Strategic Research Agenda of the MTA Centre for Energy Research related to the Atomic Energy Research

Version 2013

The Strategic Research Agenda related to the Atomic Energy Research is determined by the Mission Statement and the Research Concept. The Strategic Research Agenda outlines the main research targets and tasks of the institute and includes also the strategy of research infrastructure development. The Annual Research Program should be derived from the present Strategic Research Agenda. The Strategic Research Agenda should be actualized every five years, or more frequently, if necessary.

I. Development of multi-physics modeling and advanced numerical simulation tools

Advanced numerical simulation tools are necessary for the simulation of the various processes and phenomena occurring in nuclear installations. In the evaluation of the safety level and the operation characteristics of current and future reactor designs, new tools are expected to offer better accuracy, higher calculation efficiency. This involves the development of multi-physics tools (connecting several disciplines necessary for reactor calculations and avoiding conservative assumptions), and multi-scale tools (connecting several scales from the microscopic to the macroscopic level).

1. Fuel behavior simulation and modeling

Modernization of the steady state fuel behavior code FUROM (developing the mechanical model of fuel pellet, improving the fuel stack - cladding slip model). Feedback of the application and validation experience into the continuous development of FUROM. Participation in the Halden Fuel and Materials research programs, especially in the evaluation of Halden fuel measurements. Knowledge transfer to Paks NPP concerning Halden fuel measurements. Introduction of E110G specific material properties and models into the FRAPTRAN code, validation against AEKI and Halden experiments. Developing the fuel fragmentation model. Investigation of the parameters of TVEL cladding manufactured by new technology. Numerical simulation of activity release from leaking fuel.

2. Development and application of fine-scale thermo-hydraulic modeling

Development of various micro- and meso-scale methods. Fine scale modeling of two-phase flow. Study of turbulence by using particle methods. Numerical and theoretical investigation of the liquid-steam boundary.

3. Development and validation of calculating shroudless fuel assemblies

Modeling new Russian shroudless fuel assemblies to be applied at Paks NPP. The modeling should consider the changes in reactor physics and thermo-hydraulics.

4. Establishing an advanced code system for core physics and DBA calculations

An advanced code system for core physics and DBA calculations should be developed and validated to provide the possibility to evaluate independently the safety of new NPP units. Adaptation of the TRACE thermo-hydraulic system code. Development of the ATHLET code to include CFD-based mixing calculations.

5. *Burn-up credit investigations*

Safety evaluation of storage and transport devices with a special attention to the effect of cross section uncertainties.

6. *Development of methodologies for assessing uncertainties in core design, reactor operation and safety analysis and modernization of acceptance criteria*

Analysis of uncertainties in modeling normal operation and transients, development and application of the Best Estimate Plus Uncertainties methodology in safety analysis. Uncertainties of reactor physics, thermo-hydraulic and fuel behavior calculations. Validation of specific theoretical models.

7. *Development of multi-physics (neutronics + thermo-hydraulics + fuel behavior) simulation tools*

Study of 2D effects in heat conduction. Coupling reactor physics, steady state fuel behavior and hot channel codes. Coupling the hot channel code TRABCO and the transient fuel behavior code FRAPTRAN for RIA calculations. Coupling the hot channel calculation made by ATHLET and the transient fuel behavior code FRAPTRAN for LOCA calculations.

II. Research on reactor materials

The integrity of the existing power plants strongly depends on the ageing behavior of the structural materials. The enhanced requirements towards the new generation of reactors call for new structural materials which can preserve their properties after high neutron irradiation and operation at high temperatures. In particular, the activities will focus on the reactor pressure vessel materials in terms of neutron irradiation induced embrittlement and as well as the behavior of primary circuit components in contact with their environment. There are also some not quite well known features of the behavior of fuel cladding in extreme conditions of PWRs.

1. *Ageing of reactor materials, research of correspondence between the microscopic and macroscopic properties*

Experimental investigation of irradiation ageing of pressure vessel steels. Investigation of the applicability of local approach models. Setting limits and conditions for the applicability of PERFECT and DISFRAC calculations. Investigation of residual stresses of weld joints by neutron diffraction. Studies on thermal ageing. Improving the experimental determination of stress-strain parameters.

