V4G4 Centre of Excellence – ALLEGRO Project

The ALLEGRO Experimental Gas Cooled Fast Reactor Project

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Based on the planned presentation of
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at the FR17 Conference

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Introduction

The main advantages of Gas-cooled Fast Reactors (GFRs) beside the closed fuel cycle are:

- High operating temperature, allowing increased thermal efficiency and high temperature heat for industrial applications
- Low value of the void coefficient
- Helium is a chemically inert and a non-corrosive coolant
- Helium is transparent, facilitating in service inspection and repair.

The main drawbacks are related to:

- The need to operate under pressurized conditions
- The low cooling efficiency of Helium, in particular in natural convection.

Based on an initiative of CEA, the nuclear research institutes of the Visegrad-4 region (ÚJV Řež, a.s. - Czechia, MTA EK - Hungary, NCBJ - Poland, VUJE, a.s. - Slovakia) decided in 2010 to start joint preparations aiming at the construction and operation of the GFR demonstrator ALLEGRO. They created in 2013 the legal entity, the "V4G4 Centre of Excellence" and launched the ALLEGRO Project – Preparatory Phase in 2015. CEA joined the project in 2017.

Goals of the project

The viability of the GFR technology shall be demonstrated by constructing and operating the ALLEGRO reactor. ALLEGRO shall be used for

- GFR technology demonstration and
- development and qualification of innovative components & systems, first of all the refractory fuel (UPuC pellets in SiC-SiC_f cladding)

According to the EU nuclear research agenda sodium-, lead-, and gas-cooled fast reactor concepts should be developed before at least one of them reaches the level of industrial maturity.

Project schedule - 1

- *Preparatory phase (2015/2025)*
  - Definition of the basic safety and performance goals, specifications (2015/2016)
  - Pre-conceptual design (2017/2020)
  - Conceptual design (2021/2025)
- *Realization phase (after 2025)*
  - Basic Design
  - Detailed Design
  - Siting and Licensing
  - Construction
  - Operation

Project schedule - 2

The activities of the Preparatory Phase are planned in the Safety and Design Roadmap. The works are financed by national and EU projects, but the financial support is not satisfactory at present. The works are organized by the Steering Committee and the Project Coordination Team. Intellectual Property Rights of the design created during the Preparatory Phase will be an important contribution to the capital of the consortium to be created for the Realization Phase.

A preliminary vision has been elaborated on the Realization Phase of the ALLEGRO Project and this vision has to be refined in the coming years. According to this vision a new consortium has to be established for the Realization Phase in a form unknown at present for EU. The consortium should include:

- Representatives of the interested European governments
- The Licensee
- An industrial company (design, documentation, licensing, construction)

The legal aspects of creating such a consortium are still to be elaborated. It seems to be a common issue for any Generation IV reactor developments in Europe therefore a joint effort is envisaged.

Technical history in a nutshell - 1

The idea of Helium cooled fast reactors goes back to the early days of nuclear energy development. The first realistic concept was elaborated by CEA after 2000. The Experimental Technology Demonstration Reactor (ETDR) from 2008 was characterized by 50 MW thermal power, 560 ºC He first core outlet temperature at 7 MPa, one primary loop and water cooling on the secondary side.

A new concept was presented by CEA in 2009 with the name ALLEGRO. It was characterized with 75 MW thermal power, 530/850 ºC first/refractory core He outlet temperature at 7 MPa, two primary loops and water cooling on the secondary side. The primary circuit is enclosed in a guard vessel (close containment), a pressure boundary maintaining sufficient backpressure in the system in case of a LOCA *(see FIG 1.)* This is the reference design (ALLEGRO CEA 2009) for V4G4 CoE. The EURATOM FP7 GoFastR project (2010-2013) further refined this design. In 2011 CEA patented a GFR system with increased safety in accident conditions based on gas turbo-machinery in the secondary circuit mechanical coupled with the primary blowers ensuring decay heat removal during the first more than 12 hours (concept ALLEGRO CEA 2011).

