ÚJV Řež, a. s.

Status of the ALLEGRO Project

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ESNII Biennial Conference, Brussels, Belgium, March 17-19, 2015

Outline

- Why to have demonstrator ALLEGRO
- Project organization
- Design: ALLEGRO concepts and Philosophy
- Safety issues in ALLEGRO
- ALLEGRO Roadmap
- Financing before 2020
- Summary & Conclusions

Why to have demonstrator ALLEGRO (first ever GFR)

- **To establish confidence in the innovative GFR technology with the objectives:**

  A) 1- Demonstrate the viability in pilot scale

  2- Qualify specific GFR technologies such as:
  - **Core behavior and control, fuel and the fuel elements**
  - **Specific safety systems, in particular, the decay heat removal function**
  - **Gas reactor technologies (He purification, …)**
  - **Together with demonstrating that these features can be integrated successfully into a representative system**

  B) To contribute by Fast flux irradiation to the development of future fuels (innovative or heavily loaded in Minor Actinides)

  C) To provide test capacity of high-temp components or heat processes

  D) To dispose of a first validated Safety Reference Framework

- **No power conversion system in ALLEGRO (2009)**

Project organization

- **200x-2009** (2013)**: CEA - Development of GFR2400 & ALLEGRO 75MWt**
- **2010-2020: CZ-HU-PL-SK - Preparatory phase of ALLEGRO:**
  - MoU (05/2010): Prepare documents for decision makers: ALLEGRO Yes/No
- **08/2013: „V4G4 Centre of Excellence“ -** Association (legal entity) founded in SK

VUJE (gen. designer):	Responsible for Design & Safety (with ÚJV)
ÚJV Řež:	Helium technology, R&D and Exp. support
MTAEK Budapest:	Fuel
NCBJ Swierk:	Materials
CEA (to be associated):	Support, …

- **Content of the ALLEGRO Preparatory phase within V4G4 CoE:**
  - Pre-conceptual Design: Revision of ALLEGRO CEA 2009 → Modified concept
  - Safety & Licensing: Analyses (coolability), Pre-licensing requirements in SK
  - R&D and Exp. support: Priorities (including fuel)
  - Governance & Financing: NDA, IPR, background, foreground, rules of cooperation…

Design: ALLEGRO concepts

- **ETDR CEA 2008**
  - 50 MWt, 1 loop, He/water (FP6 GCFR STREP)
- **ALLEGRO CEA 2009**
  - 75 MWt, 2 loops, He/water (FP7 GoFastR)
- **ALLEGRO CEA 2010**
  - 75 MWt, 2 loops, He/gas(He), Patented innovative option

CEA + EURATOM

05 / 2010
Memorandum of Understanding
MTAEK-UJV-VUJE

- **ALLEGRO V4G4 20xx**
  - xx MWt, 2 loops, I. He, II. N_2 ?, III. ?

08 / 2013
V4G4 Centre of Excellence
MTAEK-NCBJ-UJV-VUJE (CEA)

Design: Philosophy of ALLEGRO (unique feature)

- **Three distinct phases of operation ⇒ three different core configurations:**

- **STARTING MOX (UOX) CORE**
  - **MOX/SS with 25% Pu (metallic hexagonal sub-assemblies)**
  - **Core outlet temperature limited to ~530 °C**

MOX/SS fuel has small safety margin

- **INTERMEDIATE CORE (containing 1 to 6 refractory FAs)**
  - **Test assembly (U,Pu)C/SiCf-SiC with 29-35% Pu fuel pins bundle within an internally insulated metallic hex-tube.**
  - **Outlet temperature: Test assembly ~850 °C (reduced flow rate at FA inlet)**
    Average core ~530 °C

- **FINAL REFRACTORY CORE**
  - **Average core outlet temperature increased to ~850 °C**

Refractory fuel still needs R&D (currently suspended)

- **Remark: ALLEGRO must be designed for the high temperature option (incl. low/high T upgrade of certain technologies)**

Safety issues in ALLEGRO

- **ALLEGRO is coolable, when active systems are available**
- **Pressurized transients (LOFA, blackout): Natural convection might be OK**
- **Depressurized transients (LOCA): Natural convection is not sufficient**
  (Except the promising Innovative option by CEA from 2010)
- **Fuel assembly blockage or ATWS may lead to rapid fuel/core overheating**
- **Massive water ingress into I. circuit: Loss of subcriticality and/or investment**

- **Feasibility studies to be performed:**
  - **Reduced power (power density) in current geometry** (by 10-40 %) **- underway**
  - **Innovative solution by CEA (turbomachinery) using suitable gas in II. circuit** (He, N_2, Ar, … ?)

