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Year 2016 was a demanding and rewarding year for the Centrum výzkumu Řež s.r.o. (Research Centre Řež, CVŘ). The organization has continued in building-up teams and technologies while strengthening international relationships with other research centres. Several important project proposals were launched, which resulted in the establishment of valuable projects. It was the year which has brought us closer to our core mission, which is to continue and expand the 60-year tradition of nuclear technology research in the Řež valley. As a member of the UJV Group, CVŘ is focused to become an excellent pre-commercial research company.

The fifth year of the Sustainable Energy (SUSEN) project opened its final stage after the first part was successfully finished in 2015. Most of the SUSEN infrastructure was already completed in the previous years, particularly the one supporting the research dedicated to studies of material degradation mechanisms and of components in the nuclear power plant operations. The microscopy and microanalysis centre, the non-destructive testing laboratories and the robotics and technologies supporting the final disposal have enabled the research to be performed at almost full scale. Our research teams have been very active in their work on research projects, while still working on the procurement and development of technologies for new laboratories. In 2016, CVŘ started the operation of important technological infrastructures such as the fusion primary wall components testing facility HELCZA. CVŘ also achieved the licence for operation of the new hot cells and it started to operate the cold crucibles – a key technology for achieving progress in understanding processes accompanying severe accidents and contributing to their prevention and control.

The technical infrastructure started to be utilized for very concrete applications and projects in all areas of CVŘ professional research and service, including work for GEN II&III assessments, for GEN IV development and for the ITER thermonuclear fusion project, one of the most exciting project of our times. Among tens of research projects in the CVŘ’s books, one can mention the development of fluoride distillation method for fissile elements extraction from corium, the investigation of new fuel cladding materials and the work on material behavior in heavy metal cooled environment.

Our research teams were active in publication of their work outcomes, in presentations of the most recent results at international conferences or in taking part of workshops and meetings – typically dedicated to contribution to an international effort to move the technology development forward.

Another large research infrastructure, the Řež Research Reactors, was involved in several research activities. The very important cooperation with the Oak Ridge National Laboratories represents an example of bringing the international research strategy of the Czech Republic into life. Under the MoM between the Czech Republic and the USA there is an ongoing research in the field of salt technologies by measurements of the neutronic properties of the FLIBE salt at the LR-0 reactor. Further, a new method for the utilization of the low enriched uranium targets for the Mo-99 production was developed for the LVR-15 reactor. The reactor continued to be utilized also by the physicists from the Czech Academy of Sciences and universities – e.g. for neutron diffraction and other measurements relevant for understanding solid state properties.
Based on our previous works for GEN IV technologies, on the experience in molten salt technologies and building on the cooperation with the US research institutions, CVŘ has started the development of an idea of small modular reactor concept (FHR) as potential product of the Czech industry.

Our involvement in the Jules Horowitz project continued in 2016 with all embedded parts finished and important technologies developed — such as the heavy doors and the cranes; important contracts for the finalization of the project were established. At the same time CVŘ maintains its involvement in the working groups preparing the future Jules Horowitz research programs.

The safety research continued in several directions, supporting SUJB, the national nuclear safety regulator, the Ministry of Interior and other core institutions of the Czech Republic.

In 2016, our Centre continued to build intensive cooperation with universities in the Czech Republic and abroad, partnering with other institutions to support research and education of students. Our laboratories and technologies have been included into shared projects and research activities with the international communities within Horizon 2020 projects, as well as in the joint programs of the European Energy Research Alliance (EERA) or in activities related to Sustainable Nuclear Energy Technology Platform (SNETP).

I would like to thank our CVŘ colleagues, the UJV Group, cooperating organizations, partners and vendors for their inspiring and fruitful cooperation in 2016.

Martin Ruščák,
CVŘ Managing Director
INTRODUCTION TO CENTRUM VÝZKUMU ŘEŽ

The Centrum výzkumu Řež s.r.o. (Research Centre Řež, CVŘ) was founded in 2002 as a subsidiary of ÚJV Řež, a.s. (previously Ústav jaderného výzkumu / Nuclear Research Institute, NRI) and continues a 60-year tradition of nuclear technology research in the UJV Group. The company has the status of a research organization under the Act No. 130/2002. There are three important milestones in the CVŘ history, which have shaped the company profile: since 2009, we have been participating in the development of the Jules Horowitz Reactor in France. As part of this project, CVŘ has created a highly-qualified team specialised in design, calculations and organization of manufacturing. It represents an opportunity for CVŘ future participation in the unique JHR project and infrastructure. In 2011, the LR-0 and LVR-15 research reactors were transferred to CVŘ, thus considerably enhancing the company’s research infrastructure. This enabled CVŘ to participate in national and international research and development projects, while strengthening the platform for cooperating with universities and research organizations, thus reinforcing its research teams. The most important activity for CVŘ’s development, i.e. the SUSEN (SUStainable ENergy) project, has been funded by the EU Structural Funds since 2012. The project goes far beyond the infrastructure rollout (buildings and equipment), as the very existence of the equipment takes the company to a new level of opportunities. The SUSEN project has also resulted in the creation of teams of researchers, technicians and support staff, which are now the CVŘ’s largest asset. The project sustainability requirement helps to promote a corporate culture attuned to the well-perceived need for research and innovation excellence leveraging interdisciplinary synergies within the company itself and the whole UJV Group.
Today, the company operates a major research infrastructure to support R&D for development of nuclear and other means of sustainable power generation. In particular, the two research reactors, create the core of the infrastructure and are linked to technological loops, hot cells, laboratories for material science, severe accident modelling, technologies for testing components and materials for fusion related R&D. This covers most of the life cycle of current technologies of GEN II–III+, future GEN IV and fusion technologies. With our enthusiastic team of technology professionals, CVŘ aims to be an enabler and driver of future technology development in the Czech Republic and the first choice for cooperation for our European and overseas colleagues via our memberships in important international R&D communities and projects. Our vision is to become a robust Central European pre-commercial research centre specialized in nuclear power generation technology while building on synergies with the UJV Group and the Czech and international research community.

2.1 Human Resources

At the end of 2016, CVŘ was employing 303 staff members. CVŘ’s status as a research and development organization is reflected in the employee education structure and employee position distribution; the employees’ expertise covers a broad range of competences based on their education and experience in various technical disciplines such as nuclear science, mechanical, chemical, and civil engineering, mathematics, physics, social and economic sciences. Almost half of the staff hold highly technical positions such as researcher, designer or computing expert and another significant part, the other near-half includes technicians, operators and support technical staff (i.e. dosimetry, security, etc.).

At the end of 2016, the median age of CVŘ employees was below 40 years (see Fig. 1). Since CVŘ is a relatively young organization and the SUSEN project has resulted in a significant growth in employee numbers in recent years, more than 75 % of our employees have been with the company for less than 5 years. CVŘ routinely uses the Personal Development Plans, which are used as medium-term career planning tools giving employees an opportunity to choose and switch between the career paths of an expert, project manager or manager. Annual goals are managed by Key Performance Indicators (KPI). All researchers are encouraged and supported to publish their work and results in highly impacted journals and at scientific conferences, such as to develop new skills and competences in their fields.

Fig.1 – CVŘ employees’ age structure as of January 1st, 2016
2.2 Company Governance

The company is divided into core business sections (Research and Development in Power Generation Section, Reactors Operation Section, SUSEN Project Section, Large Infrastructure Projects Section and Safety Research Section) and supporting departments (Finance and Controlling, Operations Management, Procurement and the Project Office). Important supporting roles are secured by the Scientific Director and Commercial Research Manager (Director Deputies, see Fig. 2). Outside of the organizational structure, the Executive Director is supported by the international Committee for Commissioning of SUSEN Research Infrastructure and the Scientific Council.

An integrated risk management system has been implemented, covering the areas of nuclear safety, quality, occupational safety, environment and projects. The system has been certified according to the respective international standards. As an operator of research reactors, the company is subject to relevant legislation and has developed support functions to ensure compliance. The safety committee oversees all security issues, including nuclear safety. The committee is independent of managers responsible for the operation of the various facilities.

CVŘ is using the internal information platform EPRA suitable for combining all important information from project management, human resources management, knowledge and risk management, publication activities, infrastructure and planning.

The research strategies and technical goals are formulated when preparing the planning for each of the CVŘ work areas (reactors, materials, fusion, and individual SUSEN research programs).
2.3 External Relations

ČVŘ has developed broad-ranging relations with the Czech, foreign and international organizations active in nuclear technology research and development. In most cases these relations are based on frequent informal contacts between most of the researchers and their colleagues at those institutions. Some of our most important collaborators in the Czech Republic include: ZČU (University of West Bohemia), AV ČR (The Academy of Science of the Czech Republic), ČVUT (Czech Technical University), VUT (Technical University in Brno), VŠB-TUO (Technical University of Ostrava), VŠCHT (University of Chemistry and Technology Prague), SÚJCHBO (National Institute for Nuclear, Chemical and Biological Protection), and SÚRO (National Radiation Protection Institute). Our international partners include: JRC Petten (Netherlands), KIT (Germany), CEA (France), NLL (UK), CIEMAT (Spain), PSI (Switzerland), IFE Halden (Norway), VTT (Finland), Studsvik (Sweden), VÚJE (Slovakia), ENEA (Italy) and many others.

Cooperation agreements or other type of formalized cooperation exist with several of these organizations, directly or through the UJV Group.

ČVŘ is a member of the Steering Committee of EERA (European Energy Research Alliance), of the Jules Horowitz Reactor Governing Board, of the Governing Board of Fusion for Energy (as part of ITER), and of the Steering Committee of the TBM (Test Blanket Module)-CA Consortium. ČVŘ is also a member of the SNETP, ETSON and FUSENET platforms.

2.4 Financial Resources for the ČVŘ Activities

ČVŘ receives his main financial resources through the following tools:

European grants within the Structural Funds provided through Czech governing bodies:
- Operational Program Research, Development and Education (SUSEN II phase).

National grants based on national financial resources:
- Support for research infrastructures (SUSEN, Research reactors, Jules Horowitz Reactor participation) is provided by the Ministry of Education, Youth and Sports (MEYS);
- Infrastructure co-financing program under NPU II – National program for sustainability also provided by MEYS (Research for SUSEN);
- Grants of the Czech Republic, mostly the grants from TAČR (technological and pre-commercial research), a minor part from GAČR (basic research);
- Institutional funding.

European funding

Horizon 2020 is the biggest EU Research and Innovation program available for over 7 years (2014 to 2020) and leaded directly by the European Commission. ČVŘ participates in consortia of Horizon 2020 projects (e.g. EUROFusion).

Commercial contracts
- Commercial research
  Contract research for industry, but also for international consortia funded wholly or partly by public funds (e.g. F4E, ESS, JHR) or contract research for the industry.

