INTRODUCTION

The Institute of Atomic Energy (IAE) emerged in 1983 as one of three independent research institutes formed on the basis of the Institute of Nuclear Research founded in 1955. The main research facility of the IAE is the MARIA nuclear reactor of 30 MW (thermal). It is the only reactor operated in Poland. In 2003 the reactor was used for investigations in the field of solid state physics and for production of radioisotopes for various applications, mainly for nuclear medicine.

The Institute research activity includes the fields of nuclear physics and nuclear technology, with applications. At present it covers the basic and applied research aiming at the development of both proecological energy systems and applications of new nuclear technologies in medicine and industry, specially regarding the use of the MARIA reactor. The newly developed subjects of research include nuclear and non-nuclear energy production, energy-related ecology, radiation protection, radioactive waste management, material sciences, nuclear methods of condensed matter physics and model calculations for assessment of risk from industrial and nuclear installations.

In 2003 the research activity was pursued in two research departments, in European Union Centre of Excellence MANHAZ (Management of Health and Environmental Hazards), in Laboratory of Dosimetric Measurements and in two MARIA research reactor operation departments.

In 2003 the reactor MARIA completed 40 operational cycles, at power level ranging from 30 kW to 18 MW, with overall operation time of 4014,3 hours. No abnormal situations occurred in this year.

During 2003 reactor MARIA operated with medium enriched (36% of U-235) fuel assemblies. The high release of fission product from new fuel assemblies limited utilization of this fuel in MARIA reactor. The visual testing of clad in discharged spent fuel shows changes of its state. Therefore in the contract for supplying of new reactor fuel - signed in December 2002 - the suitable changes of design parameters and criteria were introduced and agreed with the supplier.

The analysis of the physical parameters for operating purposes of the MARIA reactor and of spent fuel storage facilities was performed. The set of experiments and analysis was done to further improve the conditions of safe reactor operation. The specific instrumentation of irradiation channel was made for precise predetermination of irradiation conditions. Based on the results of the experiments performed in thermo-hydraulic loop WIW-300 and in the reactor, the flow resistance in primary fuel cooling circuit in the case of boiling was evaluated. The RELAP 5 code was applied for this purpose.

To prevent the corrosion damage of MR spent fuel stored in the technological pool of MARIA reactor the encapsulation technology was adapted. The spent fuel assembly was dried and stored in capsule filled with helium. Several improvements of this technology were made in 2003 year and Regulatory Body accepted this technology. A number of MR spent fuel assemblies were closed successfully. The capsules with spent fuel assemblies were located in water pool. The quality of the oldest spent fuel assemblies discharged from EWA reactor was again analysed.

The neutron beams from five horizontal channels of the MARIA reactor are used for investigation of internal structure of condensed matter. The experimental base for this research at IAE consists of 5 neutron spectrometers of the Regional Laboratory of Neutronography. At one of horizontal channels the neutron and gamma radiography facility is installed.

The Institute has also continued the design and construction of a facility for boron neutron capture therapy (BNCT), to be implemented at the horizontal channel of the reactor. After successful construction of the underwater collimator for the neutron beam, completed in 2001, the work focused on measurements of the parameters of the beam and on design of a fission converter. The design and optimization of neutron beam for neutron capture therapy is usually accompanied by the neutron spectra measurements at the target position. At the MARIA reactor, these “in-air” measurements were focused mostly on the epithermal neutron energy region (1 eV < E < 10keV) and the results were used for verification of BNCT calculations.

A subsidiary reactor loop facility, called BIMA, was used for studies of chemistry and pharmacology of boron compounds for BNCT. The device has a system of precise stabilisation of temperature along the length of the sample.

The following target materials were irradiated for the external customers: S, TeO_2, Yb_2O_3, KCl, Cu, KBr, Sm_2O_3, Co, Hf, Ag, $Ho(NO_3)_3$, La_2O_3, $Sm(NO_3)_3$ and Ir192 gamma source for brachyterapy. The investigation of neutron doping of silicon crystal was continued.

Research work in the field of condensed matter physics was based mainly on the use of neutron and X-ray diffraction and Mössbauer techniques. Neutron scattering constitutes the main research area of the Regional Neutron Research Laboratory. Neutron scattering measurements provide information on atomic scale about the static and dynamical properties of matter, which in many cases is not obtainable in other way. The instruments at the horizontal channels of the nuclear reactor MARIA are considered as the home base for the Polish research groups. Besides, the scientists from Institute have a permanent or temporary access to the foreign experimental devices – the pulse neutron reactor IBR-2 at JINR Dubna, Russia, the Swiss Spallation Source of the PSI, Villigen, Switzerland, the synchrotron radiation source DESY, Hamburg, Germany, and neutron spectrometers at CE Saclay, France. MARIA reactor constitutes also a special potential for training and provides research opportunities for younger scientists.

Thermal neutron scattering was employed in studies of the atomic magnetic moments orderings and the dynamics of crystal and magnetic structures. The formation of magnetic moments in the rare earth TmB_{12} and ErF_3 compounds was studied with the incoherent inelastic scattering and discussed in terms of the crystal field theory. The phonon dispersion relations in bismuth were found to soften only slightly when the temperature approaches the melting point. The studies on the dynamics of the magnetic fluctuations in antiferromagnetic and paramagnetic phase of Mn(18%Cu) alloy reveal the magnetic domain orientation memory effect well above the ordering temperature.