Technical history in a nutshell - 2

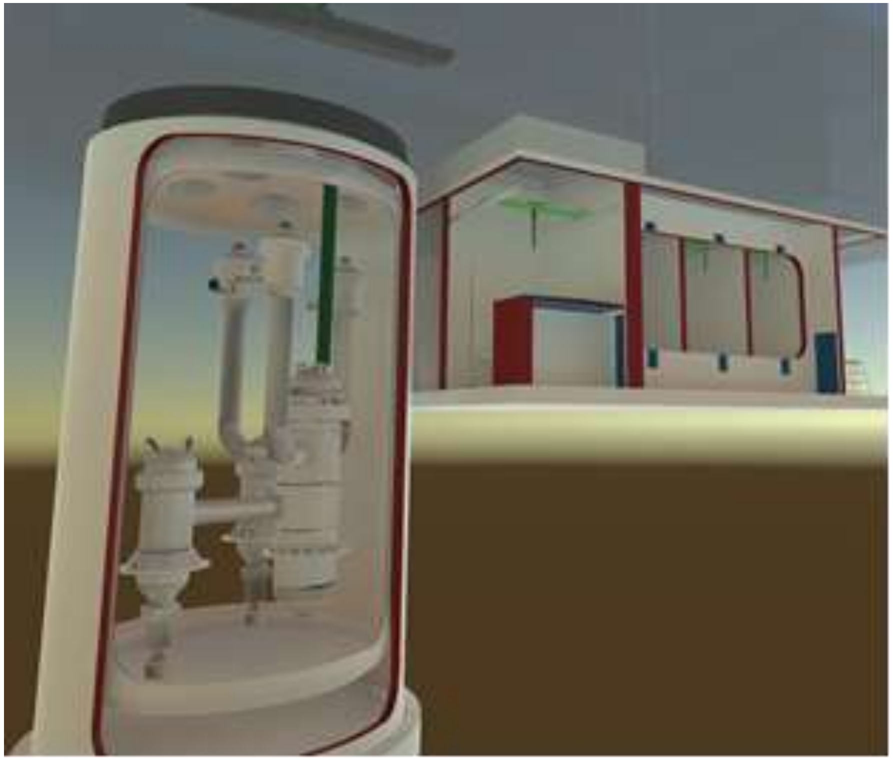


FIG 1.The ALLEGRO reactor in the close containment

Technical history in a nutshell - 3

A new ALLEGRO V4G4 concept is under elaboration within V4G4 CoE *(see FIG. 1. and FIG. 2.).* Its main features are discussed in this presentation and in the subsequent ones.

