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ALLEGRO
Gas-cooled Fast Reactor Demonstrator

R&D FOR ALLEGRO DEVELOPMENT

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  - Examples

I: Large R&D project coordination and breakdown

LARGE (R&D) PROJECT – HOW TO START?

- **Common mistake:**
  - starting with detailed technical specifications (starting with your respective field)
- **Basis of Design – a good starting point – helps you AND others to understand „what“ and „why“**
  - Intent
  - Basic description and background
  - Target parameters
  - Lowest acceptable parameters
  - Not-important parameters – left without target values to allow for some degree of freedom

LARGE (R&D) PROJECT – REACTOR

- **For a reactor:**
  - Start with the reactor type, fuel and coolant – this defines your reactor the most
  - Target power and temperatures
  - Size of the unit and manufacturing – classic full-size reactor or SMR, is it important for you and why?
  - …
- **Don‘t try to specify or limit everything**
  - Decide what is important and what is just a derived parameter
- **In the ALLEGRO project:**
  - Two living documents „Specifications on Safety“ and „Design specifications“

LARGE (R&D) PROJECT – PHASES

- **5 stages of development:**
  - **Idea** – No technical solution, just an idea that something can exist
  - **Pre-conceptual design** – rough technical solution, basic principles explained
  - **Conceptual design** – well-formulated technical solution lacking fine details
  - **Basic design** – fine details solved – materials to be used, manufacturability of parts etc.
  - **Detailed design** – Manufacturing documentation level of detail

- **Sometimes only 3 stages are used:**
  - Idea
  - Conceptual design
  - Detailed design

- **Can apply to a whole project or to individual systems and components**

PHASES OF THE PROCET – DESIGNING A REACTOR

Stage of developmnent	Description of work to be done	Fulltime people needed (at least)	Budget needed
Idea	An idea, e.g. „What about a reactor with the fuel in form of gas“ and its elaboration	1	Virtually zero
Pre-conceptual	Basic thermal balance calculations, core physics, basic safety concept and calculations, focused mainly on the reactor core and primary circuit	~ 10	Milions €
Conceptual	Detailed calculations, complex experiments, design of power conversion unit and auxiliary systems, detailed safety concept	~ 50	Tens of millions €
Basic	Detailed experiments, detailed analyses, precise desing of all main systems and components	Hundreds	Hundreds of millions €

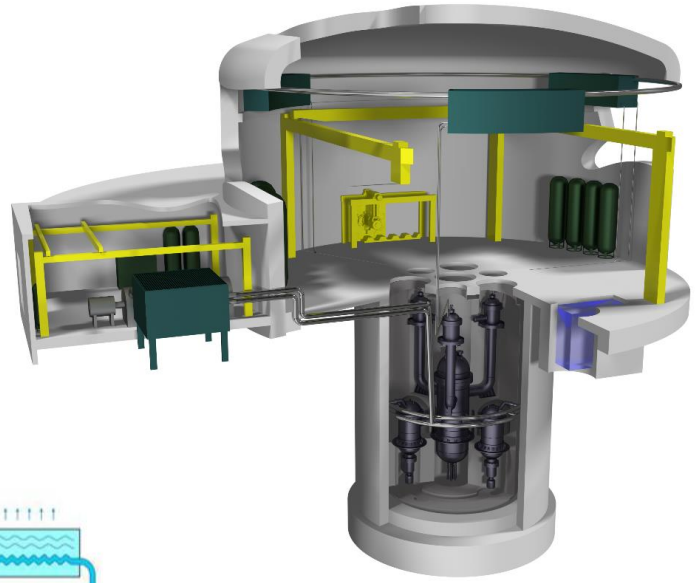
PHASES OF THE PROCET – DESIGNING A REACTOR

- **Each step = exponential growth in complexity**
  - Therefore also in budget and people needed
  - Most of the work is invisible to the outside – very little difference for outsiders between a finished pre-conceptual design and finished basic design
- **Financing:**
  - Unrealistic to reach more than mature pre-conceptual design of a reactor using just public money from grants and research projects – some bigger framework needed to finish at least the conceptual stage
- **Modern technologies (CAD, CFD, etc.):**
  - Allows to mask projects at the level of idea as projects entering basic design stage
  - Hundreds of reactor „concepts“ being just empty shells with no backbone
  - Dangerous – investors may lose interest if they find out they were scammed