Small angle neutron scattering was applied to study the molecular aggregates in surfactant – water solutions and the micropore structure of porous materials. The temperature and concentration dependence of the micelle size and aggregation in the heavy water ternary solutions containing the non-ionic (TX-100) and anionic (SDS) surfactants was studied. The bulk and surface fractal structures of the micropores in building materials were found.

Neutron radiography studies on the water imbibition in common building materials were extended beyond the normal conditions region. The temperature dependence of the water absorption rate in porous materials was found to follow the predictions of the classical capillary theory of the imbibition. The basic assumptions of the theory were discussed in terms of the surface energy minimization for static configurations. The first observations of the diffusion in H_2O – D_2O systems were performed.

Mössbauer spectroscopy was used to continue the study of magnetism in dysprosium compounds. New intermetallic series were synthesized and the X-ray and Mössbauer spectra for $Dy(Mn_{0.4}Fe_{0.6-x}Al_x)_2$ were measured.

X-ray investigations included the synchrotron topography studies of twinning in some perowskite-type crystals, growth defects in Si:Ge crystals, helium implanted Si and AlGaAs crystals and structures implanted with As, the investigation of structures of biologically-active, pharmacologically-important organic complexes, including their structural modeling using modern computer packages and experimental study of the crystalline structures of ceramic and metal plasma-sprayed protective coatings.

Crystal growth investigations were focused on the conditions of hammering of the Cu single crystal (100)-oriented plates necessary to enhance their reflecting capability for thermal neutrons.

Theoretical studies of structural changes in Fe-C and Pd-Er-H compounds at nonequilibrium thermodynamic states and of diffusion mechanism of carbon in martensite at temperatures below 80 K were carried out. A study of quantum tunneling in diffusion of carbon in Fe-C systems at low temperatures has been done. To complete the experimental study of water migration in bricks, a theoretical investigation of some capillary phenomena, based on the concept of the liquid-solid adhesion as the main driving force, was performed.

The Institute conducted the research in the field of management of health and environmental hazards. In 2003 the following works were done:

- Continuation of implementation of four projects as a part of 5-th framework Programme of UE (ENSEMBLE, EVAHYDRANET, DSSNET and EVATECH).
- Development of a computerized system SWAR for emergency planning, handling safety oriented data and decision support system in case of major chemical accidents.
- Carrying out three workshops foreseen by the work packages:
  WP 1- Short-Range Transport and Dispersion Modelling for Decision Making
  WP2 -Models and tools for assessment of risk related to transportation of dangerous goods by road and railway
  WP3 -Models and tools for assessment of risk related to transportation of dangerous goods by pipelines,
  according to program of Centre of Excellence "MANHAZ" – Management of Health and Environmental Hazards.
- Developing WWW MANHAZ portal.
- An integrated software environment for the comprehensive calculations of environmental transport and fate of chemicals released to the environment.

Research on dosimetry and radiation protection remained a vital part of the Institute activities. All the research subjects were aiming at practical applications, especially towards medical dosimetry and calibration of radiation protection instruments. The investigations were focused on neutron dosimetry, which is one of high-level specialisations of the IAE laboratories. This concerned the development of the recombination methods for dosimetry of mixed radiation fields, dosimetry of photo neutrons around medical accelerators, dosimetry for boron neutron capture therapy and neutron metrology. Considerable progress was achieved also in projects concerning internal dosimetry (assessment of internal doses on the basis of spectrometric measurements). Studies on safety and quality management for medical use of radiation sources were continued within programme of the Centre of Excellence established in the Institute.

Selected topics of nuclear energy were studied in 2003, taking into account the foreseen costs and availability of sources of energy in Europe. Various aspects of nuclear power reactors and nuclear power plants were analysed. The ecology, economy and safety of nuclear facilities were considered. The progress in new approach to interpretation of gas fission product distribution in the UO_2 fuel with high burnup and temperatures was achieved. The experiments of interaction of fast neutrons from spallation source with U/Pb pile in JINR (Dubna) were performed in the frame of Energy and Transmutation Project and interpretation of the results was perfprmed.

Qualitative evaluation of safety level of WWER reactors nuclear power plants within the neighboring countries in view of possible hazards in Poland was analysed.

The model for RELAPM. 5/MOD 3 code for MARIA research reactor to provide the capability for the analysis of the reactor core under various transient and accident conditions was elaborated. The model was qualified against the existing reliable experimental data.

The simple and efficient SOR-like iterative method for solving large matrix Sylvester equations, playing an essential role in control theory was elaborated. In a few literature examples, this method provides solutions with the relative error equal to about 10^{-12} with regard to the exact solution whereas, solutions of these examples by means of recent Krylov subspace algorithms, obtained with a significantly greater computational work, do not exeed the relative error smaller than 10^{-3}.

The laboratory plant for study of removal of volatile organic compounds from gaseous mixture by electron beam from IŁU-6M accelerator at Institute of Nuclear Chemistry and Technique (INCT) was designed and commissioned. Using this device in collaboration with INCT the studies of removal efficiencies and products of benzene decomposition in air by treatment with electron beam were carried out at the laboratory plant.

The relation between impact strength and the fracture toughness of low alloy steel in temperatures up to 650°C were investigated in the Material Research Laboratory. The changes of mechanical properties of reactor materials irradiated by heavy ions and neutrons were investigated.

The radiological protection of the activities of the Research Centre Świerk and of the National Radioactive Waste Repository was guided by the Division of the Radiation Protection Service. The radiological monitoring of personnel and environment was systematically performed and no abnormal situations were recorded during the whole year.