V4G4 Centre of Excellence

ALLEGRO
Gas-cooled Fast Reactor Demonstrator

ALLEGRO PROJECT OVERVIEW

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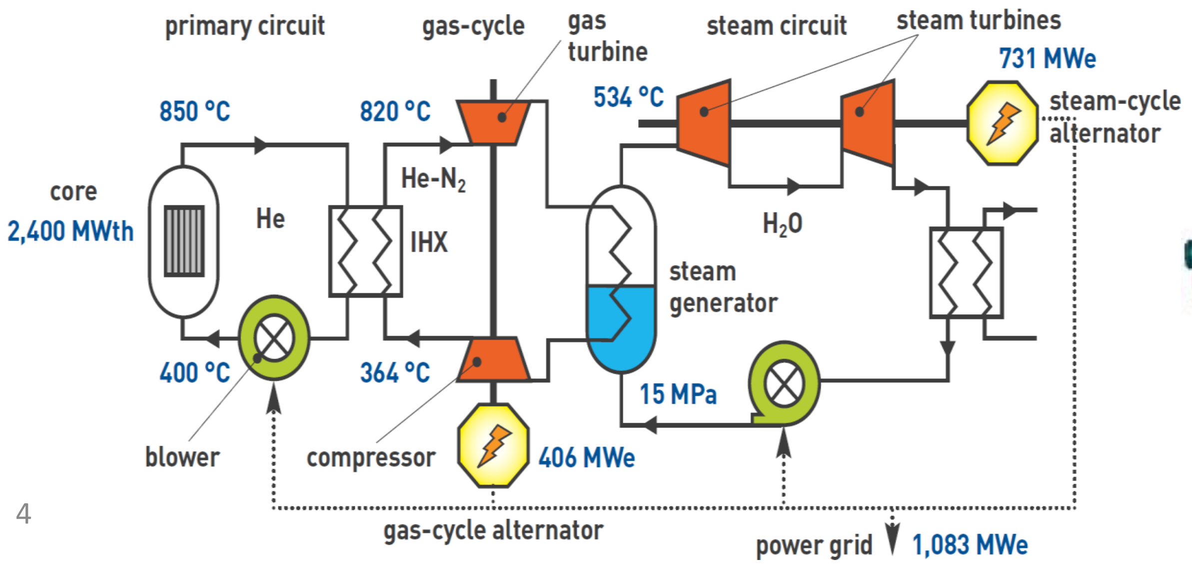
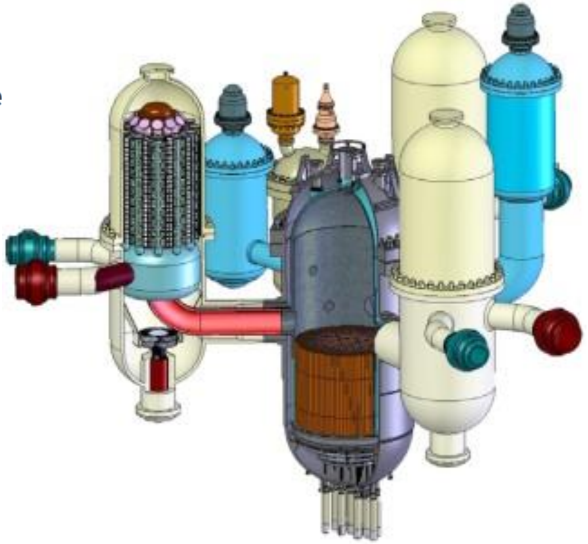
Gas-cooled Fast Reactor

- **Main goals**
  - Combine advantages of FAST and HIGH-TEMPERATURE reactors
    - Closed fuel cycle
    - Waste minimalization
    - High-potential heat production and extremely effective electricity production
- **Main challenges**
  - For a fast reactor to be most effective, it is designed to have a very high neutron flux
    - the core is tightly packed, the volume fraction of structural materials and coolant are kept to a minimum
    - As a result, the power density is usually high, for GFR in the order of 100 MW/m^3 – more than 10x more than HTRs
    - Dissipation of decay heat is very challenging
  - Materials and technologies
    - Synergy with HTRs
    - GFR-specific issues – mainly in the core (fuel, cladding, structural materials) and safety systems
- **The choice of coolant (He)**
  - High specific heat capacity and thermal conductivity
  - Very good neutronic properties for a fast reactor - small amount of absorption and moderation

