Introduction

In 2007 ENEA's Department of Nuclear Fusion and Fission, and Related Technologies acted according to national policy and the role assigned to ENEA FPN by Law 257/2003 regarding radioactive waste management and advanced nuclear fuel cycle technologies.

12.2 Entrustment of ENEA's Fuel Cycle Facilities and Personnel to Sogin

ENEA continued giving support to the Società Gestione Impianti Nucleari SpA (Sogin), both in security maintenance of ENEA's former fuel cycle nuclear facilities as well as in the decommissioning activities estimated for the installations. Antiseismic warehousing for the plutonium-contaminated waste is being constructed at ENEA Casaccia. Pending the conditioning operations and final disposition of the waste, the infrastructure will guarantee both nuclear and conventional safety and security aspects during its interim storage. The activities should be concluded within the end of 2009.

12.3 Maintenance and Restoration of Fuel Cycle and Radwaste Management Facilities

Research support. The development of technical support for the mechanical design and construction related to the research activities in the C-43 Radiochemical Laboratory and the C-5 Technologic Hall was started. Considerable experience in CAD design and 3D modelling software was acquired during the activities.

Management and safety maintenance of C-43 Radiochemical Laboratory. Renovation of C-43 is expected to start shortly. In 2007, according to the prescriptions, routine maintenance was carried out to verify the effectiveness and operability status of important safety systems of the laboratory. At the same time, the following extraordinary maintenance activities were performed:

- revision of detection and extinction fire system;
- installation of new fire cut shutters on inlet air canalisations of laboratory rooms;
- improvement of pressure control systems of glow-box air extraction network;
- renewal of process gas distribution network.

Conversion of working authorisation of C-43 Radiochemical Laboratory. In order to obtain formal authorisation for utilisation of the laboratory as Category A, the following set of documents was delivered to the Italian Agency for Environmental Protection and Technical Services (APAT) (Item n. 28, Law 230/95):

- safety report;
- laboratory operational rules;
- internal technical rules of C-43 Radiochemical Laboratory;

- qualified expert evaluations regarding the dose to the population in the case of a nuclear accident in C–43, according to the directives of Item n. 115 ter, Law no. 230/95;
- up-to-date situation regarding nuclear materials stocked in C–43.

Additional documents concerning the "Periodical Working Tests of the C-43 Laboratory Systems" were prepared and delivered to APAT.

The current situation of the authorisation procedure for C-43 is that all the documentation together with a favourable opinion were transmitted by APAT to the Ministry of Economic Development.

Renovation of C-43 Radiochemical Laboratory. During 2007, the SRS Engineering Company was appointed to organise and design the renovation of the laboratory facilities. The project includes:

- rebuilding of air conditioning plant;
- reconstruction of plumbing;
- reconstruction of process gas distribution network and manufacture of new bottle storage;
- renewal of electrical equipment;
- renovation of perimetrical walls of laboratory;
- rebuilding of roofing waterproofing of laboratory building;
- Improvement of fire detection and extinction system.

The documentation was completed by SRS Engineering and is to have a final check before the activities start.

12.4 Characterisation, Treatment and Conditioning of Nuclear Materials and Radioactive Waste

The relevant activities are carried out by the Laboratory for the Characterisation of Nuclear Materials at ENEA Casaccia. A wide variety of measurement techniques are used: segmented gamma scanner (SGS); angular scanning (AS); low-resolution emission and transmission tomography (ECT/TCT); in-situ object counting system (ISOCS). (See 2006 Progress Report for details.)

Following the 2006 experimental measurement campaigns to validate the ISOCS, in 2007 assessment of the performance of the system was extended to surface contamination characterisation. Several experimental measurements were performed with various configurations of certified gamma-emitting sources placed at different depths inside a cemented mockup simulating a contaminated wall. The results obtained have shown that the technical procedure developed is reliable. These activities were required to obtain accreditation of the technical procedures according to ISO-17025: The accreditation procedure will start in June 2008 for all the measurement systems of the laboratory.

Regarding implementation of the SEA radioactive-waste gamma analyser (SRWGA) to characterise the 400-litre drums containing gamma-emitter radionuclides, the use of spiral scanning was studied because the tomographic procedure requires too long a measuring time for the large number of drums to be analysed (see 2006 Progress Report).