ALLEGRO Roadmap (to be issued in ~06/2015)

- (Pre-conceptual) **Design process**
  - **Design requirements & Objectives:** Does not exist yet
    - **Needed for all systems & subsystems**
  - **Safety requirements & Objectives:** Draft under preparation
    - **IAEA, WENRA, local authority**
  - **V4G4 pre-conceptual design:**
    - **Based on ALLEGRO CEA 2009**

- Optimization of power & II. gas
- Core & fuel design
- Heat removal system
- Design of Reactor / Structures / Systems

- **Safety analyses**
  - **Neutronics, Coolability, Source term: With feedback to Design**
  - **PSA** (for frozen design)
- **R&D and Experimental support**
  - **Safety**: He Loops (DHR: SUSEN-CVR, …) including Analyses
  - **Technology:** Loops, Stands (CEA, …) including Analyses

R&D Roadmap will be available in 2015.

- **Project development plan (Business plan)**
  - Brief summary of the project Objectives, Design, Safety, R&D, Roadmap& Schedule, Legal & Financial matters, Site, Licensing, Construction, …

Financing before 2020 (1)

- **EURATOM Projects**
  - **FP5 GCFR** (2000-2002) – EC contribution 0.25 M€
    - Review of experience in gas reactors, formulation of future R&D
  - **FP6 GCFR-STREP** (2005-2009) – EC 2 M€
    - 600 MWt case (plate fuel & direct He Brayton cycle) abandoned after first year
    - Continued were GFR2400 (direct, indirect) & its demonstrator (ETDR, ALLEGRO)
  - **FP7 ADRIANA** (2010-2011) – CSA, EC 0.99 M€
    - Mapping of existing & required experimental infrastructure for SFR, LFR & GFR research
  - **FP7 GoFastR** (2010-2013) – CP-FP, EC 3 M€
    - Design & Safety of GFR2400 and its demonstrator ALLEGRO
  - **FP7 ALLIANCE** (2012-2015) – CSA, EC 0.86 M€
    - Support of the ALLEGRO Preparatory phase
  - **FP7 ESNIIplus** (2013-2017) – CP&CSA, EC 6.45 M€ (GFR only partially)
    - Preparing ESNII for HORIZON 2020

Financing before 2020 (2)

- **National projects on GFR/ALLEGRO related projects**
  - **CEA: Till 2009-10** (or 2013 respectively)
  - **Czech Republic (V4G4): ÚJV & CV Řež**
    - **Technology Agency of the Czech Republic** (TACR):
      ~2.37 MEUR (2012-2019): Helium technologies, Code validation, Safety analyses
    - **The RIS3 Strategy for the CZ relevant for ALLEGRO consists of both the:**

approved

- **National RIS3 strategy** referenced to „*National priorities of oriented research, experimental development and innovations*" (GENIV reactors research is explicitly referenced in Tab.2, Item 1.2.6) and approved in Dec 8, 2014. More details are in Appendix 3 „Sustainability of energetics and material resources" of the Priorities
- **14 regional RIS3 strategies** The RIS3 strategy of the Central Bohemian Region (where the **ALLEGRO project** is explicitly referenced) was approved on Sept 15, 2014 by the Regional government. UJV Rez is in this region

expected

- **Structural funds through the following national Operational programs** for R&D in Energy sector:
  - **OP Enterpreneurship & Inovation for competitiveness** (Ministry of Industry & Trade)
    (Priority Axis 1: Promotion of research and development for innovations - RIS3 Strategies)
  - **OP Research, Development and Education** (Ministry of Education, Youth & Sports)

Remark: RIS3 Strategies (Research & Innovation Strategies for Smart Specializations)

Financing before 2020 (3)

- **Slovak republic (V4G4): VUJE** (Trnava)
  - **Structural funds through national Operational programs:**
    Approved ~2.9 MEUR (2015): Support of the ALLEGRO project
- **Hungary (V4G4): MTAEK** (Budapest)
  - **Government funding:**
    Expected ~2.5 MEUR (2016-19): Support of the ALLEGRO project
- **Poland (V4G4): NCBJ** (Swierk)
  - **Significant government funding is not available for this moment**

- **„V4G4 Centre of Excellence“ is a good tool for V4 regional R&D cooperation:**

  Question: Can the ALLEGRO project within V4G4 be directly funded from the EC Structural funds (interregional cooperation) ?

