

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 2004 due to delay of supply of the nuclear fuel reactor operated in limited time and wide range modernisation program was performed.

The Institute research activity includes the fields of nuclear physics, nuclear technology, and their 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 2002 a major change of the Institute organisation was done. From 1 January 2002 the Institute Radioactive Waste Management Department was transformed into a new independent enterprise: Radioactive Waste Management Plant. It deals with radioactive waste and spent nuclear fuel management. Department of Reactor EWA and Spent Fuel Storage Facilities were moved to the new unit. The proposal to establish the Centre of Excellence "MANHAZ" - Management of Health and Environmental Hazards - within the Institute was accepted by European Commission and organized on the basis of Department of Risk Assessment and Environmental Protection. According to the new Atomic Law regulations the position of the Deputy Director for Nuclear Safety and Radiological Protection was established. Laboratory of Mixed Radiation Dosimetry was joined with the Radiation Protection Service Group, forming a new division named Laboratory of Dosimetric Measurements (LDM). The organizational changes were the steps needed for completing the process of accreditation of calibration facilities in the IAE. Such enlarged Laboratory became also a voting member of EURADOS (European Radiation Dosimetry Group).

According to the organisation of the Institute, the Scientific Division includes two research departments: Department of Nuclear Methods in Solid State Physics and Department of Nuclear Energy. Additionally, Scientific Division include two centres: Computing Centre "Cyfronet" and Scientific, Technical and Economic Information Centre. Reactor Division consists of two departments: Department of MARIA Reactor and Department of Reactor Analysis and Technology.

In 2004 reactor MARIA was operated only for 3 operational cycles at the power level of 15 MW and at a low power around 30 kW for experimental purposes. The new nuclear fuel was supplied at the end of January 2005 and from the beginning of February 2005 reactor MARIA has been at normal operation. The long period of the reactor shut-down was devoted mainly to an intensive reactor inspection, a modernisation of some reactor systems and training of operating personnel. The conservancy procedures were done for the following systems: temperature in primary cooling measurement system, pumps in primary cooling circuit, reactor building ventilation system, neutron modification of minerals equipment. The new rabbit system for irradiation of short lived isotopes enables to discharge it from and charge on irradiation channels during normal operation of reactor. It gives possibilities of irradiation short lived and long lived isotopes at long period of reactor cycles. The long period of reactor shut down enabled to repair the closing system in two horizontal channels. Basing on positive results of experimental irradiation the production facility for neutron doping of silicon crystal was designed.

During the long break in MARIA reactor operation the density of poisoning isotope He^3 in the beryllium core matrix blocks has increased as a result of the decay of previously accumulated H^3 . The two dimensional model of the poisoning process based on the REBUS-3 code, was used to monitor of this process and its influence on core reactivity deficit. The LEU (19,7% enrichment) nuclear fuel parameters for MARIA reactor with U_3Si_2 were calculated and compared with HEU (80% and 36% enrichment) fuel.

For calculation of thermal-hydraulic parameters of MARIA reactor the ATHLET and RELAP5/MOD3 were applied. Using specimens from decommissioned EWA reactor the properties of Al-Mg-Si alloys

irradiated with high fluency of neutrons ($3,7 \cdot 10^{21} \text{ n/cm}^2$) were determined.

Institute of Atomic Energy is responsible for handling all the problems concerning radiation protection in the Institute and in the vicinity of Nuclear Centre Świerk and National Repository of Radioactive Waste, located at Różan. These tasks were done by Radiation Protection Measurements Laboratory of Institute. In 2004 Radiation Protection Measurement Laboratory completed successfully the process of accreditation and obtained the official registration in the Polish Centre for Accreditation for two main domains of Laboratory:

- The determination of internal body contamination (whole body, thyroid and excretions);
- Calibration of dosimeter instruments (gamma, neutron and surface contamination monitors).

The following laboratories and facilities are available in the Laboratory:

- Whole body counter;
- Counter of thyroid activity;
- Calibration laboratory with standard radiation sources;
- Environmental measurements laboratory, and
- Radiochemical laboratory.

Whole body, thyroid and "in vitro" monitoring were carried out for radiation workers from Nuclear Centre Świerk and for 645 external customers. The results of measurements show that there is no registered influence on the environment and the population living in the vicinity of the Nuclear Centre Świerk and National Repository of Radioactive Waste Różan due to the operation of these facilities. More than 1000 environmental samples were measured in 2004.