The activities at the ENEA Casaccia CETRA Laboratory continued to address the qualification of the conditioning processes for toxic and/or radioactive waste, in accordance with Technical Guide 26 of APAT. In addition to the major tests (tensile strength; cyclic temperature gradient resistance; radiation damage resistance; fire resistance; leaching test; free liquid absence; bio-degradation resistance and immersion resistance), the following are performed in order to integrate basic information with further structural,

Fig. 12.1 – Water penetration depth under pressure

Fig. 12.2 - Climatic chamber

Fig. 12.3 - Tensile strength tester

physical, chemical and mechanical studies:

- heat of hydration of cement;
- setting-time of cement pastes;
- resistance to aggressive solutions;
- depth of penetration of water under pressure;
- Blaine fineness and porosity.

To expand the assay capability of the laboratory, apparatus for the water penetration depth under pressure, Blaine air permeability and heat of hydration was acquired (fig. 12.1-12.3)

Services. In collaboration with NUCLECO, the SRWGA and ISOCS systems were used during 2007 to characterise medically-derived radioactive wastes previously deposited at ENEA Trisaia. The aim was to verify whether any gamma emitter radionuclides were present and then decide if they required conditioning or not.

12.5 Radioprotection and Human Health

Evaluation of physiological comfort index in indoor environments

ENEA's fuel cycle facilities were assigned to Sogin SpA through the "Entrustment of Management Act" on 23 December 2005. Work on developing a physiological comfort index for workers wearing protective clothing continued. Before carrying out an experimental campaign on personnel wearing ventilated-pressurized protective clothing, a computational fluid dynamics (CFD) code was used to make a model of a person wearing the clothing. As a first step a simplified model of the gap between the ventilated–pressurised protective clothing and the skin was developed to obtain reliable data on the thermal-hygrometric behaviour of the clothing. The data will be used as input for the CFD code. CFD codes were also used to evaluate the ventilation efficiency in indoor environments, such as those used as low and medium level radioactive waste repositories.

Life cycle cost analysis of strippable coating and steam vacuum technology

In 2007, in collaboration with La Sapienza University of Rome, the life cycle assessment (LCA) was used to compare steam vacuum cleaning technology and strippable coating, an innovative technology for decontamination of nuclear plants. The results showed that strippable coating had good environmental performance. As the storage phase showed the most important differences between the two technologies, this phase and the relative economics were studied in detail.

To perform a more structured and complete analysis, a methodology for the implementation of a life cycle cost analysis (LCCA) for strippable coating was developed. A LCCA is an engineering economic analysis tool, which makes it possible to quantify the differential costs of alternative investment options for a given project. The ultimate objective of the LCCA of a product is to provide a framework for finding the total cost of design, development, production, use and disposal of the product, with the aim of reducing the total cost. There are many choices in the selection of a preferred approach to determine the total cost of a product, pertaining to its entire life cycle. A review was made of the various approaches in order to choose the most suitable for strippable coating and for the Italian context.

Influence of risk communication on people's perception of radioactive waste repositories

Risk communication is often seen as a one-way process aimed at setting right differences between the opinions of regulators, scientists and public perception. Risk communication is an exchange of information or an interactive process requiring the establishment of two-way communication channels. The communication process can only be effective if all the parties of the process are interested in communicating and if the dignity and the roles of all the parties are acknowledged. Effective communication requires the ability to discuss all issues of interest to the public.

Over the last decade the awareness of the necessity for the nuclear waste programmes to become more communicative has increased the world over. It is not possible to ignore the need to have public consent to operate hazardous processes or to simply dismiss public views as misguided, irrational and ill-informed. This reflects advances in international programmes to the phase of site selection and the necessary involvement of regional and local bodies as well as concerned citizens.

Various factors led to emphasising interest in risk communication. There are growing demands on government and industry to keep the population informed about environmental and health risks. A basic reason for the emergency of risk communication research derives from the highly visible dilemmas that have risen as a result of particular social conflicts over risks; for example, over the location of hazardous facilities. Fostering appropriate forms of communication between the parties to such disputes might contribute in some way to better mutual understanding and hence to a resolution of conflict. The success of risk communication programmes depends on their sensitivity to the perception of risk and the behaviour of the public. Some key elements, taking into account also the economic factor, for good effective risk communication have been identified.

12.6 Integrated Service for Non-Energy Radwaste

As described in the 2006 Progress Report ENEA is responsible for the guidance, supervision and control of the whole cycle of the management of radioactive waste coming from small producers. The operative and commercial tasks have been entrusted by ENEA to NUCLECO SpA. ENEA's activity is carried out through a special Integrated Service, which is also available to the private sector. During 2007, Integrated Service collected about three hundred cubic metres of low- and intermediate-level radwaste.