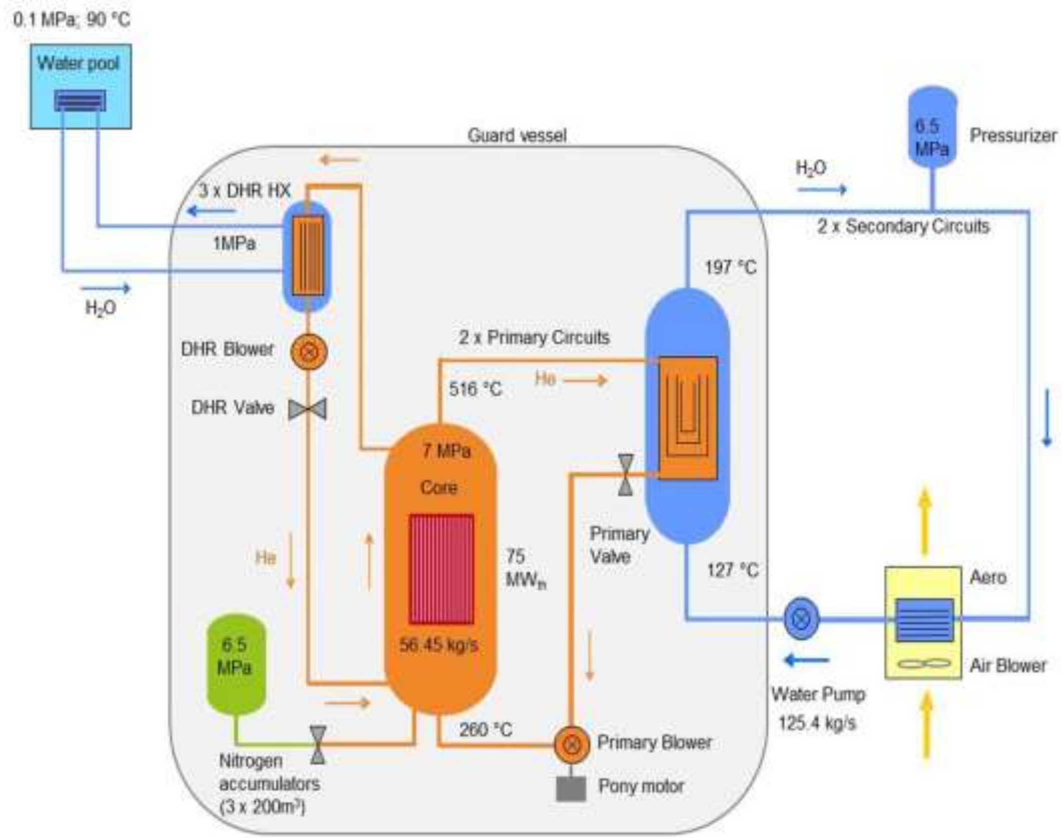


FIG 2. Schematic view of the ALLEGRO reactor

Main technical issues

Main technical issues of the ALLEGRO reactor are grouped as

- Fuel and core design issues
- Decay heat removal issues
- Further technical isssues

Now only the main issues are discussed.

Fuel and core design issues - 1

Gas-cooled Fast Reactors will be fuelled with so called refractory fuel, most probably UPuC carbide pellets in SiC-SiC_f tubes.

ALLEGRO cannot use this type of fuel from the very beginning since this fuel is not developed and cannot be qualified without irradiations in GFR conditions and the subsequent PIE. The first cores will be built up from stainless steel cladded fast reactor oxide fuel *(see FIG. 3-6)*. Some core positions will be reserved for the development of the refractory fuels through the irradiation of fragments, rods and sub-assemblies. In these positions (thermally insulated assemblies, shown in pink in *FIG 3.*) an elevated helium outlet temperature (800-850 ºC) is created by reducing the coolant flow rate.

As it is discussed in the subsequent presentations, the low melting temperature of stainless steel and the low thermal inertia of the system leads to the need of limited reactor power and power density. The related investigations are in the centre of attention.

Fuel and core design issues - 2

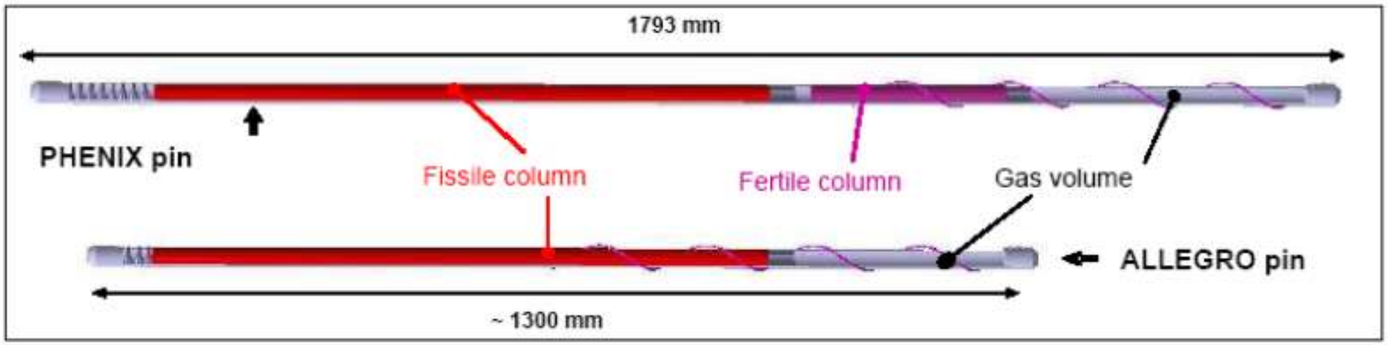


FIG 3. The ALLEGRO fuel pin compared to PHENIX pin [1]