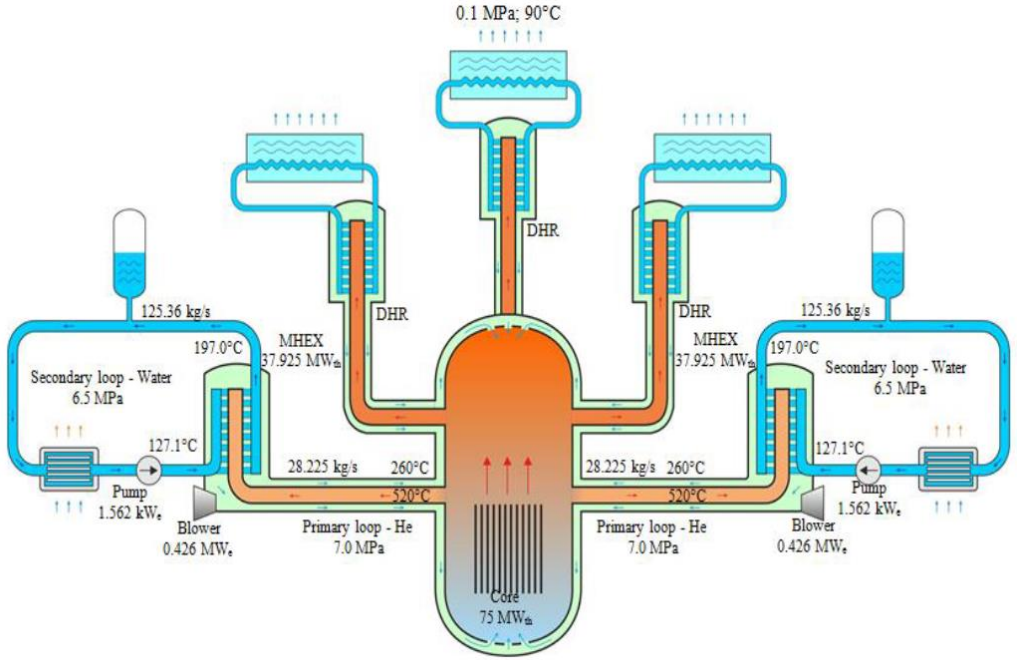
II: The ALLEGRO Project

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

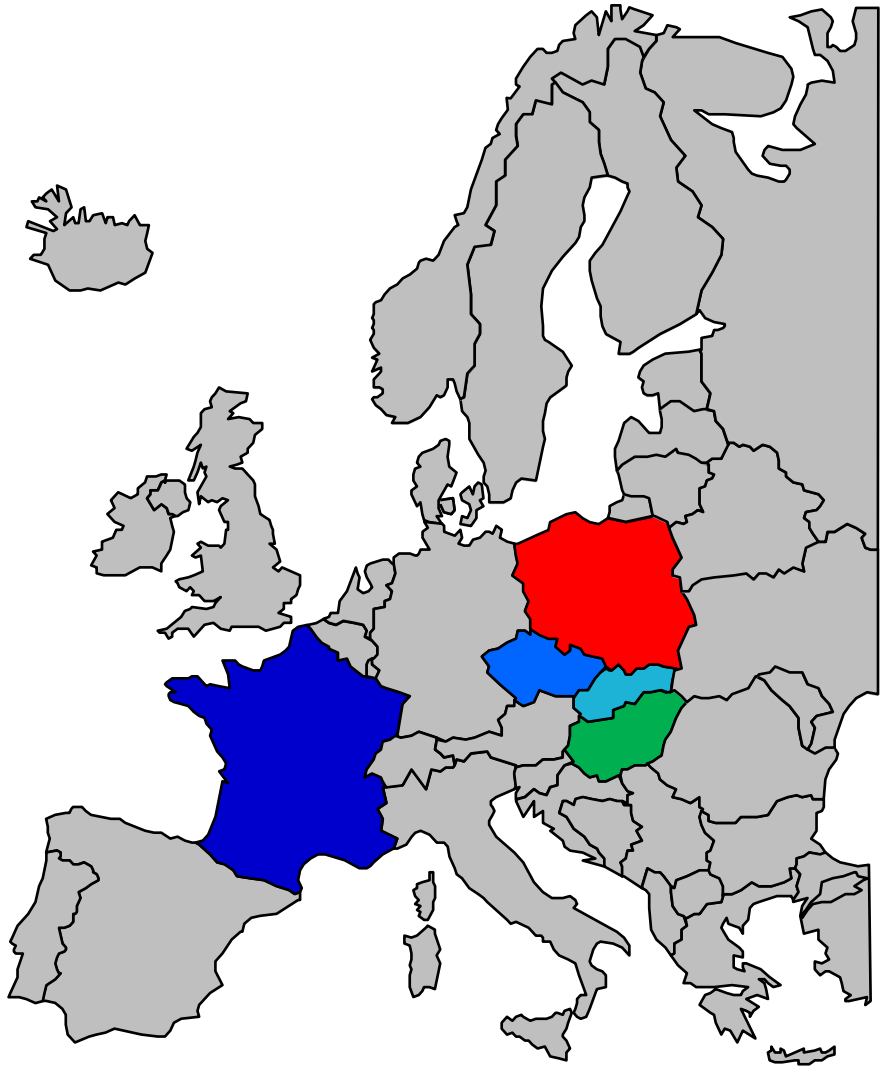


ALLEGRO main characteristics	
Nominal Power (thermal)	75 MW
Driver core fuel/cladding	MOX(UO2) / 15-15ti Steel
Experimental fuel/cladding	UPuC / Sic-Sicf
Fuel enrichment	35% (MOX) / 19.5% (UO2)
Power density	100 MWth/m3
Primary coolant	He
Primary pressure	7 MPa
Driver core in/out temperature	260°C /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



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, a s., Slovakia
- **Associated members (alphabetically)**
  - Alternative Energies and Atomic Energy Commission, France
  - Research Centre Řež, Czech Republic



III: ALLEGRO Research and Development

V4G4 ALLEGRO R&D - OVERVIEW

- **Two high-level living documents**
  - R&D Roadmap
  - Safety research roadmap
- **Currently in the pre-conceptual phase – evaluation latest in 2025**
- **Sources of finance:**
  - International research projects
    - EC funded projects, bilateral or multilateral research projects (UJV-CVR-JRC, MTAEK-KAERI)
  - National research projects
    - In recent years, mainly Czech Republic and Hungary were successful in national calls, with the total budget of ongoing projects exceeding 12M€
  - In-kind projects
    - V4G4 has been working on several topics on in-kind basis
- **Coordination of activities**
  - during Project Coordination Team and Steering Committee meetings several times a year

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	3.0
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

GFR/ALLEGRO R&D IN CZECHIA

- **Czech Republic has solid capabilities in developing cutting edge Nuclear technologies**
  - Close cooperation of R&D companies, academia and the nuclear supply chain
  - Capability to develop a reactor project from the pre-conceptual phase to manufacturing of the components
- **Organization participating in the national GFR projects:**