12.7 Transport of Nuclear Material

Packaging for transport of radioactive material. ENEA is the owner of a lot of radioactive waste and sources and has to transport the material to its final disposal facility. Based on the experience gained in developing transport packages (approved as type B in the past) ENEA continued the work on designing new packaging to store and transport radium needles, plaques and tubes. The packages will be able to contain 440 capsules, which are the small containers designed by the Department of Health to transport the radium sources used in the past. The University of Pisa is performing a detailed verification of the shielding and mechanical calculations used in the design.

This new packaging will improve storage safety not only for radium sources but also for large sources of cobalt and caesium, most of which still inside the original irradiator. Hence once the new packages have been approved by APAT as type B(U) for radium, further analyses will be performed to get approval for cobalt and caesium.

12.8 Disposal of Radioactive Waste

Artificial barriers for disposal units. The experience gained from past activities of the Task Force for Radioactive Waste Disposal was implemented in updating the Draft Proposal UNICEN 214 "Final Repository for Category 2 Radioactive Waste Packages", issued in 2003 by UNICEN – the Nuclear Energy Committee in the Italian Standards Institute (UNI).

The draft was divided into three parts:

1) Basic Design Criteria for Engineered Barriers (U54032141)
2) Basic Qualification Criteria for Engineered Barriers (U54032142)
3) Surveillance and Monitoring Basic Criteria (U54032143)

ENEA was involved in the working group charged with the revision of Part 1 and was responsible for coordinating the activities of the working group for the revision of Part 2. An important reference was given by the results of the research activity of ENEA-Milan Polytechnic (see 2006 Progress Report) on the long–term properties of cementitious material used to confine the waste packages, i.e., the cementious immobilising matrix (grout) and the concrete of the modular caissons.

Site, conceptual design and management of disposal plants. ENEA made an important contribution to the preparation of the Guidelines 2007 for the Italian Committee for Plants with Complex Technologies (CITEC), regarding the treatment and disposal of waste in general (hazardous and non-hazardous). The guidelines give general criteria, methodologies and procedures in planning location, design, construction and exploitation of the installations. Nuclear experience in radioactive waste management was brought into this context because of operational similarities in the final part of such management, i.e. in the disposal of this waste in the biosphere. According to nuclear experience (as established in the "Common Convention on the Safe Management of Exhausted Fuel and on the Safe Management of Radioactive Waste" signed and/or ratified by the representatives of the IAEA member states in 2003), it was underlined that decision–making and administrative procedures be co-ordinated to the greatest possible extent among local political groups, social groups and the population concerned, since only common agreement on the solutions to be adopted allows an effective solution to the problem to be found.

A new approach was suggested, which was to design a new installation or substantially change an existing installation by taking into account the participation of the public, which must be properly informed by an

adequate system of communication and dialogue based on a set of information items or on simple and easily understandable messages that are organised systematically, with indications on how to obtain additional information.

Structure engineering for geological disposal. In the framework of EU FP7, a collaboration was established with CEA to use the CAST3M simulation code to develop and set up high-performance concrete structural models.

Long-term storage of radioactive waste. In the wake of Italy's recent adherence to the Global Nuclear Energy Partnership, which was announced during the 20th World Energy Congress Ministerial Forum held in Rome and the May 2007 agreement between SOGIN and AREVA concerning the shipment abroad of Italy's remaining (235 metric tons of heavy metal [MTHM]) commercial spent fuel, a detailed presentation was made with the intention of making a case for Italy's recent decision to postpone the issue of storing its high level radwaste - typically in a dry storage facility - given the international difficulties in moving forward with the yet to be accepted high-level-waste repositories (Yucca) and domestic difficulties in siting an intermediate spent-fuel storage installation (ISFSI) after Italy walked away from nuclear power plants in 1987 following a national referendum.

A dedicated IAEA Technical Meeting on "Technical Conditions for Long-Term Storage of Radioactive Waste" was held in November 2007. The floor consisted of delegates from Argentina, Belgium, Canada, China, Cuba, Finland, France, Germany, Hungary, India, Italy, Lithuania, Netherlands, Russia, Slovakia, South Africa, Ukraine and the United States of America.