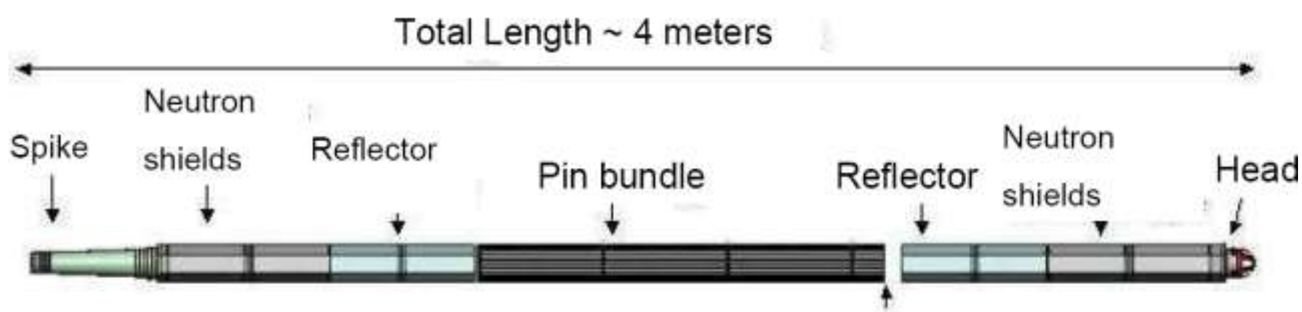


FIG 4. The ALLEGRO fuel pin bundle [1]

Fuel and core design issues - 3

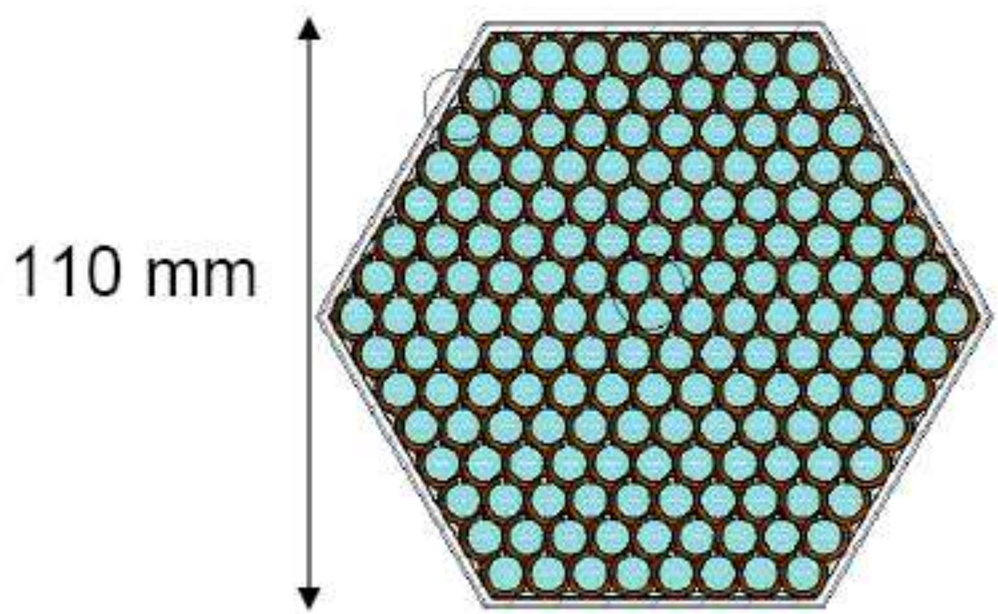
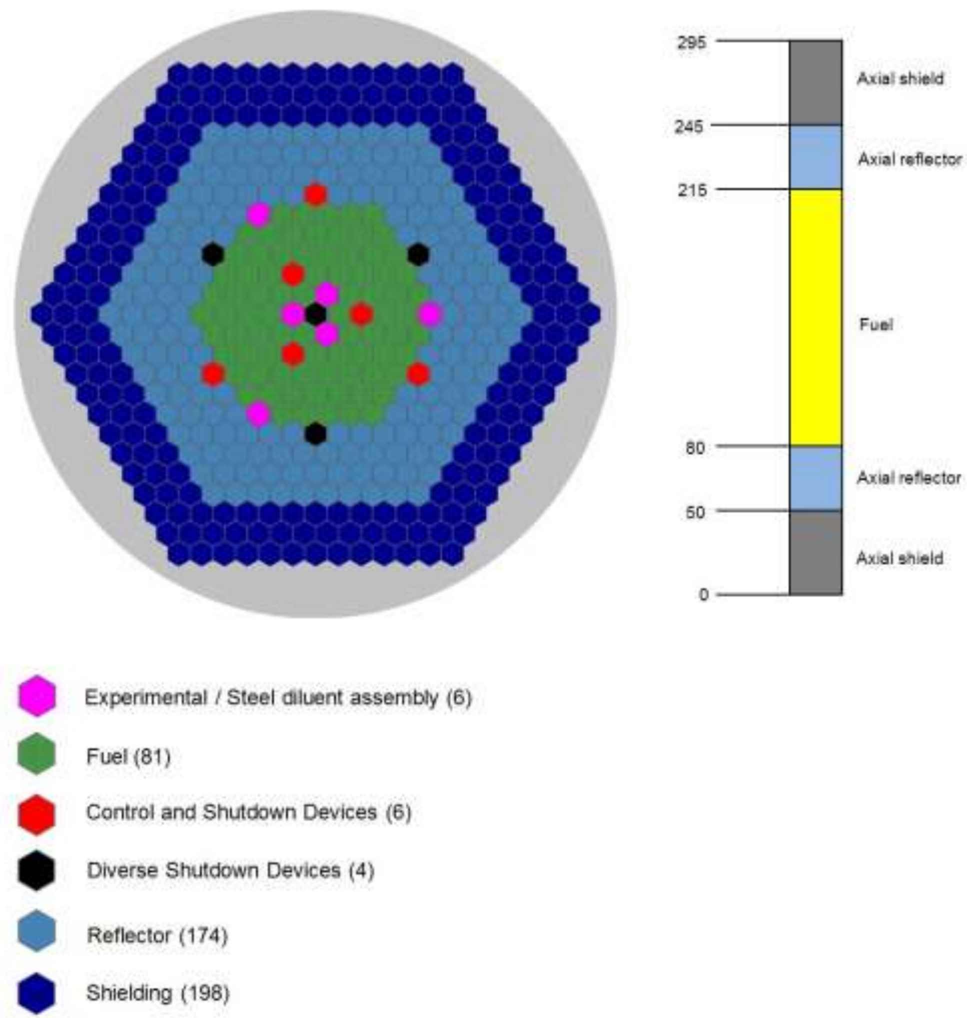


