UPDATE ON GFR R&D PROGRAM IN CZECHIA

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The presented work provides comprehensive update on GFR R&D program in Czechia, its scope and main goals. It presents the two GFR reactor concepts that has been under development with significant contribution from Czech organizations, ALLEGRO and HeFASTo, and describes the ongoing R&D program that supports the development of these concepts. . The scope of the program comprises development of reactor concepts, i.e. technology demonstrator and commercial reactor, long-term R&D on materials and other key challenges in GFR deployment and know-how and capacity building for the nuclear industry and on-job training of students and young professionals.

1. OVERVIEW, SCOPE AND GOALS

Three of the most promising fast reactor technologies have been developed as so-called GEN IV reactors within the framework of GEN IV International Forum (GIF). The main goal is to provide inherently safe, environmentally friendly (low CO_2 emissions), proliferation resistant, long lasting, and economically competitive energy source for the 21st century. One of these technologies is the Gas-cooled fast reactor (GFR) [1]. This concept combines the advantages of a fast reactor, with those of the high-temperature gas-cooled reactor technology. It can build on knowledge built by design and operation of both of the mentioned reactor types.

The history and tradition of R&D in gas-cooled reactor technology in the Czech Republic (and former Czechoslovakia) is long and rich. A Czechoslovakian reactor concept KS-150 started to be developed within the first generation of commercial nuclear reactors, in 1958. In 1972, the first unit called A1 was put into operation in Jaslovské Bohunice [2]. Czechoslovakian fast reactor R&D program [3] focused on the sodium-cooled concept. Even though no such reactor has ultimately been built, the R&D program remained active.

Nowadays, development of GFR in Czechia follows on the heritage described above. The scope of the program comprises following:

- Development of reactor concepts, i.e. technology demonstrator and commercial reactor
- Long-term R&D on materials and other key challenges in GFR deployment
- Know-how and capacity building for the nuclear industry and on-job training of students and young professionals.

In the current environment in the nuclear industry worldwide and in Czechia in particular, with several new builds of LWR-type reactors foreseen and already well into the preparation phase with outlook to starting the licensing process soon, the first mentioned goal becomes less of a priority. GFR is mid-to-long term future technology with respect to deployment, and the current level of detail of the concepts is fully sufficient for reaching this goal. The second goal is necessary to be reached in mid-term future in order to facilitate the deployment process. Nevertheless, in the current situation, the third scope has become the most relevant not only for continuation of GFR R&D and keeping the potential to proceed with the concepts to basic design stage, but also for capacity building necessary to license, build and operate the new LWR builds in Czechia.

2. CONCEPTS UNDER DEVELOPMENT

Currently, two concepts of GFR has been developed and co-developed in Czechia, ALLEGRO [4] and HeFASTo [5].

ALLEGRO is a concept of a demonstration unit of the GFR technology developed by V4G4 CoE, with the aim to become a first-of-a-kind (FOAK) GFR, and to prove viability, safety, and reliability of the whole concept of a gas-cooled reactor with fast spectrum. Main technical features of ALLEGRO are listed in TABLE.1, a cross-section of the facility in FIG. 1.

TABLE 1. MAIN DESIGN PARAMETERS OF ALLEGRO

Parameter	Value	Unit
Nominal power (thermal)	75	MW
Nominal power (electrical)	0	MW
Power density	100	MW/m^3
Fuel	MOX/ SS cladding UPuC/ SiCSifC cladding	
Primary circuit coolant	Helium	
Primary pressure	70	Bar
Core inlet/outlet temperatures	260/516	°C

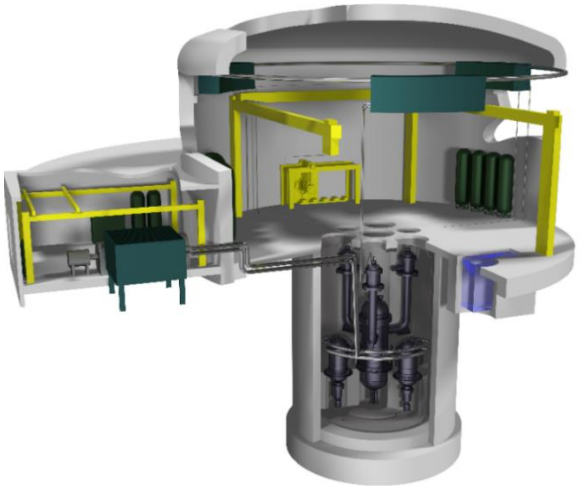

FIG. 1. : *The ALLEGRO reactor concept*

HeFASTo is a concept of an advanced modular reactor (AMR) based on GFR technology. It has been under development by UJV Rez since 2021 [5]. Its aim is to provide a concept of modern design of GFR, that will be commercially applicable in the fast-changing environment of the energy sector in the 21st century.