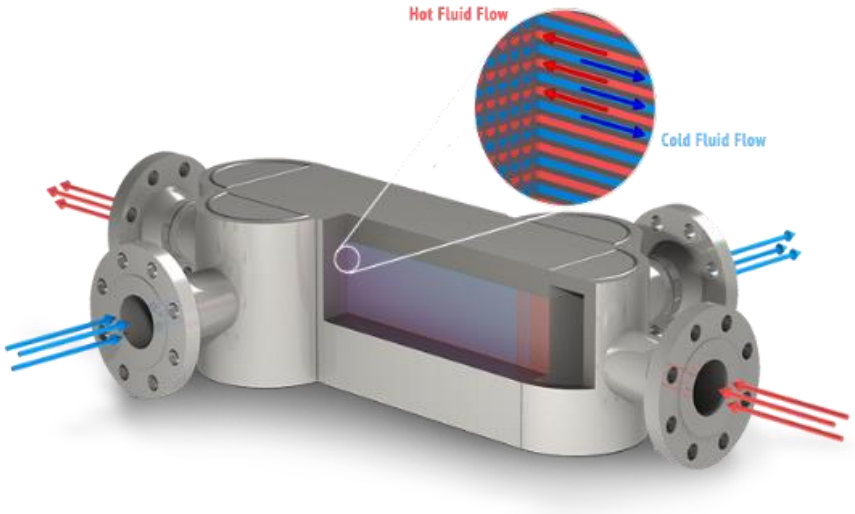
No.	Abbreviation	Name	Type of organization
1	ATEKO	-	Manufacturer/Supplier
2	CTU	Czech Technical University in Prague	University
3	CU	Charles University	University
4	CVR	Research Center Rez	R&D Organization
5	SKP	Doosan Skoda Power	Manufacturer/Supplier
6	IIC CAS	Institute of Inorganic Chemistry, CZ Academy of Sciences	Academia
7	IT CAS	Institute of Thermomechanics, CZ Academy of Sciences	Academia
8	MICO	Moravian Industrial Company	Supplier
9	Skoda JS	Skoda Nuclear Engineering	Supplier/research organization
10	SVUM	- (former National Institute of Material Research)	Private R&D Organization
11	TUL	Technical University Liberec	University
12	UCT	University of Chemical Technology in Prague	University
13	UJP	- (former National Institute of Nuclear Fuels)	Private R&D Organization
14	UWB	University of West Bohemia in Pilsen	University

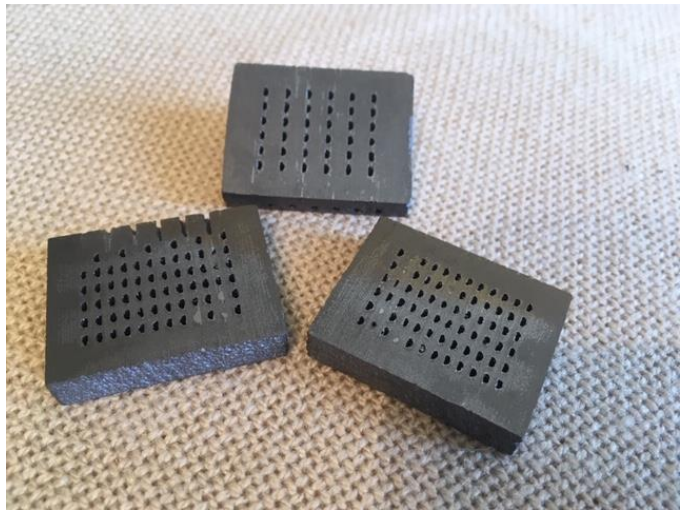
ALLEGRO R&D – MATERIALS AND MANUFACTURING PROCESSES

- **Multiple finished and ongoing projects oriented at research, development and testing of materials and innovative manufacturing processes for:**
  - Fuel and core
  - Construction materials for primary and secondary circuit
  - Thermal insulation
  - Safety systems
- **Long-term effort in exposition of materials to very high temperature gases**
  - Study of their degradation and changes in mechanical properties
  - Unique data generated
  - Obtained knowledge being utilized in design of components for the GFR