- Commercial services
  Services for industry – in particular, the commercial offer, focuses on the irradiation of material for medical and industrial applications, including neutron activation analyses.
THE SUSEN (SUStainable ENergy) PROJECT

In December 2011, after almost a five years effort, the Research Centre Řež, with the support of the Ministry of Education, Youth and Sports and the University of West Bohemia, reached the approval of the project “Sustainable Energy (SUSEN)”, funded by the European Union Structural Funds aimed at balancing the economic level of individual regions. The project was part of the programs “Research and Development for Innovation” and “Research, Development and Education” managed by the Ministry of Education, Youth and Sports. Regional research and development centres in Řež and Plzeň were selected as sites.

In accordance with the objectives of European regional policy and the Czech Republic’s priority interest in enhancing its competitiveness, the SUSEN project is oriented towards the knowledge economy. Its aim is to support the safe, reliable and long-term sustainable operation of existing energy facilities, especially the second and third generation of nuclear power plants, with an aim to extend their service life by 20–40 years. Another objective of the project is to contribute to the smooth transition from the II and III+ to the GEN IV reactors power generation through research and development of new technologies. Further, a significant part of the project addresses the research and development of advanced technologies for thermonuclear fusion.

As part of the SUSEN project, a robust and modern research infrastructure was built between 2012 and 2016, specifically a new Diagnostic Centre in Řež and a new Experimental Hall in Plzeň, and five other existing buildings in the ÚJV Řež area were reconstructed and completed. The total cost of construction of all buildings in the project SUSEN, including supplies and works procured by Research Centre Řež, was 405 million CZK (without VAT). All buildings were gradually completed between 2013 and 2015.
The newly constructed and renovated buildings were equipped with state-of-the-art experimental equipment from 2014 to 2016. The cost of the acquisition amounted to about 1,680 million CZK (without VAT). The financially most demanding technological devices were 8 hot gamma cells, 2 hot alpha cells, the experimental supercritical water loop, two experimental helium loops, a technological circuit for testing the material samples of the primary wall of the fusion reactor, equipment for the development of remote manipulation procedures for the maintenance and repair of systems difficult to access, loss of coolant accident simulation apparatus and cold crucible for high-temperature radioactively waste characterisation studies.

A significant part of the project cost was spent on the high-tech equipment for non-destructive testing laboratories, metallographic laboratories, laboratories for mechanical testing, anaerobic laboratories and other experimental facilities.

The scientific research part of the project consists of four mutually cooperating research programs:

Program 1 “Technological Experimental Circuits” is focused on research and development for GEN IV nuclear reactors and nuclear fusion, above all on the research of the thermodynamic and hydraulic properties of the coolants and their effect on construction materials. In particular, supercritical water will be studied as a medium for the primary circuit of the supercritical water reactors, helium as the medium for the primary circuit of the high temperature reactors and for cooling the primary wall of the fusion reactors, supercritical carbon dioxide as the potential medium of the secondary reactor circuit of GEN IV and eutectic lead-lithium alloy as a medium for continuous fusion fuel (tritium) production. In addition, experimental equipment for the production of hydrogen by high-temperature electrolysis of water using high temperature helium and heat recovery was built. An important part of the program is the verification of procedures for remote manipulation and development of handling tools in hot cells and research of cyclic loading of samples of the primary wall of the fusion reactor with high heat flux. Within the program, a neutron generator was acquired to study 14.1 MeV neutron interactions with materials for fusion technologies. The program is run in cooperation with the University of West Bohemia.

Program 2 “Structural and System Diagnostics” examines the degradation of nuclear reactor component properties after long-term operational exposure as a critical input for assessing the residual service life, reliability and safety of nuclear reactors. The design and development of the creation of test samples for the research of material properties and the certification program and tests are carried out. Development of tests focused on determination of the crack propagation rate at cyclic loading at temperatures up to 800 °C (including creep interaction tests) is under way. The important part of the program is the development of new methods of non-destructive testing of ferritic and austenitic steels, as well as heterogeneous welded joints and components. The LOCA Simulation Laboratory will develop new procedures for verifying the thermal and radiation resistance and behaviour of materials and components under extreme conditions. To obtain high radiation exposure to simulate these conditions, a highly active cobalt-60 source was used.

Program 3 “Nuclear Fuel Cycle”, addresses the research infrastructure for the studies of the back end of the fuel cycle of nuclear power plants, especially for the development of radioactive waste processing and treatment technologies. It also tackles the transport conditions in the deep geological repositories of radioactive waste and their impact on the construction materials of the containers for the storage of high-radioactive waste and spent nuclear fuel and for studying the migration of radionuclides in rock formations. For these goals methods of detection of very low activities of radionuclides in very small volumes of samples were developed, together with methods of detection of very low concentrations of toxic substances. The program will further develop unique technologies for the separation of fissionable and radioactive products from spent nuclear fuel produced by reactors using modern oxide fuels with inert matrices, nitride, carbide and liquid fuels for
which industrial hydro-metallurgical processes cannot be applied (PUREX process and its variants). Also this program is developed in cooperation with the University of West Bohemia.

Program 4 “Material Research” includes the creation of a unique laboratory to investigate the structure and substructure of materials during their exploitation under extreme conditions (testing of inactive materials at high temperatures, statically and dynamically stressed in environments simulating the operating conditions of nuclear installations). The program covers also the needs of other SUSEN projects and is aimed at supporting the development of ferritic martensitic steels for use in environments with temperatures up to 650 °C (steam turbines with ultra-supercritical parameters and inactive circuits of the GEN IV nuclear power plants), austenitic steels and high austenitic alloys dedicated for components operated in aggressive environments at high temperatures and pressures and new technologies for advanced materials welding. CVŘ cooperates in this task as well with the University of West Bohemia.

SUSEN project plan defines 23 specific project outputs and 54 project results that will be achieved gradually by the end of 2022. Scientific research works were in the initial phase of the project financed mostly by a start-up grant of the SUSEN project. The importance of contract research revenues and national and international grants is gradually increasing – Research Centre Řež must be able to finance the work necessary to achieve the objectives, outputs and results of the SUSEN project and the operation of the built infrastructure exclusively from these sources and the institutional support of research and development after 2017.

The users of the SUSEN project outputs are or will be primarily designers of demonstration units of selected types of GEN IV nuclear reactors, nuclear power plant component manufacturers, ITER Fusion Energy Development Program developers, Fusion for Energy Consortium (EU + USA, Russia, Japan, South Korea, China and India), nuclear, conventional power plant and radioactive waste repository operators, developers of deep repositories of radioactive waste, the International Atomic Energy Agency (IAEA) and others.

Currently 162 employees at the Research Centre Řež and 16 at the project partner University of West Bohemia are involved in the SUSEN project. In 2016, we were glad to have colleagues from 10 countries working in our teams. The international character of the SUSEN research teams brings additional benefits – mainly in developing contacts and relations with laboratories in other countries and in transferring skills and practices from foreign laboratories to CVŘ.

With the support from the European Union, the Czech Republic, its research community and, in particular, the Research Centre Řež and the University of West Bohemia received a unique opportunity to significantly expand their research capabilities for energy research and development and to maintain their position on the research market in this field. The financial support of the SUSEN project by the European Union and the Government of the Czech Republic has contributed not only to the development of a field which we consider to be crucial for the sustainable economic development of the Czech Republic and to the competitiveness of the member states of the European Union, but also to the professional growth of young researchers.
In 2016 the cold crucible delivery was completed and most of experimental equipment for hot cells was delivered. The hot cells were commissioned and non-active tests in the new hot cells were performed together with proof of safety which led to the active tests being permitted by the State Office for Nuclear Safety. Most of components for the experimental loops were procured or manufactured by our engineering works and the CO$_2$ loop was completed. The tests of LOCA facility were started in 2016.

The centre of sensitive microstructural measurements including the high resolution SEM, TEM and SIMs were put into operation.

Among other facilities, the neutron source of 14 MeV neutrons started the operation to be used for the fusion related studies. The mechanical testing laboratory, fully equipped for full scope of mechanical tests at a wide range of testing temperature, environments and loading modes was commissioned in Plzeň. The NDE laboratory has reached the operability for qualification tests of metallic and silica materials, the laboratory for artificial cracks preparation was put into operation.

The map of facilities put into operation in 2016 and those under preparation to be finalized in 2017 is shown in Fig. 3 in the technology – knowledge map.

The operation of the existing SUSEN infrastructure was supported by the grant of the Ministry of Education, Youth and Sports as the part of state help for the large research infrastructure in the Czech Republic dedicated to the period 2016–2019. The costs of the preparation of operation staff, energy, water, maintenance and certification of equipment were covered partly by this grant, while the remaining costs were paid from research and commercial projects and as over-head costs of the company.
The research infrastructure consists of two research nuclear reactors, LVR-15 and LR-0, together with the related experimental infrastructure, such as experimental loops and probes of the LVR-15 reactor or the neutron spectroscopy laboratory of the LR-0 reactor.

### 4.1 Main Utilization during the Year

Reactor LR-0 was for most of the year 2016 operated for research in the area of cores with material insertion, like FLiBe salt and other perspective materials. A number of critical experiments was made. At the end of the year the core has been changed for an experiment for the validation of neutron fluxes in VVER-1000 reactor internals.

Reactor LVR-15 was operated for 189 days and was used for material research, basic neutron physics studies and for irradiation tests and activities. The reactor also provided open access for Infrastructure CANAM, i.e. horizontal channels operated by the Institute of Nuclear Physics and Czech Technical University. During the year, new driver fuel (14 assemblies) for the reactor was acquired.

The external users of the reactor infrastructure include mainly:

- Nuclear Physics Institute AV ČR, which utilizes the horizontal beams and vertical channels for their own large research infrastructure CANAM (Center of Accelerators and Nuclear Analytical Methods);
- Czech Technical University in Prague, the Faculty of Nuclear Sciences and Physical Engineering utilizes one horizontal beam for their material structure studies;
- Czech Technical University in Prague, the Faculty of Mechanical Engineering for testing their neutronography devices;
- Czech Technical University in Prague, the Faculty of Electrical Engineering for testing their equipment for space applications;
- Masaryk University in Brno for testing a spectrometric detection apparatus;
- Institute for Anorganic Chemistry AV ČR and Technical University Freiberg for NAA of potential materials usable for development of geopolymer materials;
- Charles University in Prague for testing of radiation stability of Suprasil materials (high purity synthetic fused silica materials);
- Dubna research facility for irradiation and testing detection emulsions;
- Massachusetts Institute of Technology (MIT) for examining neutronic properties of fluoride salts;
- Università degli Studi di Milano for testing biological tissues and phantoms in epithermal neutron field;
- F4E/EFDA (European Fusion Development Agreement) – Cooperation on irradiation testing of various materials and technologies for fusion applications;
- ENEA – cooperation in Heavy Liquid Metal type reactors – benchmark measurements;
- EDF – cooperation in measurements of neutron mixed fields;
- IRE – cooperation in radioisotopes development and production;
- ENSTII, IAEA – cooperation in training activities and providing courses;
- Berthold, Gunter Meelis – radioisotopes production and development.
4.2 Research Activities and Services at the Research Reactors

FHR/MSR technology on LR-0 – The fluoride experiments program has been launched on LR-0 reactor in frame of US DoE and CZ MoIT (Ministry of Industry and Trade) cooperation and will continue to provide the designers with experimental data including detailed neutronic characteristics of the fluoride coolant such as temperature reactivity coefficients. The experiments were performed by both CVŘ and US Oak Ridge National Laboratories Teams.