GFR REFERENCE CONCEPT

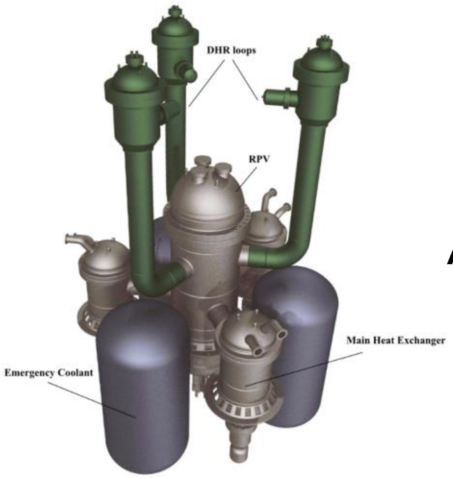
- **Thermal power 2 400 MW**
  - produced heat converted into electricity through indirect combined cycle
  - 850°C core outlet temperature
- **PCS**
  - 3 x primary loops
  - 3 x secondary loops + 3 x gas turbines (coolant mixture He-N2)
  - 1 x tertiary loop with steam turbine
  - Net efficiency (~ 45%)



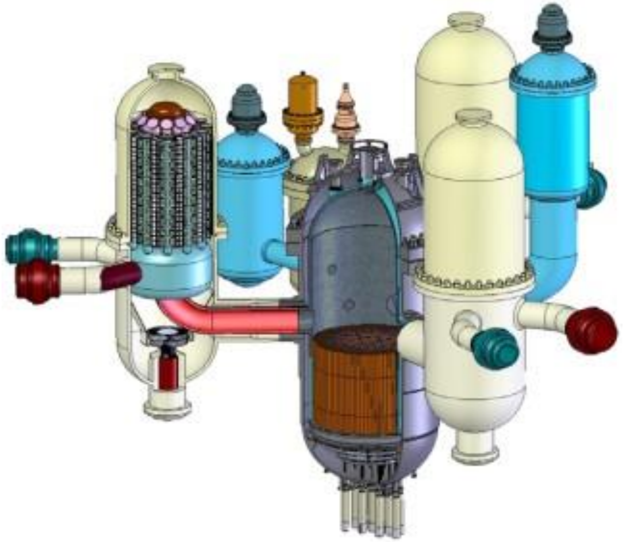


ALLEGRO - General objectives

- **Ultimate objectives of ALLEGRO**
  - Demonstration of the concept – fast reactor cooled with gas instead of molten metals
  - Proof of technological feasibility – performance, reliability, safety concept
  - Testbed for new materials and technologies – core materials in particular
  - Test of process heat utilization – hydrogen production
- **Ultimate goal – qualify the technology for commercial application**



ALLEGRO → GFR 2400



The ALLEGRO Project

- **Developed within international collaboration**
  - V4G4 CoE – 6 organizations from 5 countries (CZ,HU, SK,PL + FR)
  - Increasing numbers of officially collaborating organizations