Main features of HeFASTo are following:

- Orientation on maximization of economic feasibility by employing maximum possible levels of modularization both in its design and possible applications
- Emphasis was put on the use of exclusively fully passive systems, providing levels of safety unprecedented in a fast reactor
- Maximum utilization of advantages of a fast reactor – very long fuel campaigns with a possibility of utilization of reprocessed nuclear fuel

Main parameters of the HeFASTo reactor are summarized in TABLE 2, an overview of the whole facility is in FIG.2.

TABLE 2: MAIN DESIGN PARAMETERS OF HEFASTO

Parameter	Value	Unit
Nominal power (thermal)	205	MW
Nominal power (electrical)	82	MW
Power density	65	MW/m3
Fuel	UC in SiC-based cladding UPuC in SiC-based cladding	
Primary circuit coolant	Helium	
Primary pressure	75	Bar
Core inlet/outlet temperatures	450/900	°C

FIG. 2. HeFASTo visualization

3. UPDATE ON R&D

The main challenges in development of GFR are connected with three main features of the reactor, connected with the fact that there is no operation experience in the world:

- Very high core outlet temperature and fast neutron spectrum leads to extreme demands on properties of the materials used in the primary circuit, especially in the core.
- Gaseous coolant with relatively low total heat capacity (due to low density) is challenging for the design of the safety systems and thermal-hydraulic design of the reactor as a whole.
- Each of the GFR concepts under development would be the “first of a kind” facility with some unique features that were never used so far if it was to be build today. This fact poses a challenge in terms of proving systems and components reliability, as well as their qualification.

In order to face these challenges and to prepare the GFR technology for deployment of first units, a complex R&D program needs to be implemented. In Czechia, several organizations have been participating in this program, representing industry, academia and universities. UJV Rez and CVR are members of the V4G4 CoE consortium, while Czech Technical Universiry in Prague, University of West Bohemia in Pilsen and various institutes of the Czech Academy od Sciences contribute to this effort within national and international R&D projects.

TABLE 3: ONGOING NATIONAL PROJECTS ON GFR IN THE CZECH REPUBLIC

Project acronym	Main focus	Duration
ALLEGRO	Design and testing of key systems and components for ALLEGRO	2018-2025
MKM	Development of a new class of Zr based alloys and high entropy alloys with optimized properties for Nuclear industry	2018-2024
REDEAL	Testing of construction materials in gaseous environments at extreme conditions (high temperature, corrosive environments)	2018-2024
SODOMAHe	Stability and resistance of materials for high-temperature helium-cooled reactors	2019-2025
KOBRA	Development of a passive safety systems for GFRs/VHTRs based on prolongation of primary compressor rundown by utilization of decay heat	2020-2024
MATPRO	Development of "better concrete" based on inorganic polymers for extreme conditions	2020-2024
RENFRI	Methods for the characterization, testing, and qualification of irradiated samples of ATF materials	2024-2026

The list of the ongoing and recently finished projects is in TABLE 3. Moreover, several of Czech organizations were participating in European project SafeG [6], and are partners to a follow-up project called TREASURE [7].

As can be seen from the data listen in TABLE 3, majority of the ongoing projects is focused on material development, since it was identified as the most pressing area. Safety research and development of systems and components closely follow. Relation to key particular issues in GFR R&D, as identified in [8], is shown in TABLE 4. The development of reactor concepts is facilitated by the European projects (ALLEGRO) and by financing from internal sources (HeFASTo).

TABLE 4: RELATION OF CZECH NATIONAL PROJECTS TO THE MAIN CHALLANGES IN GFR R&D

Key particular issues	ALLEGRO	MKM	REDEAL	SODOMA	KOBRA	MATPRO	RENFRI
Fuel composition selection							X
Fuel thermal-mechanics behavior							X
Core safety							
Valves	X						
Sealing							
Heat exchangers	X				X		
Reactivity control systems							
Core materials		X					X
Structural materials of I. circuit			X	X			
Structural materials for containment						X	
Ways of passive safety	X				X		
SA prevention and mitigation	X						
Natural convection	X				X		
Coolant purification							

4. REFERENCES

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