The experiments represent an important step towards the development of the small modular reactors (SMRs) concept based on molten salt cooled technology. The SMRs developments are emerging worldwide. It encompasses existing reactor technologies and aims at simplicity of operation, inherent safety, modular construction and decommissioning. This approach could lead affordable and fast-to-build reactor, for developing countries and applicable at distant locations with poor infrastructure. CVŘ plays an important role in promoting the concept, especially the salt cooled “SFHR”.

The nuclear data community has been continuing to improve the libraries and codes for neutronic calculations, especially to support GEN IV and fusion designs. As the new reactor concepts often use new poorly investigated chemical elements, the need of appropriate experimental validation of the nuclear libraries is emerging. The LR-0 reactor has recently introduced new inserted zones experiments with fluoride salts, lead, graphite and is ready to include more new materials as they are proposed for the GEN IV & fusion applications.

Reactor Pressure Vessel (RPV) samples irradiation, as a part of the evaluation of the lifetime of the Temelín and Dukovany nuclear plants RPVs, takes place in reactor LVR-15. The irradiated material is subsequently subjected to material tests in the ÚJV hot cells. The cooperation with the Nuclear Research Institute (ÚJV) and the results of the computer calculations are the basic input for the creation of methodologies for assessing the state of materials radiation damage to which are subject the critical components of nuclear power plants.

ITER sensors testing – The aim of this project is to irradiate ITER in-vessel magnetic pick-up coils (LTCC Low Temperature Co-fired Ceramic) up to the neutron fluence reached within the ITER neutron field during its lifetime. The irradiation is performed in special high volume capsules under controlled temperature that ensures to irradiate all six requested specimens simultaneously.

An important activity has been done to enable production of Tc from low enriched targets, within the effort to decrease the proliferation risk. A new method was developed and validated for this production by the CVŘ team in 2016. The production of various radioisotopes has been performed in LVR-15. The most important was the production of Mo-99 for medical Tc-99m generators. The production of Co-60 or Ir-192 continues as well as the silicon doping. One of the latest examples of radiation utilization was the coloring of colorless topaz to “Swiss Blue”.

In 2016 a new grant from MEYS (Ministry of Education, Youth and Sports) with project identification code LM2015074 has been obtained to support the reactors’ operation. As a part of the granted support CVŘ provides also open access to other users. During the year 2016 the applicants were:

FJFI ČVUT (Faculty of Nuclear Sciences and Physical Engineering on Czech Technical University) – research application for an LR-0 experiment validating the calculations of neutron field in selected cooling channels of the VVER-1000 baffle. The main goal is to assess experimentally the neutron field in the VVER-1000...
mock-up in LR-0 reactor. As the LR-0 uses well verified methods of absolute neutron flux measurement, a direct comparison of calculated and measured reaction rates should be possible. These data will be used to validate and improve the current methods for internal components embrittlement evaluation.

ÚJF (Nuclear Physics Institute of the Czech Academy of Sciences) – application for LVR-15 neutron channels for research experiments and projects made in frame of large infrastructure “CANAM”. The individual projects in CANAM will be registered using CANAM web portal and evaluated by two experts. The CANAM infrastructure included nuclear research equipment on its horizontal beams and vertical irradiation channels.

ÚFP (Institute of Plasma Physics of the Czech Academy of Sciences) – application for LVR-15 neutron irradiation for assessment the influence of neutrons on performance characteristics of HTS ribbons and Hall sensors. The results of this particular task along with other tasks of partner European laboratories would lead to assessment of the current HTS ribbons and Hall sensors in the ITER fusion reactor magnet wirings and DEMO fusion reactor magnetodiagnostics.

4.3 Education and Training related to the Research Reactors

Both reactors and other technical equipment are used not only for research but also for education and training, to support public awareness of nuclear technologies and to host technical workshops and scientific or general public visits:

- Common Course ENSTTI/CVŘ on Operational Nuclear Safety (11.–15. 4. 2016);
- 2nd summer school of Intercontinental Nuclear Institute (workshop at the RI on 7. 7. 2016);
- SOFT 2016 FISSON (technical tour), 7. 9. 2016;
- IAEA fellowship course on Operational Nuclear Safety, 6.–7. 10. 2016;
4.4 Licencing Process and Sustainability

Both reactors represent a key infrastructure for the whole institution, mainly due to the cooperation with other CVŘ sections, being their infrastructure linked to large extent to the reactors. The availability of such infrastructure within CVŘ is one of the key elements in the international recognition as a valuable nuclear research organization.

The current license of reactors is valid till 2020 and CVŘ has already started a dedicated project of relicensing, which was categorized to the highest priority level and is monitored regularly and directly by the company’s management.

Currently, the teams are undergoing the preparatory phase for the relicensing. In 2016, the internal project was created for that purpose, including the following items:

- Assessing adequate residual lifetime of all important components;
- Refurbishment of identified obsolete systems, among others the LVR-15 neutron instrumentation, radiation monitoring system and control absorber rods;
- Updating of the operational documentation to reflect the necessary changes and the new requirements defined by the newly approved Atomic Act and related regulations;
- Preparation of necessary safety documentation to prove the safe operation of all important systems both in the present and during the period of validity of the new licenses;
- Performing evaluation of the overall safety of the reactors both internally (through periodic maintenance of the safety related systems and a follow-up periodic safety review) and by independent external experts, i.e. the “INSARR mission” governed by the International Agency for Atomic Energy (IAEA);
- The state authority which would finally issue the new licenses is involved in course of the whole project to ensure good understanding and smooth licensing process.
JHR PROJECT – SUPPLY OF HOT CELLS (HC)

The Jules Horowitz Reactor (JHR) is an international project of design, developing and commissioning a new high-power nuclear reactor for material and nuclear fuel research. The reactor is being built by an international consortium of suppliers in the French nuclear research centre CEA (Cadarache). The contribution of the Czech Republic in the JHR construction project has an in-kind form and consists in the delivery of hot cells. Construction of the JHR will continue until 2021 and the assembly of the hot cell unit should be completed in 2018. The completion of construction works will be followed by the installation of technologies and JHR equipment. The commissioning of the JHR whose operating phase is expected to be 50 years at minimum is scheduled for 2021.

The hot cells complex comprises 4 large cells, to be used for maintenance operations and for working with irradiation test devices. The 3 adjacent small cells are dedicated mainly for performing of non-destructive examinations on the irradiated material and fuel samples. Recent news about the project can be found at: http://jhr.cvrez.cz/en/

5.1 Current State of Supply: Works Carried Out by the End of 2016

Special cranes inside cells is one of the largest deliveries for hot cells which started in February 2016. It is a complex design construction of prototypes cranes. The project consists of design, manufacturing, testing in factory and testing on stand in CVŘ (scale model 1:1 of JHR hot cell). At the end of the year our subcontractor NUVIA had successfully completed the first part of the project – submitting of design of prototype cranes for acceptance. The delivery of cranes is foreseen to be finished towards the end of 2018.

In terms of overall construction of JHR, 95 % of the auxiliary unit walls had been completed by the end of 2016. The walls of the hot cells on level +1 were completed with the pouring of heavy concrete into the modules. The first floors of the hot cells and the modules of the wall on level +2 were delivered and poured into concrete. The main civil works has been finished on part of hot cells.

At the beginning of the year, our subcontractor Chemcomex carried out the assembly of small cells modules manufactured by the supplier MICO, which were delivered to the construction site as well as the modules with revolving door frames manufactured by French supplier ACPP; their assembly was finished. The highlight of the year was a successful FAT (Factory Acceptance Test), i.e. a functional and tightness tests of sliding and rotating doors. The transport of the doors to the construction site was conditioned by successful performance of the tests. At the same time, it was completed the mounting of base equalizing plates under the lower rail of the sliding door between hot cells. Further, the following items were completed: installation of small cells shielded floors, floor frames, stainless steel ceiling plates, anchor plates over small and big cells, as well as mounting of two hinged doors, including hinges, enabling access to small cells transfer area. In addition, the sliding doors rails were fixed, including the main installation of four sliding doors. From September to October the installation of remaining three hinged doors was finalized. During the final part of the year, the preparation works for mounting of...
hot cells stainless steel liner (temporary ventilation, lights, electricity and gas installations for welding) were started.

The civil engineering part (shell construction) of the hot cells is completely finished. As said, a very important part of the finished construction on site consist of heavy doors (4 sliding and 3 rotating). Due to very large dimensions, the doors had to be incorporated into civil part, therefore the ceilings P+2 was finished after installation of doors.

Embedded parts including ceilings P+2 → finished
Sliding & Rotating doors → finished
Biological doors in canals → fabrication in progress
Liner → installation in progress
Cranes inside cells → design finished, fabrication foreseen in 2Q 2017

The Czech Republic is represented in the governing bodies of the JHR consortium and in working groups preparing topics for the reactor research.

In the Governing board of the Czech Republic of JHR, the representative is CVŘ. The Governing Board reviews the status and progress of the construction works and the financial report. Regular meetings of the so called “technical seminars” are held annually and their researchers and engineers are informed about the progress of works and the state of preparedness of individual research instruments of JHR.

Simultaneously three Working Groups (material, fuel and technology) have been established for identifying research priorities and also for the assessment of the adequacy of design of individual experimental devices (probes, rigs and loops) that are incorporated in JHR for the research purposes. These groups are composed from the consortium members as well as invited experts. The main objectives are to advise the Governing Board and the Project Leader on potential scientific topics of interest for future experimental R&D programs in JHR.