- **V4G4 Centre of Excellence**

- **Full members (alphabetically):**

Centre for Energy Research, Hungary

National Centre for Nuclear Research, Poland

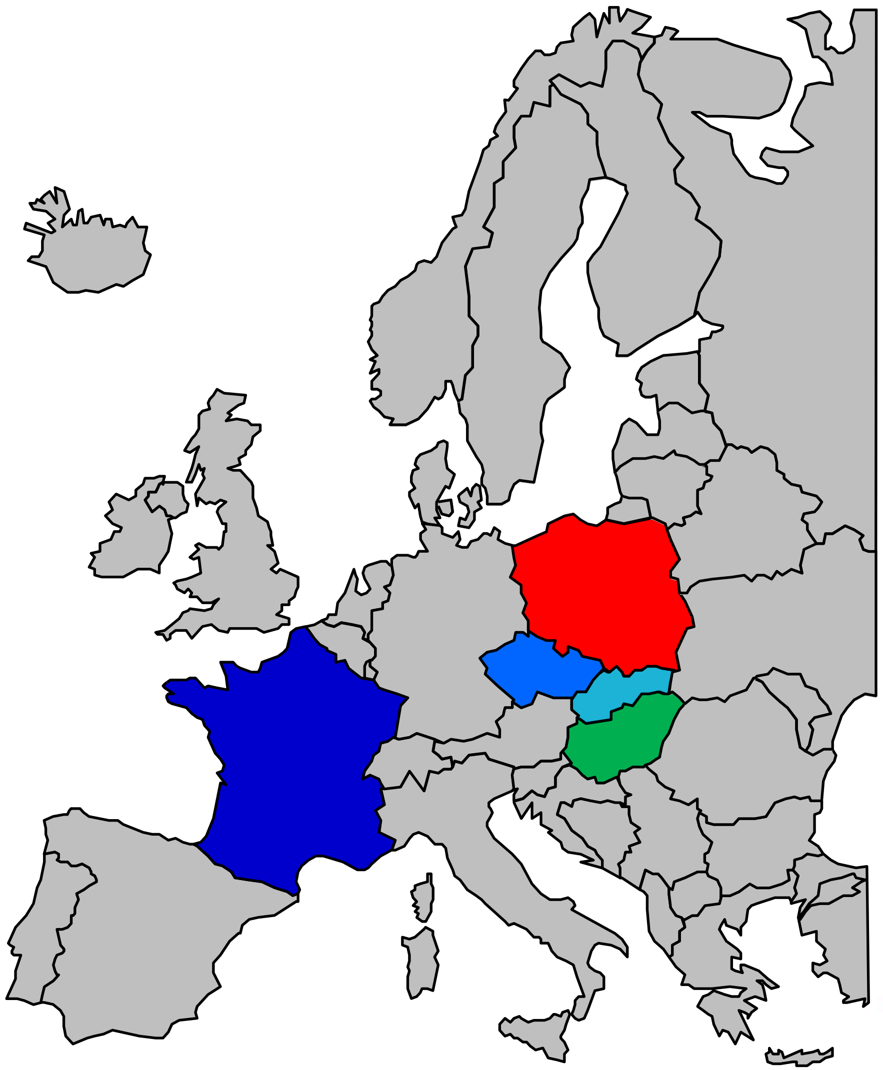
ÚJV Řež, a.s., Czech Republic

vuje VUJE, a s., Slovakia

- **Associated members (alphabetically)**

cea Alternative Energies and Atomic Energy Commission, France

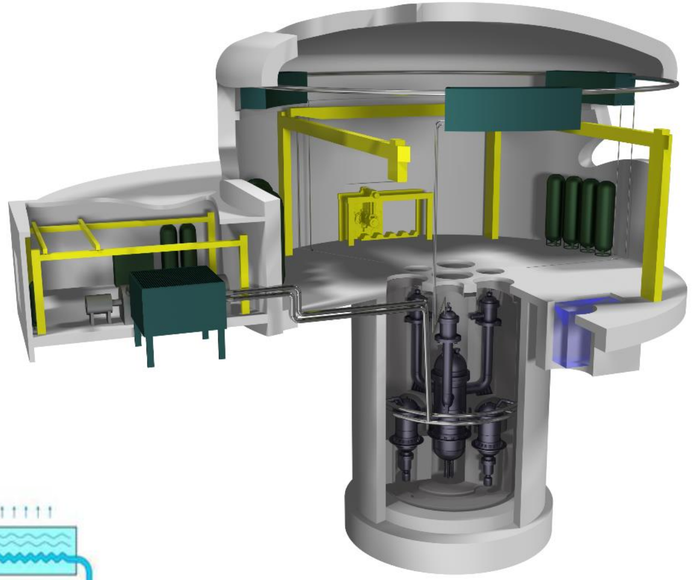
CVŘ Research Centre Řež, Czech Republic



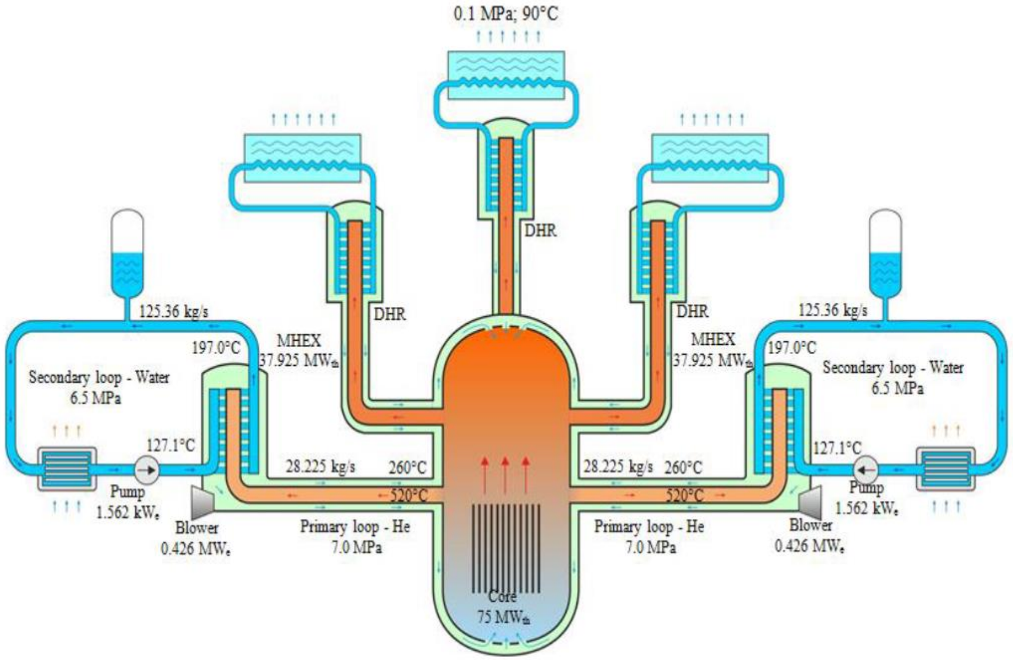
V4G4

ALLEGRO – DESIGN OVERVIEW

- **Two consecutive core configurations**
  - Driver core – MOX/UO_2 pin-type fuel in steel cladding, experimental positions for fuel qualification
