et EDF dans les années 90 et 2000
- France CNRS depuis les années 2000
- Russie depuis les années 70
- USA dans les années 90
- Tchéquie depuis les années 2000
- Chine depuis 2011

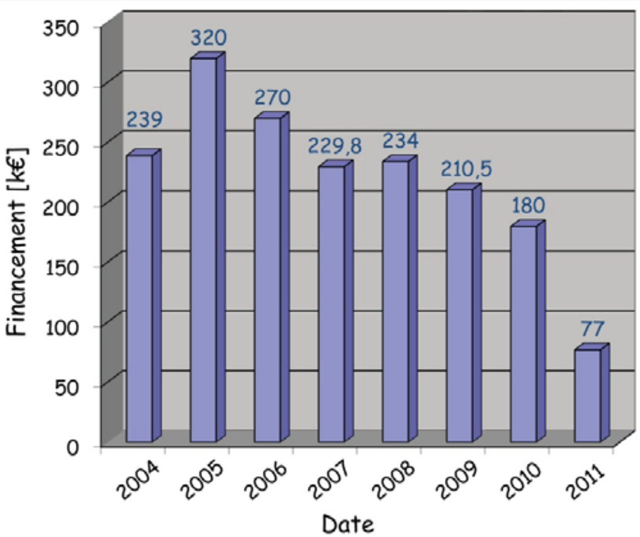
En 2002, le forum international GEN IV a retenu le MSBR parmi 6 concepts

Molten Salt Fast Reactor – Cadre national (1)

PCR-ANSF de PACEN (Applications au Nucléaire des Sels Fondus) –2004 à 2011

Des actions menées par
9 laboratoires appartenant à
5 instituts du CNRS
(IN2P3, INC, INEE, INP, INSIS)

15 hommes.mois /an - Budget moyen de 220 k€ réparti sur 5 thèmes de recherche pendant 8 ans



Technologies des sels fondus
- Pyrochimie par brassage électromagnétique
- Etude du bullage de gaz dans les sels fondus
- Boucle de sels fondus en circulation forcée (FFFER)
- Préparation de sels et fluoration

Chimie des sels fondus
- Extraction électrolytique des lanthanides en milieu fluorure
- Comportement des lanthanides (Nd, Gd, Sm, Eu, Er) dans les mélanges de sels fondus LiF-ThF_4 et LiF-NaF-ThF_4
- Etude thermodynamique par Spectrométrie de Masse à Haute Température pour les RSF du Cycle Th/U

Simulations neutronique et thermo-hydraulique
- Simulations neutroniques concernant le MSFR
- Simulations de la thermo-hydraulique du MSFR (INOPRO)
- Design du MSFR (A3I)

Etudes des matériaux
- Tenue mécanique et corrosion

Structure des sels fondus
- Structure des sels fondus fluorés pour les RSF: approche par RMN et EXAFS à haute température du système LiF-CaF_2-ZrF_4-ThF_4
- Simulations ab-initio et par dynamique moléculaire de sels fondus fluorés

Mesures de données neutroniques
- Mesure simultanée des sections efficaces de capture et de fission de ^{233}U dans le domaine des résonances

GNR GEDEPEON (Gestion des Déchets et Production d'Energie par des options nouvelles) de PACEN

Environ 20 keuros par an de soutien à la R&D sur les réacteurs à sels fondus (chimie, matériaux, sûreté)

Molten Salt Fast Reactor – Cadre national (2)

Programme NEEDS (voir présentation de S. David) et MSFR

2012 : Financement équivalent à celui attribué en 2011 au PCR-ANSF

2103 : Thématique RSF dans les projets fédérateurs « Systèmes Nucléaires et Scénarios » (physique des réacteurs, sûreté, retraitement, scénarios) et « Matériaux »

Projet structurant CLEF (Combustible Liquide pour une Énergie Future)

Projet de Grenoble INP - Durée : 3 ans (2013 – 2015) – Budget : 200 k€

5 laboratoires de Grenoble INP, UJF, CNRS (G-Scop, LEPMI, LNCMI, LPSC, SIMAP)

Objectifs

- Développer les outils et modèles numériques nécessaires pour les études de Conception et de Sûreté du MSFR
- Entretenir et développer les compétences dans le domaine des matériaux des réacteurs de Génération IV
- Proposer une nouvelle approche des études de sûreté des réacteurs nucléaires adaptée au cas d'un combustible liquide