During the NUGENIA annual Forum 2016, which was held in conjunction with the technical meeting of the 3 working groups at Marseille/France, the scientific community (more than 100 members of NUGENIA) and the JHR consortium, a common proposal of a first multilateral programme called FIJHOP (First International Jules Horowitz Programme) has been initiated: the aim was to start gathering the concerned European scientific community around the JHR and to
strengthen the European position as one of the world leader stakeholders regarding the understanding and the prediction of fuels and materials behaviour in LWRs. The FIJHOP R&D programme was composed of two scientific complementary sub-programs, called respectively FIJHOP-F and FIJHOP-M, respectively for fuels and materials. The first phase will be carried out in operating European facilities (MTR and/or hot cell laboratories) with highly instrumented experiments and benchmark on Post Irradiation Examination (PIE), leading to a second phase later on to be implemented in JHR, which will include irradiation process cross-qualification, benchmarking objectives and extension of current experimental databases for advanced model qualification (this second phase has benefit from the added value of the high performances of JHR).

As FIJHOP programs concern R&D data acquisition on fuel and materials behaviour knowledge improvement, the program objective is clearly to gather and boost the synergies of a large scientific community beyond the JHR Consortium. The project was implemented into the Horizon call in September 2016.
The Centrum výzkumu Řež (CVŘ) is strongly committed to education and training in energy technologies, with a particular focus on the nuclear field. We believe in a strong role of trainings in building national and international networks and in building a strong knowledge-based and safety-focused workforce. For this purpose, courses for universities students and industry stakeholders are organized. One of the aims of our Centre is to support and promote scientific and technological education of the young generation and to assure the effective knowledge transfer from senior experts to newcomers.

In order to achieve this goal, CVŘ keeps strict relations with universities both in the Czech Republic and abroad, to which it offers topics both for bachelor, master and PhD theses: the students are followed by CVŘ experienced specialists and can highly profit from its unique facilities, in particular the LVR-15 and LR-0 reactors, as well as the technological loops (i.e. liquid lead, supercritical water, helium and supercritical carbon dioxide technologies). In 2016, 45 students used the SUSEN infrastructure and 16 graduated – 2 foreign students joined CVŘ in the frame of the ERASMUS project. CVŘ, together with its mother company ÚJV Řež, a. s., supports the activity of the ENEN association (European Nuclear Education Network) and its Czech counterpart CENEN.

Given the strong attention of CVŘ to education of students, our management issued a specific internal regulation which is intended to guarantee to every student proper tools, training and assistance. Students are encouraged to provide a feedback about their experience from their cooperation with CVŘ at the end of their work.

In order to facilitate meeting both the CVŘ and the students’ needs and interests, at least one dedicated open doors day per year is foreseen, during which a tour around the facilities is organized and a poster session presenting the offered topics will follow, during which the student can meet our experts and discuss details with them.

CVŘ is also open to international students exchange programs, like for example the IAESTE internships and the ERASMUS program.

For specialists and university students, CVŘ offers training courses oriented to the practical and operative aspects of nuclear facilities. For the general public, there are technology tours in which professional guides explain the construction and principles of the functioning of our research infrastructure facilities.
In the frame of the Open Access policy, it is offered the possibility to institutions, to access infrastructure for performing experiments and for training students in specific fields of interest such as diffraction studies on materials and neutron analytical methods both in fundamental and applied research fields. Support is also provided to education of undergraduate and post-graduate students in the following fields: energy generation, materials science, metallurgy, nuclear physics, biology, biomedicine, environment, geology, archaeometry, agriculture, environmental sciences, geo- and cosmochemistry, cultural heritage and analytical chemometry.

The training courses, profiting of the infrastructure available and specific knowledge and experience gained by our team in this field, in particular neutronics, radiation detection and spectroscopy, thermohydraulics, chemistry and material science are oriented to Universities, Government bodies, research institutes and vendors. The training offers also a wide range of reactor physics experiments, subdivided into three main groups: the first consists of basic nuclear reactor experiments, the second oriented to more advanced users and focused on core reactivity, delayed neutrons characteristics and neutron instrumentation characteristics measurements, gamma or mixed field spectroscopy, etc. and the third one is user-tailored and tuned in order to satisfy customer’s specific needs (e.g. courses for nuclear reactor operators).

ČVŘ offers an opportunity for the public to visit the research facilities on request, in particular schools and University students (both Czech and foreign) are encouraged, although nuclear professionals and enthusiasts’ groups are frequent as well. For this purpose, our Center organizes regularly also Open Days, during which we receive up to two hundred visitors every year.
One of the pillars of the research activity in CVŘ is represented by development of advanced knowledge and technologies for the safe and reliable nuclear power generation in current generation fleet (i.e. GEN II, III and III+). This goal is achieved by focusing on various aspects of power generation.

In relation to this, material testings are carried out in order to assess component properties and performance in suitable laboratory experiments simulating actual operating conditions. Of special importance is considered the aging and radiation damage on materials, components and systems important for nuclear safety (mechanical components, electrical systems, cables, civil parts) and the behavior of current materials (fuels, claddings, structure components) under irradiation to support long term and safe plants operation.

Suitable methods and computing codes are developed for assessing nuclear safety, in particular with the aim to evaluate safety margins, taking into account all the physical effects and different sources of uncertainties both in normal operating and in emergency conditions. The focus of CVŘ’s work is to adopt (also considering and adapting procedure) available computing codes for the conditions in nuclear power plants in the Czech Republic and their validation and independent analysis of selected design accidents and extended project conditions at nuclear power plants (including severe accidents).

The importance of researching severe accidents in nuclear power plants was confirmed and highlighted by some severe accidents occurred in the nuclear power generation history, in particular considering the Fukushima Nuclear Power Plant accident. Our current research concerning the phenomenology of severe accidents entails experimental research of physical and chemical processes related to core melting, namely simulation of corium behavior and interaction between it and structural materials.

This field integrates well with CVŘ studies on materials for the Accident Tolerant Fuel (ATF) concepts, focused on new special alloys and advanced coatings development. It also fits with the development of new NDT (Non Destructive Testing) methods for the assessment of material (e.g. concrete) condition in power plants.

As part of the deep geological repository development community, CVŘ focusses on multidisciplinary research, based on which the disposed waste and spent nuclear fuel will be isolated from the biosphere using a multi-barrier system to prevent any negative impact of the repository on the environment for periods of the order of tens of thousands of years. In particular, the focus is on the research and mapping of corrosive and migration processes in deep geological repository environments, in the development and validation of physical models of radionuclide transport, and in the study of the kinetics and mechanism of the degradation of engineering barriers in deep geological repositories, i.e. in anaerobic environments.

CVŘ carries out hydrogen embrittlement and hydride orientation studies – also by exploiting very sophisticated and advanced techniques (like neutron imaging) – in order to assess the fuel canisters dry storage behavior and other safety aspects (especially during the transport to the final storage).

We are implementing the strategies described above in the following projects:
**H2020 MIND**

**Project scope:**
Development of the safety case knowledge base about the influence of microbial processes on geological disposal of radioactive wastes.

**CVŘ contribution:**
Biocorrosion of canister material (carbon and stainless steel) and the effect of radiation on anthropogenic polymers (e.g. polystyrene).

**Infrastructure:**
Anaerobic glove boxes.

**User of the results:**
Waste management organizations (WMOs).

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**H2020 IVMR**

**Project scope:**
In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs.

**CVŘ contribution:**
Testing various corium compositions, fully oxide pool and stratified pool later.

**Infrastructure:**
Cold Crucible.

**User of the results:**
Nuclear Power Plants, TSO.

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**H2020 JOPRAD**

**Project scope:**
Prepare the conditions for the setting up of a Joint Programming on Radioactive Waste Disposal.

**CVŘ contribution:**
Expertise function.

**Infrastructure:**
No infrastructure involved.

**User of the results:**
Regulators and Technical Safety Organizations, waste management organizations.

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**H2020 SITEX 2**

**Project scope:**
Constitute a sustainable European and international cooperation in order to support a robust and reliable expertise function at national level in the field of safety of radioactive waste disposal.

**CVŘ contribution:**
Expertise function.

**Infrastructure:**
No infrastructure involved.

**User of the results:**
Regulators and Technical Safety Organizations, Waste management organizations.
TAČR MSO

**Project scope:**
Disposal radioactively contaminated ion exchange by melting salt oxidation.

**CVŘ contribution:**
Testing and evaluation oxidation processes in melting salt.

**Infrastructure:**
Laboratory equipment and large scale prototype.

**User of the results:**
WMOs.

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MAT-Fretting

**Project scope:**
Experimental assessment of a sliding wear of components RPV in the power plant Dukovany.

**CVŘ contribution:**
The core barrel wall with the thickness 60 mm made from austenitic steel 08Ch18N10T and the key of cantilever with cladding deposit from CN6 hard metal constitute a frictional pair with a risk of abrasion. In order to experimentally evaluate the wear coefficient, the special workplace with free servo cylinders was set up and the wear properties for different forces and amplitudes were determined.

**Infrastructure:**
Machines and devices from material testing laboratories (G2 mechanical, chemical and metallographic devices).

**User of the results:**
Power generation utilities.

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SOTERIA

**Project scope:**
Improve the understanding of the phenomena occurring in aging reactor pressure vessel (RPV) and in the internals steels in order to provide crucial information to regulators and operators to ensure safe long-term operation (LTO) of existing European nuclear power plants.

**CVŘ contribution:**
- Radiation effects microstructural evolution RPV and internals under different fluence levels – flux;
- Evaluating uncertainties in fracture toughness measurement on irradiated RPV steels and mitigation approaches;
- Training and education.

**Infrastructure:**
Centre of highly sensitive analytical devices (HR-STEM, Active Laboratory for TEM Sample Preparation, non-active sample preparation laboratory).

**User of the results:**
End-user group are composed of European industrial representatives from the SOTERIA consortium (EDF, VFAB, AR-F, ARG, ÚJV) and non-European industrial representatives: EPRI (USA) and CRIEPI (Japan), participating as external experts through the signature of an NDA.
SAMARA II

Project scope:
The objectives of the project are to complete former projects focused on the sensitivity to IASCC (Irradiation Assisted Stress Corrosion Cracking) of the specimens irradiated in the frame of the Samara experiment. SAMARA II will be mostly focused on further microscopy observation: the main objectives are to characterize the microstructure defect population, the Radiation Induced Precipitates (RIP) and the microchemical changes due to irradiation such as Radiation Induced Segregation (RIS).

CVR contribution:
HR-STEM analysis of austenitic stainless CW316 steel exposed to fast and mixed neutron spectrum.

Infrastructure:
Active Laboratory for TEM Sample Preparation, High Resolution Transmission Electron Microscope (HR-STEM).

User of the results:
Power generation utilities.

ASATAR

Project scope:
Development and analysis of the suitability of accelerated test methods for assessing long-term reliability against SCC degradation, i.e. environmental assisted cracking in nuclear components.

CVR contribution:
Proposal of the accelerated cracking test methodology for components, especially fuel cells and non-destructive tests. Proposal of the new Horizon 2020 project on this topic.