FIG 5. Fuel pin positions within the ALLEGRO fuel pin bundle

Fuel and core design issues - 4

FIG 6. First ALLEGRO reactor cores



Fuel and core design issues - 5

A serious problem may emerge if any Generation IV reactor is built in any country not being a nuclear power. The qualification and use of MOX fuel involves several legal and proliferation issues. In order to overcome these potential difficulties, now it is investigated whether using <20% enriched UOX pellets a feasible ALLEGRO core can be designed which allows for an acceptably low irradiation time needed for the experimental investigation of refractory fuel.

It has to be added that the use of UOX does not solve in itself the future problem of investigating and using refractory Pu-containing fuel. This issue has to be solved by negotiations with the appropriate powers and institutions (EURATOM, IAEA and others).

In the existing design of the ALLEGRO core, safety and control rods of identical type are grouped into two independent groups of absorbers. In order to increase the safety of core design a completely diverse type of absorber has to be developed which would be activated purely by physical principles in a completely passive manner.

Decay heat removal issues

This is the most important technical issue:

- the limiting reactor power and power density is currently investigated
- LOCA scenarios are to be handled using passive features as
  - gas turbo-machinery in the secondary circuit supplying energy for the primary blower in the first hours after LOCA
  - on the long run the decay heat is to be removed by natural circulation, utilizing nitrogen injection into the primary circuit
  - natural circulation can be promoted by elevated backpressure in the guard vessel
- the potential risk of core bypass in a LOCA scenario must be carefully analysed and has to be minimized by design
- water ingress from a DHR heat exchanger into the primary circuit represents a further challenge, that can be practically eliminated by the isolation of the affected DHR loop if necessary.

Further technical isssues

- Important development of Helium technology is still expected.
- The containment system has to be designed from scratch but well-known solutions exist.
- A core catcher system should be built in the containment.
- Fuel handling was designed by CEA as far as the removal of spent fuel from the reactor vessel is concerned, but the strategy of shielding the irradiated fuel transport between the reactor vessel and the spent storage facility is still under development.
- The existing concept of storing spent fuel is under discussion. A temporary wet storage of originally dry fuel elements before storing them in a medium term dry storage facility and a temporary dry storage system are the alternative solutions.
- A system of accident management measures is completely missing at present. A special attention should be devoted to radiation protection considerations.

Conclusions

We are convinced that nuclear energy remains one of the major components of electricity production in the 21st century and fast reactors will play a crucial role in developing the sustainable use of nuclear energy.

The ALLEGRO reactor can fulfil the role of a European GFR technology demonstrator allowing for fast neutron irradiation of ceramic fuel and other perspective reactor materials.

Co-operation with partners seems to be extremely important in developing all technical issues.

THANK YOU FOR YOUR ATTENTION!