Summary of V4G4 priorities (2014-2017)

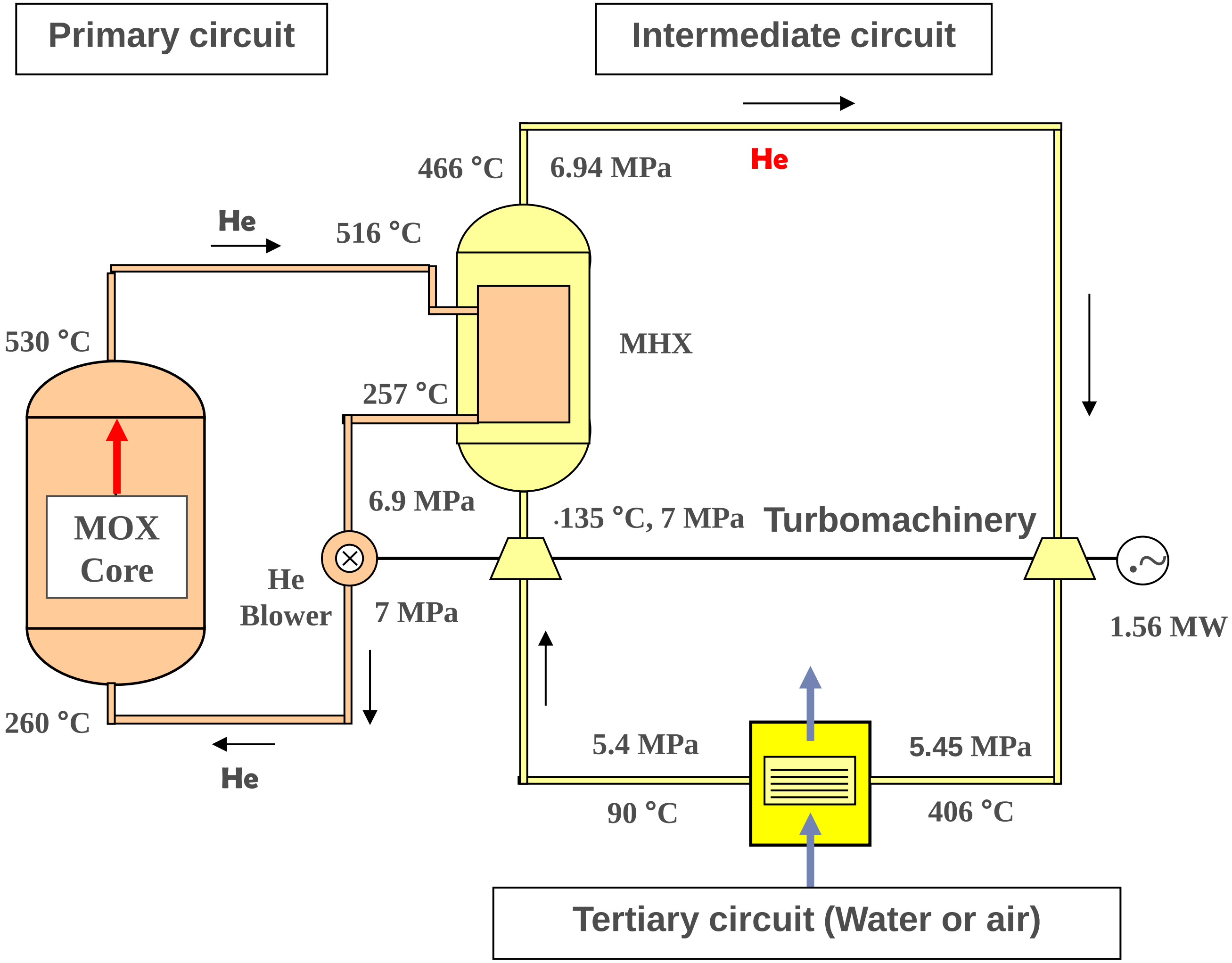
- **Design requirements & objectives (2015)**
- **Safety requirements & objectives:**
  - Draft UJV exists since 11/2013
- **R&D Roadmap to be issued in 2015**
- **ALLEGRO Project development plan (Business plan)**
- **Feasibility & Optimization of basic ALLEGRO characteristics:**
  - Thermal power (iterative thermal/neutronic/thermalhydraulic analysis)
  - Gas in secondary circuit
  - Innovative option (turbomachinery)
- **V4G4 Pre-conceptual design & Safety analyses**
  - Focus especially on DHR system & ALLEGRO coolability