Infrastructure:
No infrastructure involved.

User of the results:
GEN II&III nuclear power plant utilities.

BETONY (CONCRETE) MVČR

Project scope:
The project focuses on the development of non-destructive methods for monitoring the quality of the concrete around the nuclear reactor pressure vessel. Biological concrete shielding is used for protection of the personnel at the nuclear power plant from ionizing radiation.

CVR contribution:
Methodology development and its verification using a robotic manipulator.

Infrastructure:
NDT Concrete Lab.

User of the results:
GEN II&III nuclear power plant utilities.

MICRIN

Project scope:
The goal of the project is the understanding the ageing and degradation mechanism of structures, systems and components is one of the key aspects of reliable and safe long term operation of nuclear power plants.

CVR contribution:
Study of conditions of corrosion cracking and development of accelerated testing. Proposal for standardization of surface component processing to minimize SCC, verification of accelerated testing.

Infrastructure:
No infrastructure involved.

User of the results:
NUGENIA, GEN II/III community.
Nuclear fusion is considered to be one of the most promising energy resources for the future, especially considering the fossil fuel resources and environmental issues. CVŘ decided to join the international efforts for developing this demanding technology, both in the frame of the ITER (International Thermonuclear Experimental Reactor) and DEMO (DEMostrating fusion power reactor) projects.

In particular, fusion research at CVŘ focuses on testing and development of key components. Our priorities especially include testing the first wall materials (High Heat Flux test facility) and support for the development of certain ITER and DEMO fusion reactor components. A beryllium dedicated laboratory is being developed as well, implementing the most modern and sophisticated surveillance techniques. This is enabled by CVŘ’s position as an operator of unique testing, CFD computing and sub-scale testing facilities. A long-term contract for F4E (Fusion for Energy) and research in the EUROfusion consortium are highly prospective for us.

Another relevant area is represented by the support for the development and testing of the handling and maintenance methodology for Test Blanket Module (TBM) subsystems on our mock-up in combination with the development of software and 3D virtual reality environment and the use of cutting-edge CAD/CAM technology in robotics. Our position moreover profits by a unique experimental infrastructure and contacts within the fusion science community. Our research is active also in the field of the He and PbLi coolant loops, which support research and development of fusion reactor components (breeding blanket, divertor). There has been strong interest from potential users in scientific and research activities performed on the above-mentioned infrastructures.

Concerning the field of material development for fusion applications, our infrastructure is suitable for a wide range of testing and evaluation of properties, including cutting-edge microstructure analysis. CVŘ has developed significant experience with this experimental issue (the TW3 probe, Pb-Li probe and loop, etc.). The possibility of the complementary use of the LVR-15 reactor for materials irradiation enables research into combined corrosion and radiation environments.

An important issue our team is dealing with is the problem of tritium disposal. The combination of existing knowledge and equipment indicates new opportunities, especially in cooperation with other partners (such as VŠCHT, University of Chemistry and Technology Prague).

CVŘ was implementing in 2016 the fields mentioned above in the following projects:
**EUROFusion**

**Project scope:**
Development of conceptual design and technologies for the European fusion demonstration reactor DEMO including R&D experimental activities and supporting engineering and safety analyses.

**CVŘ contribution:**
CVŘ involved in the divertor, breeding blanket, safety and materials work packages. The main tasks are:
- High Heat Flux testing and evaluation of the mock-ups related to DEMO divertor;
- development of the breeding blankets for the DEMO fusion reactor;
- development of related technologies such as PbLi technology, tritium extraction technology, first wall and manufacturing techniques;
- experimental assessment of developed techniques;
- experimental testing of functional and structural materials;
- experimental testing of components (mock-ups, technological prototypes etc.) for the Breeding Blankets, first wall, PbLi ancillary loops, and tritium extraction and removal systems;
- irradiation of selected materials and material characterization.

**Infrastructure:**
HELCZA, MATLOO, RVS-3, dedicated rigs.

**User of the results:**
EUROFusion consortium, DEMO reactor designers.

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**F4E OPE 319**

**Project scope:**
This project is focused on the testing of the plasma facing components. These are especially the first wall modules, divertor in-vertical targets and Antenna Faraday screens. These tests will be performed at heat flux in ranging from 0.5 MW/m² up to 20 MW/m².

**CVŘ contribution:**
Whole project (no partners).

**Infrastructure:**
HELCZA.

**User of the results:**
Fusion for Energy (F4E), ITER Organisation.
**F4E-FPA372-SG04**

**Project scope:**
Testing of the devices and instrumentation for the ITER PbLi systems. Analysis of the experiments runs carried out in IELLO facility.

Analysis and Tests on PbLi instrumentation (in PbLi loops IELLO at ENEA and MELILOO at CV Řež).


**CVŘ contribution:**
Testing instrumentation in MeLiLoo (electromagnetic – phase shift flowmeter and thermocouples).

**Infrastructure:**
MeLiLoo.

**User of the results:**
Fusion for Energy (F4E).

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**OFC 358-LOT1**

**Project scope:**
The aim of the project is to irradiate ITER in-vessel magnetic LTCC (Low Temperature Co-fired Ceramic) pick-up coils up to the neutron fluence, that will approach that reached within the ITER’s neutron field during its lifetime.

**CVŘ contribution:**
Design of the irradiation experimental set-up, procurement, assembly and commissioning of the test, conduct and report of the irradiation test, Post-Irradiation Examination (PIE).

**Infrastructure:**
LVR-15, reactor hot cells.

**User of the results:**
Fusion for Energy (F4E).
IN INVOLVEMENT IN THE GEN IV TECHNOLOGIES DEVELOPMENT

The Generation IV International Forum (GIF) selected six concepts for the next generation reactors technology with the clear aim to enhance fuel resources, to address the environmental issues and to improve the safety aspects related to nuclear systems. Depending on their respective degree of technical maturity, the first GEN IV systems are expected to be deployed commercially around 2030–2040.

ČVŘ was in 2016 actively involved in lead, helium, molten salt and supercritical water cooled technologies.

The study of the behavior of materials in these environments combines the material research in the area of high temperatures with the specific environments represented by these coolants. One of our research goals is to develop and test a new and unique in-pile SCWL (SuperCritical Water Loop), which will provide us the opportunity to test materials in relevant conditions for this type of technology. The planned experiments raised the interest of the international community involved in this research area.

Another important area is the development of small modular reactors (SMR), especially those based on molten salt FLiBe technology. This opportunity leverages the unique knowledge obtained in Czechia in salt technology thanks to grants from the Ministry of Industry and Trade in recent years. This work has enabled the Czech Republic to gain international recognition in this area.

In 2016, as well as in previous years, our research centre has been counting on using the massive technology infrastructure created in the Czech Republic in recent years, in particular the SUSEN project and major research infrastructures (Řež Reactors, i.e. LR-0 and LVR-15).

In the area of high-temperature helium technology, ČVŘ will use its experience with corrosion testing in the HTHL-1 and HTHL-2 loops, which represent unique facilities in Europe for studying material behavior in environments simulating HTR and GRF reactor environments. In the study of interactions between materials and liquid heavy metals, a priority will be to analyze the degradation due to particular corrosive mechanisms.

We see significant opportunities in cooperating in the development of heavy metal technologies, in particular concerning studies on some critical components like pumps or valves, in deploying our experimental installations and heavy metals know-how in fusion research, in participating in the ALFRED international consortium or in following-up the studies for the MYRRHA reactor. For the latter, ČVŘ is developing a forced circulation pure lead loop, a loop for the development of simple components, an experimental facility with natural circulation and active air cooling to be used mainly for research of Heavy Liquid Metal (HLM) freezing phenomenon. These facilities will allow us to effectively study the long-term performance in HLM, the chemistry control and monitoring, the instrumentation, the thermalhydraulics and CFD.

Our cooperation with the Czech industry also provides opportunities in the non-nuclear energy sector.

In this frame, ČVŘ carries out the following projects:
**TAČR FLUS**

**Project scope:**
The development of new sealing technology focused on applications using molten fluoride salt.

**CVŘ contribution:**
Long term testing of sealing materials in the FLiBe molten salts and their evaluation.

**Infrastructure:**
Technological line FERDA and fluorination technology.

**User of the results:**
Producers of sealings.

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**MATISSE (Materials’ Innovations for a Safe and Sustainable nuclear in Europe)**

**Project scope:**
The JPNM (Joint Program on Nuclear Materials) partners propose, through MatISSE, a combination of Collaborative Projects and Coordination and Support Actions to face the challenge of implementing a pan-European integrated research program with common research activities establishing, at the same time, appropriate strategy and governance structure. Focusing on cross-cutting activities related to materials used in fuel and structural elements of safe and sustainable advanced nuclear systems. The project aims at covering the key priorities identified in the JPNM: pre-normative research in support of ESNII systems, Oxide Dispersed Strengthened steels, refractory composites for the high temperature applications, development of predictive capacities.

**CVŘ contribution:**
- Characterization of ODS cladding tubes;
- Creep/fatigue testing of materials for the ESNII;

**Infrastructure:**
Machines and devices from material testing laboratories (G2 mechanical, chemical and metallographic devices).

**User of the results:**
Designers and future manufacturers of GEN IV fast systems.
KAMILE (Kinetic and mechanism of crack initiation of Liquid Metal Embrittlement)

Project scope:
The project focuses on the understanding of mechanisms of LME initiation in T91 and 15-15Ti in Heavy Liquid Metals (Pb, PbBi). The work aims to address the issue of LME occurrence within allowable operating stresses and corresponding liquid metal condition as well as above the limit condition.

CVŘ contribution:
- in order to provide a direct evidence of the mechanism of LME for the system T91/HLM, mechanical testing of various specimens in contact with liquid metals were carried out. A limited number of 15-15Ti specimens were tested in contact with HLM to obtain a direct comparison of the behavior of the two candidate materials. The tests will provide fundamental knowledge and evidence on the role of the microstructure and alloying elements in the LME;
- before and post-test microscopy observation were performed using methods of FIB-SEM (equipped with EDX, WDX, EBSD), TEM and SIMS. Using these methods will allow to determine morphological (SEM, TEM) and crystallographic (EBSD) surface structure, chemical composition of surface in 2D and 3D (EDX, WDX, SIMS). The analysis will be focused to indicate traces of HLM elements on and under the LME crack surface.

Infrastructure:
Machines and devices from Material testing laboratories (G2 mechanical, chemical and metallographic devices), CVČAP – SEM-FIB, CVČAP – Inactive sample preparation for SEM, TEM, SIMS, CVČAP – HR-STEM.

User of the results:
Fundamental research users.

H2020 SESAME

Project scope:
thermal hydraulics Simulations and Experiments for the Safety Assessment of MEtal cooled reactors.