The study of new technology of nuclear energy generations is mainly devoted to nuclear transmutation of long lived radioactive isotopes in spent fuel and radioactive waste. The series of experiments for investigation of neutron generation in spallation processes were performed on "Gamma 2" and "Energy plus Transmutation" using NUCLOTRON accelerator in Joint Institute of Nuclear Research Dubna. Using Y^{89} activation detector the spatial distribution of various reaction rate in PbU assembly irradiated by 0,7 GeV protons was measured. Using cross section dependence upon neutron energy the space and energy distribution of neutron flux in PbU assembly can be estimated. The neutron distribution in "Gamma 2" facility was calculated. The fireball model of the spallation processes was tested using experimental results. The efficiency of various neutron sources for transmutation processes was analysed.

The analysis of various processes occurring in UO_2 in fuel at high burnup and at high temperatures were performed. On the basis of the results the size of fuel pellets and leakage of xenon from fuel pellets can be estimated for various nuclear fuel operating conditions.

Discharged from research reactor EWA spent nuclear fuel elements were stored for long time in water pools. The periodic quality test of longest stored fuel elements were performed. For this purpose the following methods were used: determination of value of fission product leakage from fuel elements (sipping test), visual inspection and ultrasoning scanning of spent fuel clad surface. The results are compared with previous tests. On results of test the sequence of encapsulation in helium filled canisters was proposed. On the frame of International Atomic Energy Agency Coordinated Research Program "Corrosion of research reactor aluminium clad spent fuel in water" four experimental racks were placed in two spent fuel storage water pools: two of them in the pool with MR-6 spent fuel assemblies and two other in the pool with WWR assemblies. After one year storage, two racks were removed (one from each pool) and corrosion processes in aluminium samples from racks were investigated.

The solid state physics is one of the active research fields in the Institute. IAE provides experimental facilities and research experience in neutron and X-ray diffraction as well as Mössbauer techniques. The magnetic moment of the neutron, low energy and its strong scattering by hydrogen form the merits of thermal neutrons scattering in condensed matter research. X-ray scattering is used mostly for studies of organic compounds structures and inorganic monocrystalline systems important for electronic and computer technologies. Nowadays many of the X-ray diffraction studies are carried out at the synchrotron radiation centres. The Mössbauer effect is used for studies of local magnetic properties of materials.

The condensed matter research aims at the determination of atomic and magnetic orderings in new materials and phase transitions occurring with variation of external factors such as temperature or magnetic field. Neutron scattering is used as the major technique in determination of magnetic structure and the dynamical properties of lattice systems. Six instruments including two triple axis spectrometers, two wide angle and two small angle scattering diffractometers are in use at the MARIA nuclear research reactor. Some research on macroscopic phenomena of water migration is performed with the neutron radiography station. One should mention studies and tests on the mechanical properties of the irradiated materials.

Some of the research is of theoretical character and aims in determination of the structure of the organic materials. The macroscopic phenomena of water migration in porous systems are also described within various theoretical approaches.

In 2004 the analyses of previous experiments were performed yielding the new insight into the water migration in soils and its description in terms of the capillary forces. The features of the spin glass region in Mn-Cu alloys have been registered and some new characteristics of spin waves in Pd-Fe determined. The small angle neutron scattering data for water solutions

of the non-ionic classical surfactants gave support for the idea of cylindrical micelles formation.

In Mössbauer studies the ^{161}Dy isotope was used for determination of the Slater-Pauling plots for Dy-Fe-Co-Al and Dy-Fe-Ni-Co systems. The slow oscillations of the hyper-fine magnetic fields and tetragonality of the martensite were studied and analysed in terms of the carbon diffusion. Some important observations on the phase transitions occurring in the thermal barrier surface coatings were made.

The structure of two Catharanthus derived alkaloids have been resolved by means of X-ray diffractometry. The structure of the N,O-diacetyl derivative of cyclic 3-hydroxymelatonin was elucidated with the same technique after growing suitable single crystals. The theoretical *ab initio* calculations of the proton affinity of furancarboxylic and thiophencarboxylic acids were performed and the geometry optimisation carried out.

Synchrotron radiation studies were performed of Se ions implanted GaAs and AlGaAs yielding the strain profiles for various implantation conditions. The synchrotron topography was applied in studies of the defects in neutron irradiated silicon and calcium oxyborates. The Uragami fringes were observed in the white beam Bragg case topography.