Summary & Conclusions

- **Establishment of V4G4 CoE answered the question: Who is Mr. ALLEGRO ?**
- **Continuation of the ALLEGRO development within V4G4 requires formulation of fundamental "Design & Safety requirements and Objectives"**
    - **Targets & Limitations for the designer must be known before the work restarts**
- **The required increase of safety margin in ALLEGRO with the first core is a challenge for the V4G4 members** (less active & more passive systems)
- **Feasibility & Safety of ALLEGRO with oxide fuel in metallic claddings is a condition for restart of R&D on refractory fuel (at CEA)**
- **The available Roadmap for the V4G4 ALLEGRO development enables immediate restart of design work & safety analyses**
- **Direct funding of ALLEGRO within V4G4 from EC Structural funds may accelerate the progress of this ESNII project** (using interregional cooperation)

Backup slides

ALLEGRO CEA 2010: Innovative option



Analyses to be performed (1)

- CORE
  - Heat transfer from MOX core into helium
  - Gagging of the wire-wrapped SS claddings at the core level
  - Fuel rod bowing in helium
- RPV & PRIMARY CIRCUIT
  - Asymmetry of the temperature field in the RPV
  - Gamma heating of the RPV
  - Risk of water ingress into I. circuit (from the DHR system)
  - I. circuit insulation
  - Transition from the first to second core (HXs, blowers, other technology, …)
  - Azimuthal symmetry of T-field in the coaxial piping (risk of bending)
  - Dilatation of structures fixed to both the RPV and GV
- DHR SYSTEM
  - Temperature field in the DHR coaxial piping
  - Conditioning of the DHR system
  - Battery backup of DHR blowers (~550 kW …)

Analyses to be performed (2)

- HELIUM TECHNOLOGY
  - Helium make-up system
  - Location of the He purification system incl. its main parameters
  - Removal of activity from primary helium (incl. space requirements)
  - Type & source of impurities contaminating the I. circuit
  - Transport & deposition of activity in I. circuit (incl. the associated He technology)
  - Management of exchange of (contaminated) filters
- GUARD VESSEL INTERNALS
  - Heat removal (&Ventilation) from GV
  - Temperature of the concrete structures inside GV
  - Space requirements, maintenance & repair of all structures inside GV (tbc)
  - Vibrations inside guard vessel
  - SA mitigation measures (core catcher, …)
- COMPONENTS
  - Reliability of passive valves (ageing, corrosion, …)
  - Cooling of components: Main & DHR blowers, RPV bushings

ALLEGRO V4G4: Pre-conceptual design: Planned work

- **Review & Assessment of the CEA concept (underway)**
  - **Identification of the CEA background - basis for the V4G4 concepts**
  - **Identification of analyses not performed at CEA**
  - **Feasibility & functionality of the CEA design, for example:**
    Structures inside GV, check valves, …

- **Technical issues to be solved in short-term:**
  - **Effect of reduced power density onto ALLEGRO coolability**
  - **Secondary gas to be determined (nitrogen at 800 °C ?)**
  - **Final heat dissipation to be determined – study available at UJV**
  - **Analysis of heat transfer from MOX fuel rods into helium for a 100 MW/m^3 core**
  - **MOX rod acceptance criteria (cladding material)**
  - **Space requirements inside GV:**
    - He technology (He storage, He makeup, He purification,…)
    - GV ventilation (I. circuit insulation, HX for heat removal, ventilation, …)
    - Core catcher (type, size, cooling)
  - **Other fuel & core-related issues**

ALLEGRO V4G4: Safety analyses (priority list)

- **Review of analyses for the 50 & 75 MWt CEA concepts**
  - **List, Assumptions, Boundary conditions, Main results**

- **Neutronics**
  - **Assessment of reactivity coefficients**

- **Performance of the DHR systems**
  - **Conditioning of the coaxial DHR piping (in operational conditions)**
  - **Unification of the initial & boundary conditions of the DHR system**

- **Core-bypass scenarios in LOCA**
  - **Interference between DHR & Main loops**

- **Residual risk analyses**
  - **Study using MELCOR is underway at UJV (Blackout, LOCA, …)**
  - **Evaluation of fuel assembly blockage**