CVŘ contribution:
Pre-test simulations and measurements and from the Meliloo test facility, FLUENT simulations of Meliloo and TALL-3D facilities.

Infrastructure:
MeLlOo.

User of the results: Designers of LFR and GFR reactors.

SUPERCRITICAL CO₂ – HERO

Project scope:
Design of the CO₂ based emergency cooling system for decay heat removal at severe accidents. The system is self-powered and doesn’t require any external power source. The system is compatible with current PWR/BWR reactors.

CVŘ contribution:
Experimental demonstration of the designed system, ATHLET code simulations.

Infrastructure:
SUPERCritical CO₂ loop.

User of the results:
Emergency cooling system designers.
**H2020 VINCO**

**Project scope:**
Conduct a variety of capacity building activities aiming at strengthening the coordinating role of the “V4G4 CoE” and supporting its member organizations. Each of “V4G4 CoE” member organization will focus mainly on a following specialization: (i) Slovakia – reactor design and safety analyses, (ii) Czech Republic – helium technologies, (iii) Hungary – fuel studies and (iv) Poland – structural materials laboratory.

**CVŘ contribution:**
- Contribute to R&D activities coordinated by the “V4G4 CoE”; perform analysis of existing research capabilities in V4 countries (Czech Republic, Hungary, Poland and Slovakia) in the field of nuclear technologies;
- Describe and propose research and investment priorities in each participating organization;
- Set-up common education and training programs, schools, seminars, hands-on exercises, on-job trainings, etc.; assess possibilities of common activities for Structural Funds acquisition;
- Identify priority topics and start common research activities, with the special emphasis to the research on gas-cooled reactors.

**Infrastructure:**
No infrastructure involved.

**User of the results:**
V4G4 partners, policy stakeholders.

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**TAČR INOVMAT HT**

**Project scope:**
Design and experimentally evaluate new types of high temperature gas/gas heat exchangers for application in industrial and energy sectors.

**CVŘ contribution:**
Theoretical analyses of state of the art, performance and evaluation of the selected material properties in high temperature helium, thermohydraulics tests on the experimental S-ALLEGRO loop, data validation.

**Infrastructure:**
S-ALLEGRO loop.

**User of the results:**
Designers of gas cooled reactors, producers of components (heat exchangers).

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**TAČR ČIPERA**

**Project scope:**
Development of leak-tight joints and regeneration of leaked He-mixtures. The project continues with TAČR REGNET project.

**CVŘ contribution:**
Development and testing of flanges and construction and verification of unit for He-mixture regeneration.

**Infrastructure:**
HTHL-1, HTHL-2.

**User of the results:**
Producers of sealing, gas-processing companies.
**TAČR ARMAT**

**Project scope:**
Testing of metallic and ceramic materials in the VHTR and SCWR environment.

**CVŘ contribution:**
Testing of the proposed innovative materials in SCW and VHT environment, evaluation of results, validation of methodology for testing at extreme conditions.

**Infrastructure:**
HTHL-1.

**User of the results:**
Producers of materials and components (new power plants, piping, flue gas systems).

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**TAČR KARELIA**

**Project scope:**
Design and experimental verification of the components for reactors cooled by liquid metals.

**CVŘ contribution:**
Development and evaluation of the pump for fission and fusion reactors based on the HLM cooling. Design and validation of valves for HLM environment. Experimental validation of codes.

**Infrastructure:**
MeLiLoo.

**User of the results:**
Producers of valves and pumps.

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**GAČR AVOCADO**

**Project scope:**
Participation in the development of ODS steels for use in GEN IV resistant to higher temperatures and in heavy liquid metals. Specifically, 14Cr and 20Cr ODS are studied and their properties before and after exposure in COLONRI loops filled with liquid Pb and PbBi.

**CVŘ contribution:**
Testing in HLM and metallography.

**Infrastructure:**
COLONRI I and II, SEM.

**User of the results:**
Fundamental research useful for development of HLM cooled reactors.
R&D FOR NON-NUCLEAR TECHNOLOGIES

Although CVŘ is mainly focused on nuclear research, non-nuclear technology development is also considered an asset, with a considerable research and application potential and important financial return. The interest of our centre is presently focused in some specific areas.

The unique properties of supercritical CO\textsubscript{2} present important advantages for closed-loop and power generation systems that use traditional steam Brayton and Rankine cycles. Due to its high fluid density, it enables extremely compact and highly efficient turbomachinery. For these reasons CVŘ is performing a research activity on thermal hydraulic properties of supercritical CO\textsubscript{2} and study of corrosion and erosion to enable the testing of turbine-generator systems and CO\textsubscript{2}/air coolers. The supercritical CO\textsubscript{2} loop was designed mainly for corrosion research usage, testing of the thermal cycle components, collecting of the experimental thermal-hydraulic data (heat transfer coefficients) and computational codes validation. As the loop was completely designed in CVŘ, a lot of experience with stress analyses and thermalhydraulic calculations was achieved.

The CVŘ teams are involved in the development of NDT methods for diagnosing non-nuclear energy generation equipment, for instance turbine defects, as well as the development of methods for NDT techniques. For this purpose, ultrasonic and eddy current testing techniques are used. 3D profilometry represents one of the non-contact NDT techniques used as well.

Within the field of hydrogen technologies, the focus is on its production by high-temperature electrolysis for co-generation applications. For this purpose, a dedicated loop was developed, including a test bench for testing of single cells in electrolysis or fuel cell mode and measuring instruments (process gas chromatograph, electrochemical impedance spectroscopy).

Another special area of research is development of knowledge for water management in nuclear and fossil fuel power plants. Power plant chemistry includes water treatment, corrosion control, material fatigue and service life under the presence of...
chemicals in steam streams of traditional and nuclear power stations, steam production, chemical cleaning of water and steam cycles. CVŘ is developing methods to remove heavy metals from water flows using magnetically modified materials gained from industrial waste.

Last but not least, CVŘ has been in 2016 performing research activities in the field of renewable resources, in particular in the Concentrated Solar Power (CSP) field: for this purpose, a passive circulation loop with Pb-Bi eutectic consisting of a light source, an energy storage and heat engine (Stirling type) was developed, dedicated to the verification of use of liquid metal in a concentrated solar power plant and to development of related components.

Some of the projects in which we are involved are:

**KOLT:**
Joint project with Doosan Škoda Power & VZÚ Plzeň, funded by TAČR.

**Project scope:**
Development a corrosion resistant material for steam turbine blading.

**CVŘ contribution:**
Study of corrosion mechanisms relevant to the damaging of Low Pressure turbine blades, including pitting, stress corrosion cracking (SCC) and corrosion fatigue (CF). Fatigue life tests on smooth specimens of precipitation hardened or martensitic chromium steels (T552, T571, MLX17) in the air and steam condensate contaminated with chlorides. Advanced surface modification techniques by laser shock peening (LSP) with the aim to improve the mechanical and corrosion properties such as fatigue strength, wear and erosion resistance.

**Infrastructure:**
Machines and devices from material testing laboratories (G2 mechanical, chemical and metallographic devices).

**User of the results:**
Doosan Škoda Power s.r.o.
**Development of proper methodology for turbine blade control**

**Project scope:**
Development of quick and effective NDT method for inspection and evaluation of status of turbine blades for the evaluation of the residual life and preventing accidents of the rotors on fossil as well as on nuclear power plants.

**CVŘ contribution:**
- finding methods for quantifying the damage to the blades pitting;
- development and qualification of the proper methodology.

**Infrastructure:**
Laboratory of metallic materials, flaw manufacturing laboratory.

**User of the results:**
ČEZ.

**ExFo**

**Project scope:**
Development of proper methodology for oxide measurement on steam pipelines with use of UT. Methodology will be used specially on fossil and conventional plants.

**CVŘ contribution:**
Development and qualification of the proper methodology.

**Infrastructure:**
Laboratory of metallic materials, flaw manufacturing laboratory.

**User of the results:**
ČEZ.
The paper reviews the so far known information about the properties of biological shielding concrete used in the containment vessel of nuclear power plants (NPP) and its behavior when exposed to radiation. The damage of concrete caused by neutron and gamma radiation as well as by the accompanying generation of heat is described. However, there is not enough data for the proper evaluation of the negative impacts and further research is needed.

Udalov Y.P., Poznyak I.V., Sázavský P., Kiselová M., Šrank J., Strejc M.
A study of the liquid and gaseous phases upon the interaction of molten corium with the sacrificial material based on iron oxide and Portland cement.

The paper presents study results of evaporation intensity and the composition of condensing oxides which was experimentally studied upon diluting corium by iron (III) oxide and Portland cement. Interaction of corium with Portland cement was realized using cold crucible melting technology. It is found that the formation rate of aerosols over the melt is reduced upon diluting the corium by the studied sacrificial material by almost an order of magnitude up to 0.5 g/(cm²s). In the reducing atmosphere, the form of the particles of the aerosols is octahedral and in an oxidizing atmosphere it is spherical.

The sacrificial material to ensure safety during severe accidents of nuclear reactors VVER-1000 have been proposals for practical application in 2000. Since then a large number of works was carried out, which, on the basis of theoretical analysis and direct experimentation, are considered different physical and chemical processes during interaction of molten corium and sacrificial materials of different composition. Corium is a multicomponent melt, which is formed from fuel assemblies and structural elements of the inner part of a nuclear reactor during emergency shutdown cooling of the reactor. The molten corium is a two-phase fluid. One liquid phase is composed of oxides of uranium, zirconium oxide and dissolved in the melt of elements (zirconium, uranium, iron, chromium, etc.). The other liquid phase is a multicomponent metallic melt consisting of iron, zirconium, chromium, etc. Data on the properties of liquid, gaseous and solid products of the interaction between corium and sacrificial materials are the basis for modeling real processes during severe accidents and the substantiation of efficiency of the device melt localization for VVER-1000 and EPR. In the simulation, the necessary information about the temperatures of the liquidus and solidus of the multicomponent mixtures, the rheological properties of these melts, the evaporation rate and the composition of the gas phase above the melt. The main part of the studies to date focused on the properties of the liquid phase, which is formed by radio frequency interference of the corium with the sacrificial material. The problem of the formation of aerosols, which are products of the evaporation of components of complex melts has received relatively little attention. The most thorough study of vaporization processes of the major components of the corium and dissolved fission products as a function of the oxidation potential of the melt for the original of corium meeting the composition and temperature inside the reactor vessel.

Morphology of aerosol particles in experiments U45

For this study was used COMETA facility – induction furnace with cold crucible for melting oxides.
Schulc, M., Tomášik, B.