The slight improvement of the manganin pressure sensors properties due to the Kr ion implantation was found. The thermal spike model was elaborated in detail for description of the thermal effects in high energy electron deposition.

The Centre of Excellence MANHAZ ("Management of Health and Environmental Hazards") of the Institute of Atomic Energy was founded under the FP5 Contract EVG1-CT-2002-8001 MANHAZ. The mission of the Centre is to provide a leadership, expertise and integration of efforts related to the risk assessment of activities involving hazardous substances in Poland and other countries of the region. The main objectives of the Centre are:

- To apply advanced scientific approach and technologies in management of environmental risk,
- To enhance the combined understanding of multiple health and resource factors and their interrelationships, to better inform decisions made to protect ourselves and our environment,
- To become a catalyst for improved environmental decisions through sound risk management.

The main achievements of the staff of the Centre are:

- Development of methods, models, computer programs and databases for assessing health and environmental risks related to major accidents of stationary nuclear and chemical processing installations and other facilities connected with the use and/or transportation of dangerous substances (by road, railways and pipelines).

- Development of stand alone computer codes and real-time computer-aided emergency decision support systems for complex technical facilities (nuclear power plants, chemical process installations, pipelines etc.), and for industrial areas.
- Development of dedicated weather numerical prediction system with emphasis on application to the analysis of the behaviour of nuclear and chemical installations and to the assessment of the environmental impact major accidents.
- Preparation of guidelines and training materials for assessment of risk from industrial installations, and for Security Vulnerability Analysis.

The staff of IAE/MANHAZ has been involved in the following EC projects: a) ENSEMBLE (2000-2003) – Methods to reconcile disparate national forecasts of medium and long-range atmospheric dispersion, b) RODOS (1993-1995, 1996-1999, 1999-2000) – several projects on the development, enhancement, customization for the operational use the Real-time On-line Decision Support System for Nuclear Emergencies in Europe (RODOS), c) EVANET-HYDRA (2001-2004) – Evaluation and Network of EC Decision Support Systems in the field of Hydrological Dispersion Models and of Aquatic Radioecological Research, d) EVATECH (2002-2005) – Information requirements and countermeasure evaluation techniques in nuclear emergency, e) DSSNET (2000-2004) – Improvement, extension and integration of operational decision support systems for nuclear emergency management, and f) EURANOS (2004-2008) – Integrated project, European approach to nuclear and radiological emergency management.

Furthermore CoE MANHAZ has been engaged in such strategic national projects as: a) Computerized crisis management system for chemical plants; b) Tools for assessing health and environmental risks related to major accidents of chemical process installation and other facilities connected with the use of dangerous substances, including recommended methods, models, computer programmes and data bases; c) Enhancement of RODOS system for the use in radiological emergency centre. The Centre is currently engaged in a development of modules for Decision Support System for management of crisis in urban areas related to acts of terror.

In 2004, similarly as in the previous year, a series of workshops with participation of foreign experts were carried out, to present to the broad spectrum of specialists and persons engaged in decision making process, "the state of the art" models and tools relevant for the topics covered by work packages included in the program of activities of the Centre. The topics of the workshops covered the following issues:

- Long-range transport and dispersion modelling for decision making,

- Models and tools for assessment of risk related to transportation of dangerous goods by road and railway
- Models and tools for estimating the risk of pipeline transport of hazardous substances
- Approaches to comparative risk assessment of fuel cycles of electricity generation
- Safety system for medical applications of radiation - present regulatory framework in Poland and harmonisation with EU standards

Recently the Centre started also activities on the development of:

- computer tools facilitating assessment of vulnerabilities of technological systems to acts of terror,
- models for assessing consequences of accidental or intentional releases of chemical, biological and radiological agents in the urban areas and confined spaces,

- computer aided system for emergency planning and crisis management related to act of terror.

Using experience in application of computer codes for the thermo-hydraulic properties analysis of nuclear reactors we succeeded in an application of these codes for modelling of thermo-hydraulic phenomena in chemical reactors.

In 2004 the analysis of the toxicity of various compounds in flue gases was performed. Two methodologies were presented for its calculation. The carcinogenicity of various flue gases components was estimated.

The Institute was visited in 2004 by 2950 peoples. They have basic information about nuclear physics, and nuclear techniques application in medicine, technology and science. After lectures they visited MARIA reactor and Hot Chambers Laboratory.