Example of R&D in materials – Main Heat Exchanger

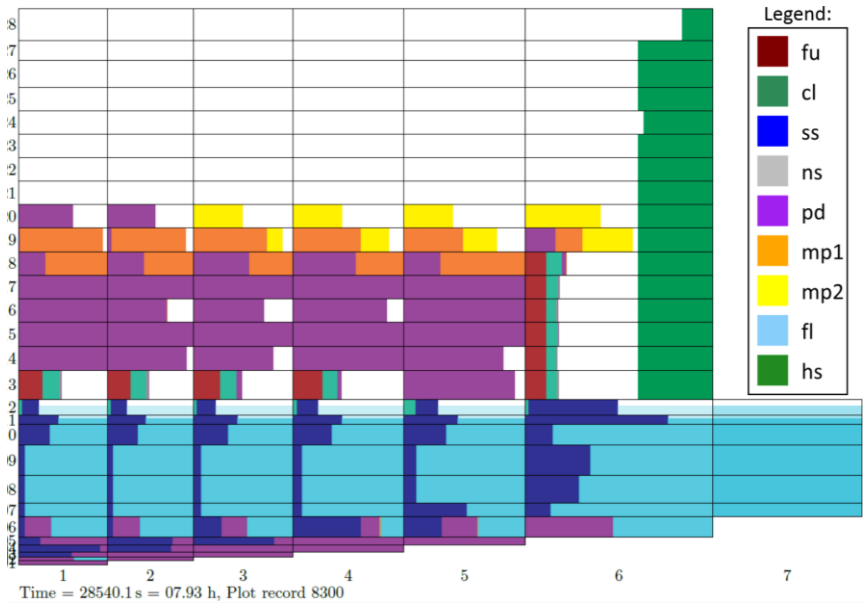
- **Gas/gas heat exchanger for very high temperatures**
  - Goal: To design, fabricate and test a new high performance heat exchanger suitable for application in GFR
  - Current status:
    - Unique fabrication process of ceramics developed, tested, optimized
    - Scaled-down prototypes manufactured
    - Testing ongoing

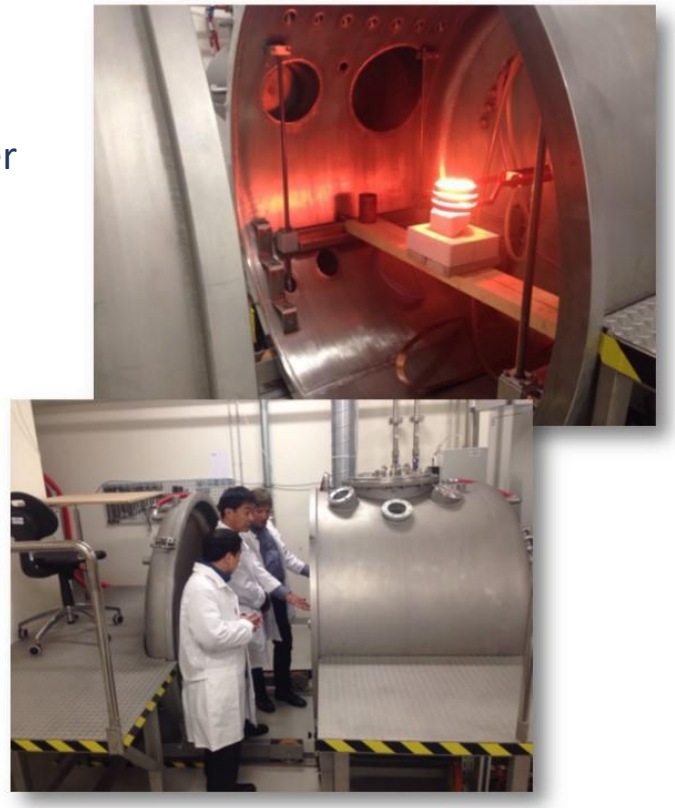




Example of R&D in materials – Severe Accident Research

- **Severe accident research and SAM development**
  - MELCOR analyses of severe accident scenarios
  - Development of a core catcher for GFRs (project TACR ALLEGRO)
  - Research and development oriented at advanced sacrificial materials for core catcher





ALLEGRO R&D – HELIUM TECHNOLOGIES

- **Several topic addressed:**
  - Helium purification - separation of solid particles, moisture and NCG
  - Helium sealing
  - Tribology and contact surfaces interactions in hot helium
  - Leaked helium recovery

- **Long-term development in the Czech Republic within multiple research projects (2013-2025)**