The effect of momentum deposition during fireball evolution on flow anisotropy,

The highest LHC energies give rise to the production of many pairs of hard partons which deposit four-momentum into the expanding fireball matter. We argue that it is necessary to include momentum deposition during fireball evolution into 3 + 1 dimensional hydrodynamic simulations of the collision. This influence cannot be accounted for simply by modifying the initial conditions of the simulation. The resulting contribution to flow anisotropy is correlated with the fireball geometry and causes an increase of the elliptic flow in non-central collisions. The results are presented for various scenarios with energy and momentum deposition to clearly demonstrate this effect.

Parameters $v_n$ from collisions at $b=0$ for charged hadrons. Different symbols represent:

- energy loss of hard parton $dE/dx|_{0} = 7$ GeV/fm (black square),
- scenario with hot spots with momentum deposition in initial conditions (red -),
- scenario with only hot spots in initial conditions (purple X),
- and scenario with smooth initial conditions (blue *).
Evaluation of neutron fluence in a reactor pressure vessel (RPV) together with surveillance specimen programs for RPV materials are the most important parts of in-service inspection programs that are necessary for realistic and reliable assessment of RPV residual lifetime. This paper covers transport of neutrons through the RPV of a VVER-1000 nuclear reactor. This problem is of increased importance as it concerns issues around VVER NPP life extension. With regards to the construction (reduced thickness of the lateral reflector), this issue plays greater role in VVER reactors than in Western types of PWR reactors. RPV material degradation depends mainly on neutron flux and spectra. Both quantities can be calculated or measured. This paper compares MCNP calculations and measurements on zero-power experimental reactor LR-0 with TORT calculations for VVER-1000. The goal is to find a reasonable method for precise estimation of neutron fluence and attenuation factor through the RPV. The calculations were performed with MCNP stochastic code and TORT deterministic transport code. The measurements were performed in a VVER-1000 mock-up placed in reactor LR-0 (Research Centre Řež).

Comparison of calculated (blue MCNP and red TORT) and experimental (green dots) of relative neutron fluxes in the RPV model.
Graphite is an often-used moderating material on the basis of its good moderating power and very low absorption cross section. This small absorption cross section permits the use of natural or low-enriched uranium in graphite moderated reactors. Graphite is now being considered as the moderator for Fluoride-salt-cooled High temperature Reactors (FHR). The critical moderator level was measured for various graphite block configurations in an experimental dry assembly of the LR-0 reactor. Comparisons with experiments were performed between Monte Carlo simulation tools for which satisfactory agreement was obtained with the exception of some systematic discrepancies. The larger discrepancies were observed when using the ENDF/B-VII.0 library. To decrease the uncertainties, based on conservative assumptions, relative comparisons were done. The results provided by the different nuclear data libraries are within 3 sigma interval of experimental uncertainties. It has been determined that differences between the results of calculations are caused by variations in the $(n,n)$, $(n,n')$, $(n,g)$ reactions and also by various angular distributions, while the $(n,g)$ cross section variations play only a minor role for these configurations.
Collaboration at the Fusion Technologies Development

Vála, L., Reungoat, M., Vician, M.


This article deals with description and current status of a project of a non-nuclear, full size (1:1 scale) test platform dedicated to tests, optimization and validation of integration and maintenance operations for the European TBM (Test Blanket Module) systems in the ITER port cell #16. The facility called TBM platform reproduces the ITER port cell #16 and port interspace with all the relevant interfaces and mock-ups of the corresponding main components. Thanks to the modular design of the platform, it is possible to adapt or change completely the interfaces in the future if needed or required according to the updated configuration of TBM systems (TBS). In the same way, based on customer requirements, it will be possible to adapt the interfaces and piping inside the mock-ups in order to represent also the other, non-EU configurations of TBM systems designed for port cells #02 and #18. Construction of this test platform is realized and funded within the scope of the SUSEN project.
Domalapally, P.
Assessment of hypervapotron heat sink performance using CFD under DEMO relevant first wall conditions,

Among the proposed First Wall (FW) cooling concepts for European Demonstration Fusion Power Plant (DEMO), water cooled FW is one of the options. The heat flux load distribution on the FW of the DEMO reactor is not yet precisely defined. But if the heat loads on the FW are extrapolated from ITER conditions, the numbers are quite high and have to be handled none the less. The design of the FW itself is challenging as the thermal conductivity ratio of heat sink materials in ITER (CuCrZr) and in DEMO (Eurofer 97) is ~10–12 and the operating conditions are of Pressurized Water Reactor (PWR) in DEMO instead of 70 °C and 4 MPa as in ITER. This paper analyzes the performance of Hypervapotron (HV) heat sink for FW limiter application under DEMO conditions. Where different materials, temperatures, heat fluxes and velocities are considered to predict the performance of the HV, to establish its limits in handling the heat loads before reaching the upper limits from temperature point of view. In order to assess the performance, numerical simulations are performed using commercial CFD code, which was previously validated in predicting the thermal hydraulic performance of HV geometry. Based on the results the potential usage of HV heat sink for DEMO will be assessed.

The European DEMO power reactor is currently under conceptual design within the EUROfusion Consortium. One of the most critical activities is the engineering of the plasma-facing components (PFCs) covering the plasma chamber wall, which must operate reliably in an extreme environment of neutron irradiation and surface heat and particle flux, while also allowing sufficient neutron transmission to the tritium breeding blankets. A systems approach using advanced numerical analysis is vital to realizing viable solutions for these first wall and divertor PFCs. Here, we present the system requirements and describe bespoke thermo-mechanical and thermo-hydraulic assessment procedures which have been used as tools for design. The current first wall and divertor designs are overviewed along with supporting analyses. The PFC solutions employed will necessarily vary around the wall, depending on local conditions, and must be designed in an integrated manner by analysis and physical testing.
The design of a DEMO reactor requires the design of a blanket system suitable of reliable T production and heat extraction for electricity production. In the frame of the EUROfusion Consortium activities, the Breeding Blanket Project has been constituted in 2014 with the goal to develop concepts of Breeding Blankets for the EU PPPT DEMO; this includes an integrated design and R&D program with the goal to select after 2020 concepts on fusion plants for the engineering phase. The design activities are presently focalized around a pool of solid and liquid breeder blanket with helium, water and PbLi cooling. Development of tritium extraction and control technology, as well manufacturing and development of solid and PbLi breeders are part of the program.

Typical blanket segmentation for a vertical maintenance system and Multi-Module-Segment architecture
In the European fusion roadmap, reliable power handling has been defined as one of the most critical challenges for realizing a commercially viable fusion power. In this context, the divertor is the key in-vessel component, as it is responsible for power exhaust and impurity removal for which divertor target is subjected to very high heat flux loads. To this end, an integrated R&D project was launched in the EUROfusion Consortium in order to deliver a holistic conceptual design solution together with the core technologies for the entire divertor system of a DEMO reactor. The work package “Divertor” consists of two project areas: “Cassette design and integration” and “Target development”. The essential mission of the project is to develop and verify advanced design concepts and the required technologies for a divertor system being capable of meeting the physical and system requirements defined for the next-generation European DEMO reactor. In this contribution, a brief overview is presented of the works from the first project year (2014). Focus is put on the loads specification, design boundary conditions, materials requirements, design approaches, and R&D strategy. Initial ideas and first estimates are presented.
Involvement in the GEN IV Technologies Development

Uhlíř, J.,

FHR neutronics benchmark study and MSR technology development FHR neutronics benchmark study and MSR technology development in the Czech Republic,


Research on Molten Salt Reactor technology based on fluoride salts as a convenient way of higher actinides incineration and/or utilization of thorium fuel utilization has tradition in ÚJV Řež and later in Research Centre Řež in Czech Republic since 1999. Neutronic testing is an inseparable part of the development and was at first carried out in series of experiments with (40–60 mol %) LiF-NaF salt subjected to neutron field shaped by different moderators in frame of EROS experiments. Later on, neutron spectrum was measured in this salt and significant variations in calculation to experiment C/E comparison were discovered. Further tests were performed with real MSR/FHR reactor (66–33 mol %) LiF-BeF$_2$ coolant salt containing Li-7 isotope (99.994 mol %), which was provided by ORNL and were aimed at studies of neutron spectrum shape to confirm previous results with LiF-NaF salt. Neutron spectrum behind the layer of salt was measured by method of recoiled protons in different energy ranges. The independent measurements were done by set of hydrogen proportional detectors (HPD) for energies 0.1–1.3 MeV and by organic scintillator (Stilbene) detector for energy ranges 0.8–10 MeV. In addition to activities mentioned above, a new project focused on MSR and FHR development is prepared for following four years. The objectives of the project are focused on the MSR/FHR physics, MSR fuel cycle technology and MSR reactor core chemistry, further development of MSR/FHR structural material – Ni-based alloys and subsequent design and manufacture of selected components of the MSR/FHR technology. The project creates a platform for running Czech-US cooperation in MSR/FHR development.

Filling of capsule for LR-0 inserted zone with FLIBE salt
Molten Salt Reactor (MSR) is classified as a non-classical reactor system due to a specific character of its fuel, which is liquid – constituted by a molten fluoride salt mixture circulating between the reactor core and a heat exchanger. The fissile and fertile material are dissolved in a carrier molten salt, which concurrently plays a role of a heat-transferring agent. Moreover the reactor is connected with the on-line reprocessing technology, which also include the final processing of fresh MSR fuel. MSR is a breeder reactor type, which can be effectively operated within the thorium – uranium fuel cycle. Development and experimental verification of selected parts of MSR fuel cycle technology is still a crucial point for the future deployment of the of the reactor system. The paper summarizes the existing progress achieved by Czech companies and institutions in last three years in the area of MSR fuel cycle technology and molten salt technique:

- development and experimental verification of fresh MSR uranium-thorium liquid fuel processing,
- development of electrochemical methods of on-line fuel reprocessing from fluoride molten salt media,
- development and practical tests of selected structural material and its components compatible with molten fluoride salts at high temperature – nickel alloys and special graphite gaskets suitable for application in Molten Salt Reactor and fluoride pyrochemical partitioning technologies.

Main fields of described results in the area of MSR fuel cycle technology cover the verification of liquid uranium and thorium fuel processing using LiF-BeF$_2$ as carrier salt and verification of electrochemical separation possibilities of uranium and thorium from fission products. Also, the results of material compatibility investigation and corrosion studies of new nickel alloy MONICR and graphite gasket technique were done at conditions corresponding to liquid fuel processing. The R&D has been realized as a contribution to future deployment of MSR and thorium – uranium fuel cycle technology.
Berka, J., Kalivodová, J.,
Testing of high temperature materials within HTR program in Czech Republic,

Research institutes and also industrial companies in Czech Republic are involved in High Temperature Gas Cooled Reactor (HTGR) program and activities related to the study of advanced materials and HTGR technologies. These activities are supported by EC (within international projects, e.g. FP7-ARCHER, ALLIANCE, GoFastR can be mentioned) and also by Technology Agency of Czech Republic. Within these activities, degradation of metallic and ceramic materials in the high temperature helium atmosphere is investigated, and also new experimental facilities for material testing are built. As examples of tested materials, Alloy 800 H, ferritic steel P91, austenitic steel 316, Inconel 713 and 738 and corundum ceramics could be named. The selected results of exposure experiments in the high temperature helium environment are presented in this paper.