  - Refractory core – (U,Pu)C pin-type fuel in SiC-SiCf cladding <- GFR reference fuel
- **Target core outlet temperature 850°C**
- **Power density up to 100 MW/m^3**
- **Focus on fully passive safety**



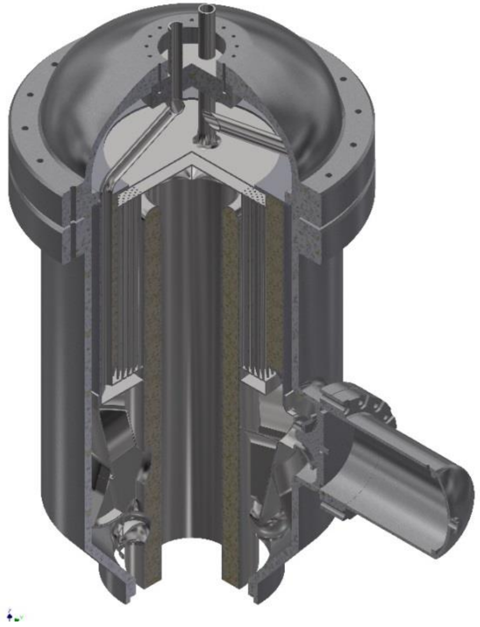
ALLEGRO main characteristics	
Nominal Power (thermal)	75 MW
Driver core fuel/cladding	MOX(UO2) / 15-15ti Steel
Experimental fuel/cladding	UPuC / Sic-Sicf
Fuel enrichment	35% (MOX) / 19.5% (UO2)
Power density	100 MWth/m3
Primary coolant	He
Primary pressure	7 MPa
Driver core in/out temperature	260°C / 530°C
Experimental fuel in/out T	400°C / 850°C