2. *Studies related to the structural integrity of the primary circuit*

Coupled CFD and fracture mechanical calculations. Modeling local ageing effects. Modeling the WPS effect. Load history modeling. Propagated error of stress-strain curve approximations in fracture mechanical calculations.

3. *Experimental studies of fuel components in extreme conditions*

Experimental and theoretical studies on Zirconium corrosion. Investigation of high temperature phenomena (oxidation, hydrogen uptake, ballooning, change of mechanical properties). Preparation and evaluation of Halden LOCA measurements. Application of mandrel testing methods for RIA simulation. Experiments related to severe accident phenomena, oxidation of fuel cladding in high temperature steam during ATWS. Investigation of the new cladding type E110G, secondary hydriding studies. Irradiation of Zirconium cladding samples in the Budapest Research Reactor, mechanical testing of irradiated samples. Experimental investigation and numerical simulation of leaking fuel rods under normal operation and storage conditions.

III. Research related to fuel cycle modernization and radioactive waste management, Generation IV reactor systems

The Hungarian fuel cycle strategy has to be revisited because of

- the lifetime extension of the existing units,
- the units to be built,
- the intention of the country to use nuclear energy on the long run and
- the emerging new technologies.

To reduce waste production and to guarantee the availability of fissile materials are the main goals which can be probably achieved by closing the fuel cycle. The Generation IV fast reactors may facilitate the closure of the fuel cycle. The institute should be involved in the joint international research. Active participation in the preparation of the ALLEGRO reactor clearly indicates this aim of the institute.

1. *Fuel cycle and radioactive waste of new nuclear units in Hungary*

Comparison and assessment of the potential fuel cycles and radioactive waste production of various Generation III+ reactor systems. Fuel cycle and High Level Waste management considerations.

2. *Establishing the national knowledge centre on closing the fuel cycle*

Complex investigation of the fuel cycle. Development of the SITONG4 code for the simulation of a large reactor park with Generation II, III and IV reactors and different reprocessing and fuel fabrication technologies. Evaluation of the potential scenarios for the spent fuel produced by the currently operating and planned new units in Hungary. Review of current international knowledge on reprocessing, transmutation, actinide chemistry, fuel fabrication.

3. *Studies on spent fuel reprocessing*

Research related to currently available and future partitioning technologies. Studies on closing the fuel cycle with MOX utilization. Analysis of spent fuel reprocessing options offered by different countries to Paks NPP.

4. *Safe disposal of high level radioactive waste*

Engineered and natural barriers of high level nuclear and radioactive waste repository will be studied on macro- and microscopic scale in order to obtain appropriate and accurate input data for repository safety assessment. Versatile X-ray microanalytical techniques and modeling tools will be developed based on laboratory experiments with inactive and radioactive samples. Studies concerning intermediate and final disposal of spent fuel and high activity radioactive waste. Studies on the direct disposal of UO_2 and MOX fuel. Characterization of high level wastes produced by different scenarios. Examination of clay samples to produce data necessary for the modeling of nuclide migration in the deep geological repository. Analyses of potential activity wash out from spent fuel by ground water. Evaluation of technological barriers used/planned in other countries.

5. *Disposal of decommissioning waste*

Analysis of the activation of reactor vessel, core internals and concrete. Determination of the composition of the activated components and their activity. Review of the requirements for the final disposal of decommissioning waste components. Participation in the categorization of the different kinds of radioactive waste produced during the operation of NPP.

6. *Neutronics, thermo-hydraulics and safety studies for Super-Critical Water Reactor*

SCWR core optimization. Development of a fine mesh code for SCWR core calculations. Complex NDT studies characterizing the properties of SCW. Heat transfer and critical flow in SCW. Investigation of the normal – supercritical transition. Safety analysis of SCWR.

7. *Neutronics, safety and fuel cycle studies for fast reactors and for a combined fleet of thermal and fast reactors*

Reactor physics and fuel utilization in new reactors. Investigation of the fuel cycle by combining various reactor systems. Development of reactor physics codes for liquid metal cooled fast reactor calculations (multi-group version of the KIKO3D reactor kinetics code).

Remark: Investigations on the gas cooled fast reactor and the ALLEGRO demonstrator are mentioned in Section V.2.

8. *Nuclear data measurements related to Generation IV reactors and nuclear waste characterization*

Cross-section measurements on new-generation reactor materials. Nuclear data of minor actinides. Nuclear data needed for nuclear-waste drum characterization.