The High Temperature Helium Loop HTHL and microstructure of welded specimen of Alloy 800 H before and after exposure in HTHL (500–750 °C at 260 hours)
In this paper, the effects of high temperature exposure in air as well as in impure He on mechanical properties of 316L and P91 steels were investigated. The experimental program was part of material design of new experimental facility – high temperature helium loop. Some of the specimens were exposed in air at 750 °C for up to 1,000 h. Another set of specimens were exposed in impure helium containing 1 ppmv CO₂, 2 ppmv O₂, 35 ppmv CH₄, 250 ppmv CO and 400 ppmv H₂ at 750 °C for up to 1,000 h. Metallographical analysis, tensile tests, fracture toughness and hardness tests of exposed and non-exposed specimens were carried out. After the exposure both in air and He, the ultimate tensile strength of P91 decreased significantly more than that of 316L. After the exposure in He, the fracture toughness of 316L was reduced to 60% while fracture toughness of P91 showed no significant changes. The hardness of P91 decreased with exposure time in air. The measurement of the hardness of 316L was very scattered the most probably due to the heterogeneities in microstructure, the trend was not possible to evaluate.

The tensile curves for P91 steel in the as-received state, in air and in helium exposure for 1,000 hrs. at 750 °C and the overall fracture characteristics of exposed P91 specimen.
Hojná, A., Di Gabriele, F., Klečka, J.,

This paper summarizes results of the work carried out on the evaluation of the susceptibility to LME (Liquid Metal Embrittlement) of the ferritic/martensitic steel T91 in contact with LBE (Lead–Bismuth Eutectic). The influence of LBE on the fracture toughness of the steel was studied using 0.5T CT specimen at 355 °C, pre-cracked by cyclic loading in the liquid metal. Tests were carried out in well-defined conditions and according to ASTM standard. It was observed that the LBE decreased the apparent fracture toughness, JIC, by more than 30 %, compared to the value in air. The results are discussed based on examinations of the fracture surface evidencing LME occurrence. The stretch zone accompanying the pre-crack tip blunting was not observed in the specimens exhibiting LME. Therefore, a new fracture toughness, Jmap, determined as J integral at the maximum applied load, is proposed to be the appropriate value for fracture resistance evaluation in LBE. The Jmap can be applied for the assessment of a pre-existing LME crack stability.

Scheme of a crack tip and following onset of the crack extension
(a) via ductile fracture; (b) cleavage-like LME and
(c) corresponding J integral – crack extension curves.

Fracture surface of specimen showing low fracture resistance (J integral 39 kN/m) in LBE (oxygen content 2×10⁻⁵ wt%) – a) macro-view highlighting the lack of denting on sides; b) detail the interface between the pre-crack and the crack extension showing cleavage-like fracture typical for LME. The crack growth direction is marked with arrow.
R&D for Non-Energy Applications


Magnetically modified peanut husks were used as an adsorbent of cadmium and lead ions from aqueous solutions. Sorption and desorption experiments were carried out and adsorption isotherm models were calculated to assess the sorption capacity of the material. Langmuir adsorption isotherm was the best fitting model both in one-metal ion and two-metal ions solutions suggesting monolayer adsorption taking place. The observed desorption rate was very low, metals are therefore strongly bound on the surface of the adsorbent. Magnetically modified peanut husks were found to be a suitable adsorbent for removal of heavy metal ions from water.

![SEM images of magnetically modified peanut husks after adsorption of (a) Pb²⁺ ions, (b) Cd²⁺ ions](image)

*The amount of Pb²⁺ ions (solid line) and Cd²⁺ ions (dashed line) adsorbed per unit mass of material in one-metal-ion solution (left) and in two-metal-ion solution (right)*
Rozumová, L., Seidlerová, J., Šafařík, I.,
Nanomodified low-cost biological material for the removal of heavy metal ions,

This article examines the sorption capacity of a new magnetically modified biosorbent obtained from peanut husks for removing Pb(II), Zn(II) ions and Pb(II)-Zn(II) binary metallic system from test metallic solution. Peanut husks represent a possible replacement for the current expensive adsorbent for removal of heavy metals from wastewater. The peanut husks waste from locally available roasted peanuts was ground in a coffee mill in an experiment. Fractions smaller than ca 0.5 mm were collected and used for magnetic modification. The peanut waste husks were stabilized by perchloric acid. Chemical compositions of the samples were determined using X-ray fluorescence spectrometry (SPECTRO XEPOS). Iron oxides in the samples were detected by a power X-ray diffractometer (BRUCKER D8 ADVANCE). The chemical composition is expressed via oxides in original sample of peanut husks (OPH) and magnetically modified peanut husks (MMPH). It should be noticed that the process of magnetic modification lead to pronouncedly enhanced Fe content.
**R&D for Non-Nuclear Technologies**


Ion implantation of metal ions, followed by annealing, can be used for the formation of buried layers of metal nanoparticles in glasses. Thus, photonic structures with nonlinear optical properties can be formed. In this study, three samples of silica glasses were implanted with Cu+, Ag+, or Au+ ions under the same conditions (energy 330 keV and fluence 1×10^16 ions/cm^2), and compared to three identical silica glass samples that were subsequently co-implanted with oxygen at the same depth. All the implanted glasses were annealed at 600 °C for 1 h, which leads to the formation of metal nanoparticles. The depth profiles of Cu, Ag, and Au were measured by Rutherford backscattering and by secondary ion mass spectrometry and the results are compared and discussed.

*A powerful analytical instrument – a Secondary ion mass spectrometer (SIMS) has been used for characterization of advanced photonic materials.*

![Image](image-url)

**SIMS and RBS depth profiles of Au implanted in silica glass. Dashed line depicts SRIM simulation data. The values of the projected ranges Rp and the range of straggling ΔRp were determined by Gaussian fits.**
Řehořek, J., Vodárek, V.,
Creep behaviour and microstructure evolution in AISI 316LN +0.1 wt.% Nb steel at 600 and 625°C,

The paper deals with microstructural evolution in the AISI 316LN + 0.1 wt. % Nb steel during long-term creep exposure at 600 and 625 °C. The following minor phases formed: Z-phase (NbCrN), M23C6, M6X (Cr3Ni2SiX type), h-Laves (Fe2Mo type) and s-phase. M6X gradually replaced M23C6 carbides. Primary Z-phase particles were present in the matrix after solution annealing, while secondary Z-phase particles formed during creep. Precipitation of Z-phase was more intensive at 625 °C. The dimensional stability of Z-phase particles was excellent and these particles had a positive effect on the minimum creep rate. However, niobium also accelerated the formation and coarsening of s-phase, h-Laves and M6X. Coarse particles, especially of s-phase, facilitated the development of creep damage, which resulted in poor long-term creep ductility.
The paper deals with a problem of stress crack initialization on surface of low pressure steam turbine blade during operational regime. The mention stress analysis together with described environment indicate procedure of experimental works. The other goals of research should lead to a concept of assessment methodology of resistance of moving blades against corrosion and technology increasing fatigue strength of blade steels using surface strengthening. A prototype of the moving blade of the low pressure stages of steam turbine with the increased corrosion resistance should be an output of developed efforts.

Subsurface initiation of fatigue damage in steel T671
Janoušek, J., Hřeben, S., Špirit, Z., Strejcius, J., Kasl, J.,
Fatigue performance of blade steel T671 for different kinds of loading,

This contribution is based on the experiments and assumptions which have been described in the previous authors’ works. The experimental program, which deals with the issue of blade steel T671 fatigue damage, has been extended for another comparison. The specimens were taken from a reference material delivered for blade production and from the low pressure blade body of L-0 stage of a turbine generator set. Since this is the area of the steam condensation (phase transition zone), the specimens were also tested in the corrosion cell under pre-stress of 300 MPa. The chloride solution of 35 ppm was chosen as the environment at the temperature of 80 °C. Such an environment can be considered as the limit state that should not occur during the operating regime. The results were compared with previous experiments and the conclusions were summarized.

Detail of the initial Al₂O₃ inclusion
Czech Republic and Slovakia can look back on a history of several activities in the field of hydrogen technologies. Unfortunately, so far this has not lead to the development of a consistent and long-term research strategy in a broader context. This is because political representations in both countries are still lacking a clear national strategy of transition to an energy supply system based on renewables and carbon neutral technologies. As a consequence, the gap in technology level between highly developed states and these two countries continuously increases. It is reflected, among others, by a low visibility of these countries in the European research space, like e.g. in Fuel Cell & Hydrogen Joint Undertaking programs. On last year’s conference “Hydrogen Days 2015” it was stated that the situation is very similar in all post-communist countries. The energy sector in these countries relies mainly on coal, natural gas, and nuclear. In the following-up of the conference the Visegrád countries Poland, Czech Republic, Slovakia, and Hungary together with the partner Romania initiated a project called “Hydrogen Competencies in Visegrád countries”. The aim is to join the forces and to act as a crystallization seed for stronger group acting in collaboration with each other and on the national public administrations in the individual countries. In this regard, the Visegrád project can be seen as a loose continuation of the European project ENFUGEN. Since the last conference another progress has been achieved in the Czech Republic. Through a continuous effort several contact persons were identified with corresponding competences at different ministries and other subjects of public administration. In close collaboration with this network the strategy of support of renewable energy and its integration to the energetic mix of the Czech Republic is now started to be developed. This is supposed to be reflected in the corresponding national grant programs. The lesson learnt from this effort is that without convincing politics and bringing the topic into public, no major change will happen. In this context, the support of the Visegrád fund is gratefully acknowledged. Actual research going on in the Czech Republic covers substantial part of the hydrogen economy scheme. Beside high-temperature electrolysis in co-generation with high-temperature processes studied by the Research Centre Řež, built up in the project SUSEN, development and testing of material properties of solid oxides fuel cells, as well as steam electrolysis, is conducted at the UCT, Prague, Dep. of Inorganic Technology. At the same university, also high-temperature PEM fuel cells research is dedicated towards implementation into cogeneration units. Innovative polymer alkaline electrolysis, methanation as well as an energy accumulation system are experimentally investigated by the engineering company ÚJV. In Slovakia experiments on use of biogas as fuel for SOFC by University of Nitra and development of gas turbines burning hydrogen are explored.