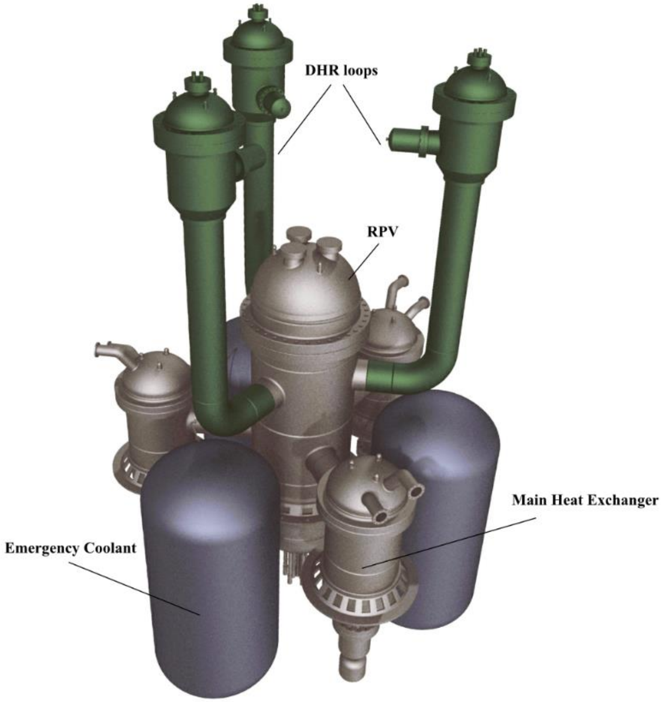
ALLEGRO – Safety Concept

- **Three key safety systems**
  - Guard Vessel

DHR system



Emergency coolant injection

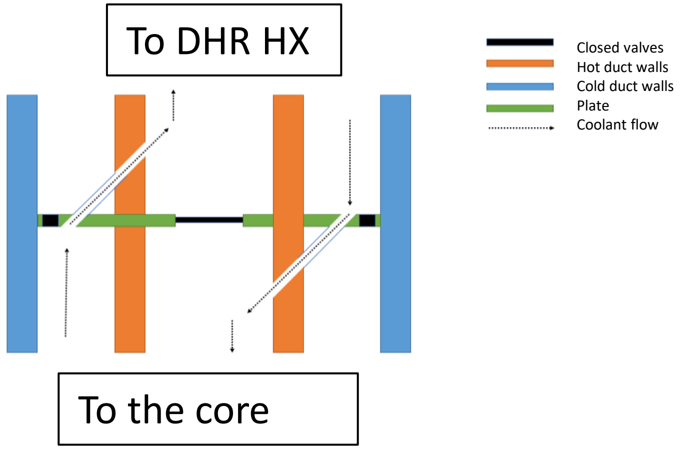


GUARD VESSEL

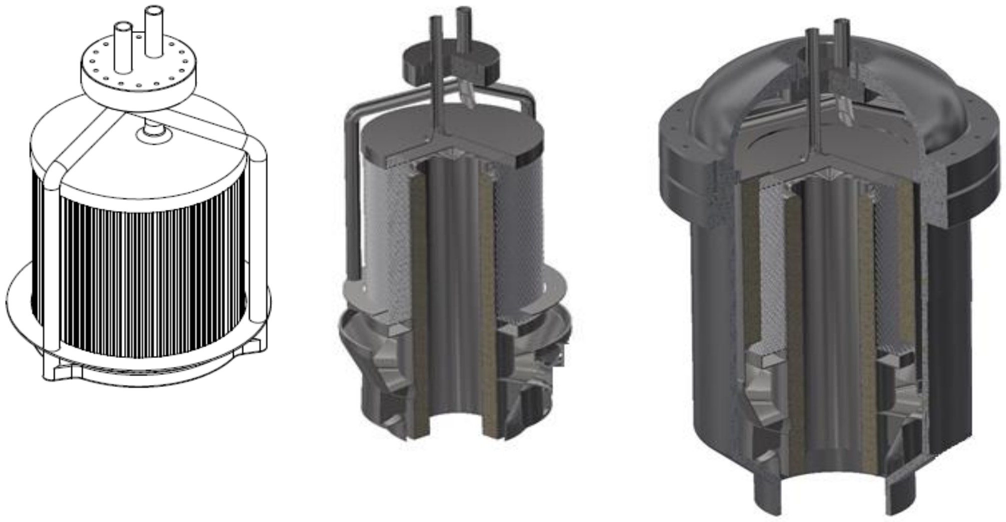
- **Pre-stressed concrete or steel close-containment**
  - Both versions under development
- **Main functions**
  - Barrier to prevent release of RN
  - Keeps elevated residual pressure in LOCAs
- **Features**
  - Free volume ~10 000 m3
  - Filled with pure N2 at atm. Pressure in operation
  - Maximum design pressure 1,1 MPa in LOCA situation
  - Target leakage under 5 %/day at the design pressure