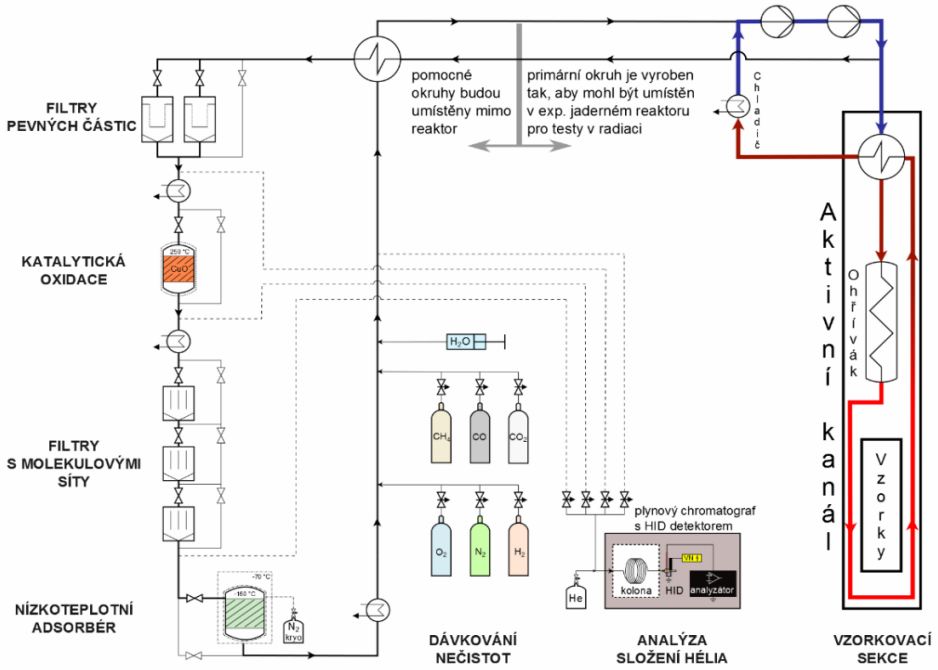
Helium Technologies R&D – Helium Purification

- **Test-facilities for separation of impurities/gases from gaseous media**

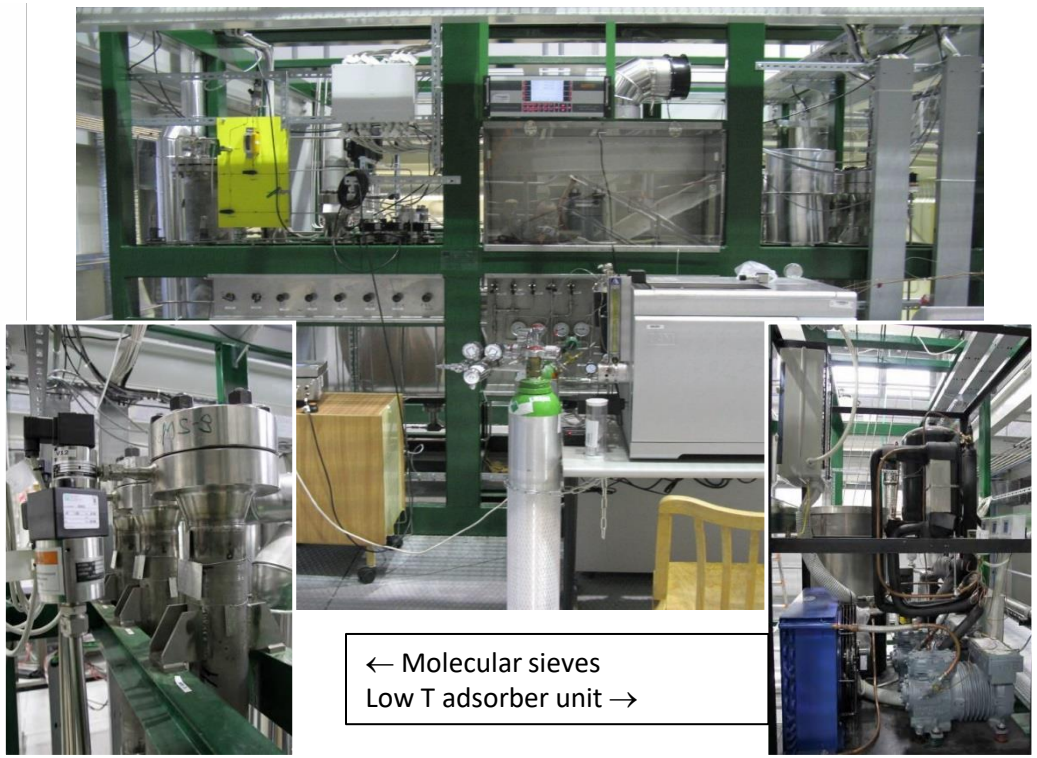
Performance of Helium purification unit in the HTHL1 loop (CV Rez)