IV. Research related to nuclear power plant technology

Since Paks NPP will solve the remaining safety problems to receive the license for lifetime extension, on the medium run the institute will deal with ageing-related and other problems belonging to its competence. Moreover, it is expected that new nuclear units will be constructed in Hungary. The institute intends to be involved as a partner of HAEA, MVM and Paks NPP in the preparatory works aiming at the construction of new nuclear units. The following topics are combined research and application tasks related to the existing and new units at Paks.

1. *Considering new acceptance criteria*

Consequences of the new NRC LOCA rules to the VVER fuel. Analysis of the role of inner oxide scale on the embrittlement of cladding during LOCA. Investigation of breakaway phenomena and H uptake by Zirconium.

2. *Studies on extreme thermo-hydraulic phenomena and the use of results in safety and stress-strain analysis*

Investigation of water hammer phenomena related to the new nuclear units to be constructed in Hungary

3. *Experimental validation and application of CFD methods*

Flow mixing measurements by using PIV and LIF for CFD validation purposes. Validation of the FLUENT CFD code to mixing experiments. Application of CFD to mixing problems. Prediction of assembly temperature on the basis of actual thermocouple measurements corrected by the results of mixing measurements.

4. *Preparation and implementation of mitigative Severe Accident Management*

Potential errors in EOPs caused by the temperature measurement. CERES test facility: experiments to measure the effectiveness of ex-vessel cooling.

5. *Development of a coupled neutron physics - thermo-hydraulics code for the VERONA-e expert system*

Development of a coupled code system to be used in the off-line VERONA-e core analysis expert system. Neutron physics calculations are to be performed by the RONA reactor physics program taken from the on-line VERONA system. The thermo-hydraulics should be covered by the RETINA code, developed by AEKI. The basic aim is to develop a flexible tool applicable for a very detailed core analysis, including the calculation of subchannel flow and thermal phenomena.

6. *Development of reactor diagnostics systems and interpretation models*

Software development for interpreting the signals of the PAZAR system. Development of noise analysis methodology. Noise analysis of Paks NPP signals. Developing a fault detection system.

7. *Process monitoring systems*

Participation in the activities of the MTO section of the Halden Reactor Project. Development of on-line systems for various process monitoring purposes (e.g. condition-monitoring). Development, testing and validation of human-machine interfaces for fission and fusion facilities. Maintaining and improving the CERTA VITA remote process monitoring system.

8. *Various tasks related to I&C reconstruction*

Modernization of the training simulator and its upgrading for I&C reconstruction. Solving methodical problems of using the simulator for the preparation of I&C reconstruction. Development of an integrated simulator system, real time modeling of plant systems. Contributing to selected tasks of the I&C reconstruction, e.g. human-machine interface design and validation, process-control computer design, development, implementation, licensing support.

9. *Expert opinions contributing to the establishment of new nuclear units in Hungary*

Participating in the tendering process. Checking the fulfillment of European Utilities Requirements. Participation in the Environmental and Site licensing procedure.

10. *Comparative analysis of the environmental consequences of electric energy production modes*

Estimation of environmental consequences of various electric energy production cycles.

V. Radiation protection, biological effects of radiation, nuclear chemistry

1. *Derivation of the dependencies between releases of radioactive materials and health effects*

Dispersion and dose calculations. Establishing dose-release correlations for Paks NPP units similar to correlations proposed by EUR.

2. *Research of health and environmental risks*

Biological effects of low radioactive doses. Environmental monitoring and models. Developing radon detection. Development of environmental measurement and dosimetry techniques. Improvement of methods for evaluation of the results.

3. *Activity transport and radiation shielding*

Modelling atmospheric and hydrospheric activity dispersion. Estimating dose consequences of inhalation and ingestion, early and late health effects. Model, algorithm and software development. Performing activity transport calculations for safety analyses and studies with software codes developed in EK as well as with commercial software tools.

4. *Space weather and space dosimetry*

Development of advanced radiation detector systems for studying space weather effects and for space dosimetry purposes on board aircraft, stratospheric balloons, sounding rockets and spacecraft. Analysis of impacts of space weather on energy networks. Maintenance of the PILLE and the TRITEL dosimetry systems flying on the International Space Station. Modernization of PorTL. Investigation of cosmic rays by using passive and active detector systems.