DHR SYSTEM

- **Dedicated cooling loops connected to RPV**
  - Fully passive system – natural convection
  - Continuously pre-conditioned during normal reactor operation for faster start-up
  - Crucial in SBO/LOFA situations - main way of decay heat dissipation from the core
  - 3x100% redundancy (or 2x100 % fully passive + 1 semi-active)



System in the pre-conditioning settings



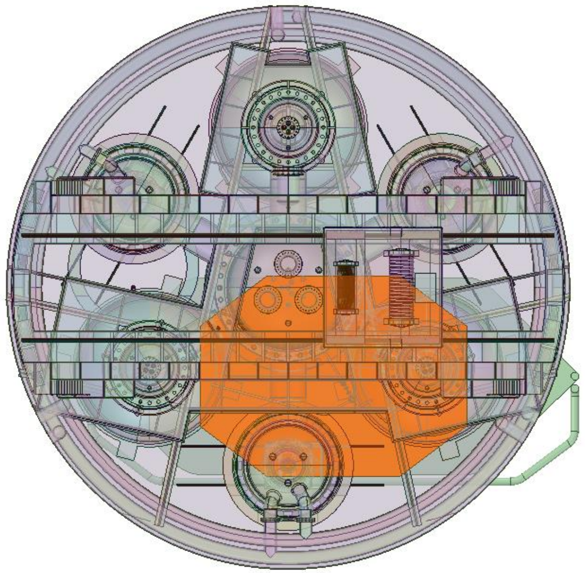
New DHR HX

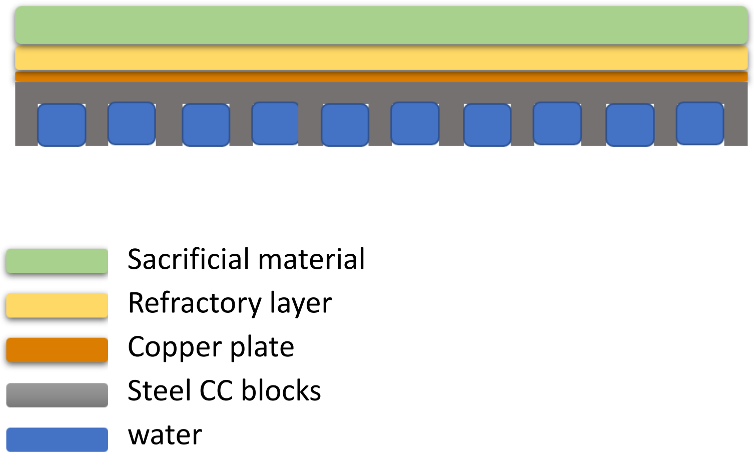
GFR SAFETY – ABOVE AND BEYOND

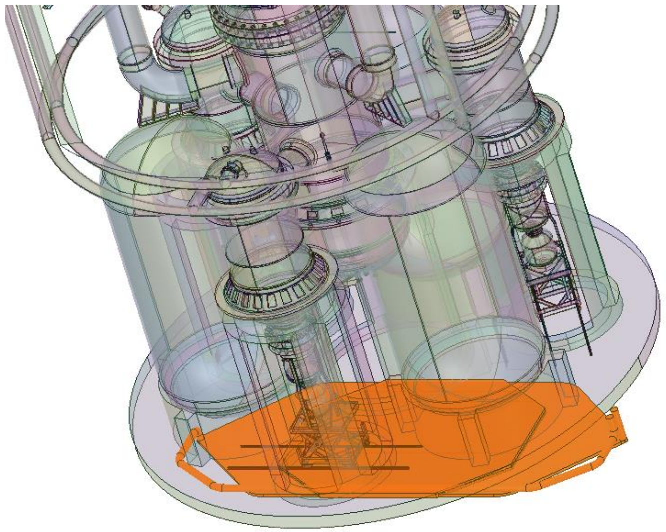
- **Goal - scenarios leading to core melting practically eliminated**
  - Seems achievable due to recent development
- **Practically eliminated ≠ physically impossible**
  - Since ALLEGRO will be the first of a kind prototype, precautions need to be taken
- **Residual risks elimination**
  - Implementation of a core catcher
  - Additional active DHR loop with battery-powered blower for low-pressure scenarios (large rupture of Guard Vessel)