- Purification unit (H2, CO, CO2, CH4): Mech. filters, Room-T mol. sieves, CuO bed 250 °C, Adsorber -70 °C
- Doping unit & Analytical unit (Gas chromatograph & optical hygrometer)
- Out-off pile training facility

Scheme of the HTHL1 loop



View of the HTHL1 loop purification unit



← Molecular sieves
Low T adsorber unit →

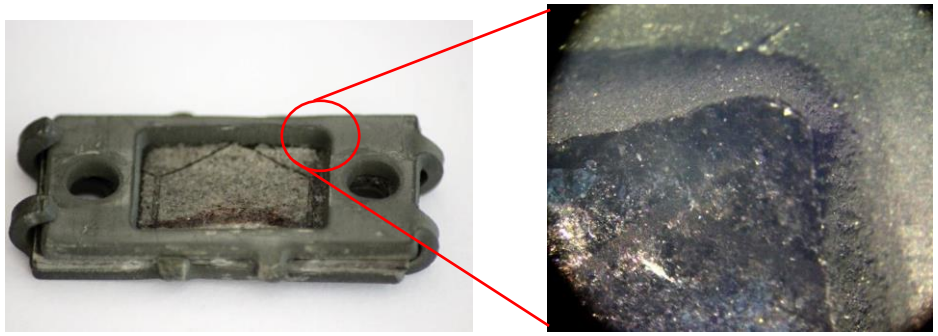
HELIUM TECHNOLOGIES R&D – HELIUM SEALING

- **Sealing prototypes for systems containing high temperature helium**
  - R&D on sealing applicable to ALLEGRO prototypic conditions (resistance to high T)

Exposition & analysis of standard sealing material coupons in He loop HTHL1 (CV Řež)

- Small Graphite & Mica foil coupons fixed in a AISI316 frame
- Ageing tests of sealing coupons in flowing helium
  770 ºC, 1000 h containing impurities CO, H2, H2O, CH4.
- Evaluated was erosion & mechanical properties of coupons
  (thermogravimetry & optical microscopy)

Mica coupons (framed)



Before exposure

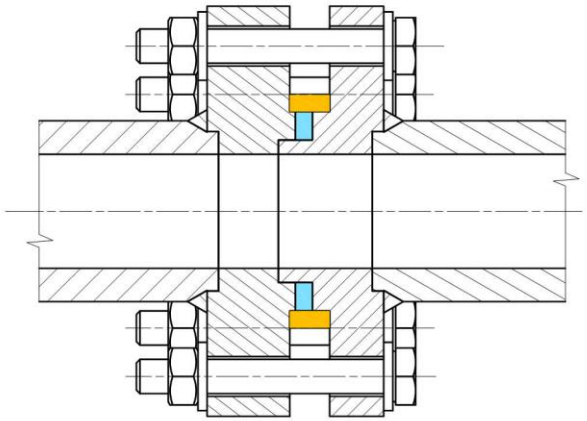
After exposure

HELIUM TECHNOLOGIES R&D – HELIUM SEALING

Development of new sealings for flange joints & first scoping tests in a dedicated loop

- To increase heat resistance of sealing in hot helium by dosing expanded graphite by means of boracic acid
  Result: Compressed H3BO3-modified graphite rings combined with a mica foil
- Tests using substitute gas (N2, Ar, at 700 °C, 55 bar to get experience with the test loop & procedure
- Test results: Good performance, easy disassembly

Vertical cut of the test rig *(sealing in color)*



Test rig

Ring sealing *Before/after exposure*

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

ALLEGRO

Gas-cooled Fast Reactor Demonstrator

Thank you for attetntion!

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