VI. Development and utilization of the research infrastructure

1. *Renewal of nuclear competence, education and training; research and development in nuclear science*

The Centre should operate the research reactor in a safe and undisturbed manner also in the future. This requires a highly dedicated work of the management and the reactor staff. The Centre, as the host organization of the Budapest Neutron Centre consortium, should also promote the utilization of the significantly improved measuring potential around the reactor.

The development of the research infrastructure should be decided upon, taking into consideration the planned lifetime of the reactor (by 2023). The financial conditions of this program should be ensured by the Centre together with the other participants of BNC. There are specific tasks dedicated to the Centre:

- *Operating the BNC, as a host organization of various national and international user access programs*
- *Participating in EERRI*
- *Participating in training and research activities organized by IAEA*
- *Sustaining research, applications, and developing the infrastructure in the fields of nuclear analytical techniques (neutron activation analysis, prompt-gamma activation analysis, Mössbauer spectroscopy), imaging (neutron, gamma and X-ray radiography) and nuclear physics*
- *Promoting international scientific collaborations in the field of neutron science*
- *Participating in domestic, European and word-wide research projects*
- *Control of water chemistry*
- *Preparing the final deposition of beryllium*
- *Modernization of the Environmental Monitoring System. Modernization of the Mobile Dosimetry Laboratory.*
- *Developing emergency preparedness. The use of dosimetry in emergency preparedness.*
- *Developing the quality management of the dosimetry services*

- *Preparing the second transport of spent fuel to Russia*

The establishment of large European nuclear infrastructures is a major contribution to the sustainability of the peaceful use of nuclear energy. This development is a very demanding task where the participation of the institute would be very desirable, however, the research topics arising from this task cannot be well defined at this stage.

2. *Preparation of the ALLEGRO gas cooled fast reactor demonstrator*

The European Strategic Energy Technology Plan (SET-Plan) identifies nuclear fission as one of the key low carbon energy technologies. In the frame of the SET-Plan, the Sustainable Nuclear Energy Technology Platform (SNETP) is proposing the European Sustainable Nuclear Industrial Initiative (ESNII) aiming at the demonstration of the fast neutron Generation IV reactor technologies with closed fuel cycle. Among the systems considered, ALLEGRO is the demonstrator of the gas cooled fast reactor.

Several objectives are assigned to ALLEGRO. At first, it will demonstrate the viability of the Gas Fast Reactor (GFR) reactor system, as no reactor of this type has been built in the past. Most of the GFR architecture, material and component features are considered at reduced scale in ALLEGRO, excluding the energy conversion system.

The development of structural materials requires the use of fast spectrum research reactors, which can generate relevant damage rates to the next generation reactors and fusion devices. In ALLEGRO, the core neutrons can also be used to irradiate advanced fuel and structural materials with fast neutron spectrum and in a large temperature range.

The institute, together with its Czech and Slovak partners and CEA, France launched a project for the preparation of the ALLEGRO Project, aiming at the construction of the reactor in this region (the Polish partner joined in 2012). The FP7 project ALLIANCE (2012-2015) is strongly related to the objectives of the preparatory phase of the ALLEGRO project. The four East European member of the project (with the scientific and technical help of CEA) established in 2013 the V4G4 Centre of Excellence to perform the experiments needed for safety and qualification purposes. The contribution of MTA EK is the Fuel Laboratory..

The main tasks of the institute in the preparatory phase of the project are as follows.

- *Participation in the preparation of the general design of the reactor. Preparation of the licensing Roadmap. Preparations to Environmental Impact Assessment and Site Licensing.*
- *Preparation to safety analysis. A study will be elaborated according to the relevant issues of nuclear regulation, and the tools of safety analysis (computer codes, initial events, acceptance criteria, etc.). Adaptation and development of the advanced analysis tools ERANOS and PLEIADES.*
- *Preparation of the strategy of spent fuel and radioactive waste management.*
- *Constructing the Fuel Laboratory and starting the ALLEGRO fuel qualification program in the Fuel Laboratory.*
- *Preparation of governance and financing principles of the ALLEGRO project after the preparatory phase.*

3. *Studies related to large research facilities (ESS, ITER)*

Environmental evaluation of large research facilities. Shock waves and cavitation in the Hg target of ESS. ESS related research. Radiation damage of electronic devices of ITER.