DESIGN OF THE CORE CATCHER

- **Main features**
  - Octagonal shape, only the bottom cooled
  - Made from steel blocks with fins
  - Copper plate for more even heat distribution
  - Water flowing in channels between the fins







R&D Program on ALLEGRO

- **General direction of R&D at regular V4G4 meetings**
  - (3x-4x per year)

- **ALLEGRO R&D Roadmap document**
  - Summarizing main goals, state of the art, prioritization of further R&D
  - Under preparation

- **National level**
  - Each member of V4G4 is responsible for coordination of the R&D activities on the national level according to expertise and national priorities

- **Most of the activities co-financed by the governments or the EU**
  - GFR/ALLEGRO not ready for commercial applications, thus not yet very attractive for private investors
  - Private co-Financing of specifically targeted (usually cross-cutting) R&D activities

GFR/ALLEGRO R&D PROJECTS IN CZECHIA

- **Ongoing national R&D projects that include GFR/ALLEGRO:**
  - Collaboration with more than 15 universities, academic institutions, manufacturers, suppliers
  - Compulsory co-financing by private companies (up to 40 % of total project budget, depending on the call)

Name	Duration	Main goal	Total budget (M€)
NOVA	2018-2022	Development of sacrifical materials for core catchers of GFRs	0.8
REDEAL	2018-2024	Testing of construction materials in gaseous environments at extreme conditions (high temperature, corrosive environments)	1.3
MKM	2018-2024	Development of a new class of Zr based alloys and high entropy alloys with optimized properties for Nuclear industry	1.7
ALLEGRO	2018-2025	Desing and testing of key systems and components for ALLEGRO	2.1
SODOMAHe	2019-2025	Stability and resistence of materials for high-temperature helium-cooled reactors	3
MATPRO	2020-2024	Developmnet of "better concrete" for extreme conditions	0.7
KOBRA	2020-2023	Developmnet of a passive safety systems for GFRs/VHTRs based on prolongation of primary compressor rundown by utilization of decay heat	1.3
PMATF	2020-2023	Methods for the characterization, testing, and qualification of irradiated samples of ATF materials	1.7
			Total: 12.6

SafeG Project - overview

- **Recieved funding from the Euratom H2020 programme NFRP-2019-2020-6**
- **Full name:**
  - Safety of GFRs through innovative materials, technologies and processes
- **Consortium:**
  - 15 organizations from 7 European countries + Japan

    VUJE(SK), STUBA(SK), UJV Rez(CZ), CVR(CZ), CTU(CZ), EK(HU), BME(HU), CEA(FR), NCBJ(PL), Cambridge U.(UK), AMRC(UK), WOOD(UK), BriVaTech(GER), Kyoto U.(JAP), Evalion(CZ)
- **Total budget: 4.5M€**
- **Duration: October 2020 – September 2024**
- **Work packages:**
  - Core design and safety
  - Innovative materials and technologies
  - Decay heat removal
  - Results integration, standardization and codes
  - Education and training

SafeG Project - objectives

PROJECT OBJECTIVES

The global objective of the SafeG project is to further develop the GFR technology and strengthen its safety. The project shall support the development of nuclear low-CO2 electricity and industrial process heat generation technology through the following main objectives:

- To strengthen safety of the GFR demonstrator ALLEGRO
- To review the GFR reference options in materials and technologies
- To adapt GFR safety to changing needs in electricity production worldwide with increased and decentralized portion of nuclear electricity by study of various fuel cycles and their suitability from the safety and proliferation resistance points of view
- To bring in students and young professionals, boosting interest in GFR research
- To deepen the collaboration with international non-EU research teams

SUMMARY

- **GFR goals**
  - combining fast reactor and high-temperature technologies
  - Very versatile technology allowing for wide range of applications

- **GFR demonstrator ALLEGRO**
  - One of ESNII technologies
  - Developed internationally under governance of V4G4 Centre of Excellence

- **R&D of GFR technology in Europe**
  - 8 national R&D projects
  - 1 international R&D project in Europe and 2 within GIF – collaboration with Japan
  - Total budget over 17M€

Thank you for your attention

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