The presentation exceeded the issues called for by IAEA, which were expected to address the feasibility of designing long-term storage facilities - also in the light of the recent accomplishments of the single countries represented in the meeting- in which to stock high-level radwaste until repositories such as Yucca Mtn, Gorleben, Bure, Forsmark, Scanzano Ionico etc., are finally built and approved for operation. It may take more than a few decades before some of them are ready for emplacement of spent fuel and/or vitrified waste disposal casks and other high level waste classified for final disposal.

The following topics were discussed:

- The legacy of nuclear power generation in Italy and the inventories.
- Italy's recent decisions regarding reprocessing of its remaining spent fuel.
- Current positions: once through cycle (USA, etc.) and partial recycle (France, etc.).
- Basic considerations on the Global Nuclear Energy Partnership (GNEP) and full recycle to the benefit of all countries.
- Current American Nuclear Society (ANS) standards and practices applicable in some countries storing spent fuel.
- Suggestions for a new IAEA standard to apply for long-term storage facilities.
- Italy's outlook for disposal of its vitrified and greater-than-class-C (GTCC) waste (2020-2025).

12.9 Additional Protocol and Dual-Use Directive

Throughout 2007, specific software was implemented, under a convention with the Department for Economic Development, to help the people involved with the declarations required by the Additional Protocol and Dual-Use Directive, as small discrepancies had been found in the past by the IAEA. The software makes it possible to navigate through the Additional Protocol documents and to check in the meantime similar requirements fixed in the dual-use directive. Since the convention is related to the

Additional Protocol, only nuclear materials have been taken into account. In the future other materials, items and activities could be added to cover completely the dual-use directive. After a complete check on the materials and items subject to the Additional Protocol, it is possible with an internal link to use directly the editor prepared by the European Commission (Coordinated Action for Pan-European Transport and Environment [CAPE]) for the declaration to be sent to APAT or the Department of Economic Development in agreement with the Italian law.

At present the software is on a CD but it is ready to be used online when the Department of Economic Development, on the advice of APAT and the Department of International Trade, decides on the opportunity to diffuse some of the available technical information to facilitate the recognition of materials to be declared.

ENEA has followed the work of the European Commission, IAEA and the USA Department of Energy, which with the National Nuclear Security Administration (NNSA) are carrying out a campaign on security in nuclear activities on the basis of the non-proliferation treaty and Additional Protocol.

12.10 Advanced Techniques of Instrumentation and Control

Neural networks application to control rod drive mechanisms and thermohydraulic data validation

Advanced research work with artificial intelligence (AI) tools was carried out in 2007 for reactor core control, on the RC-1, a Triga Mark II, 1-MW, demineralised water/natural convection cooled research reactor at ENEA Casaccia. The activity was aimed at developing intelligent data processing of reactor measurements through soft-computing models based on neural networks (NN). A first application concerned validation of the rod position of the control rod drive mechanism (CRDM) and a second was devoted to fuel temperature prediction. Both implemented NN-based algorithms, with the use of real data coming from sensors. The first net used a second-order algorithm (Levenberg-Marquart); the second, a first-order algorithm (steepest descent algorithm).The net geometry both in the first and in the second application was the same: a three-layer feed-forward network.

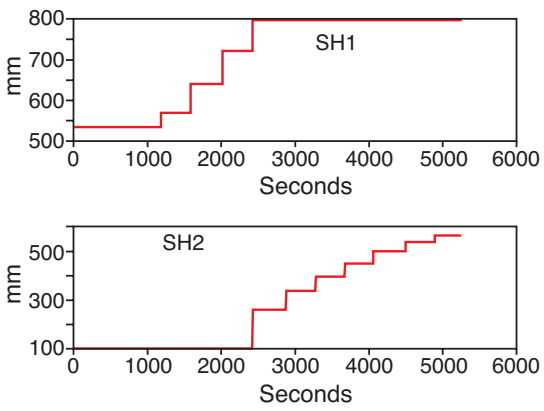

Fig. 12.4 - Rod position channels: measured data (blue); simulated data (red)

In the first application the related NN consisted of two nets working in parallel: the first, for data validation, trained initially through the reactor data set (input data: fuel temperature, water temperature; output data: rod position); the second, used for training, updated its parameters each time a difference occurred between the value of the first net and the measurement from instruments. The simulation result is shown in figure 12.4. In the second application the neural net had a simplified layer structure I/O (input data: power reactor; output data: fuel temperature). The outcome of training is reported in figure 12.5.

The outcome obtained in the two applications was satisfactory as the error in

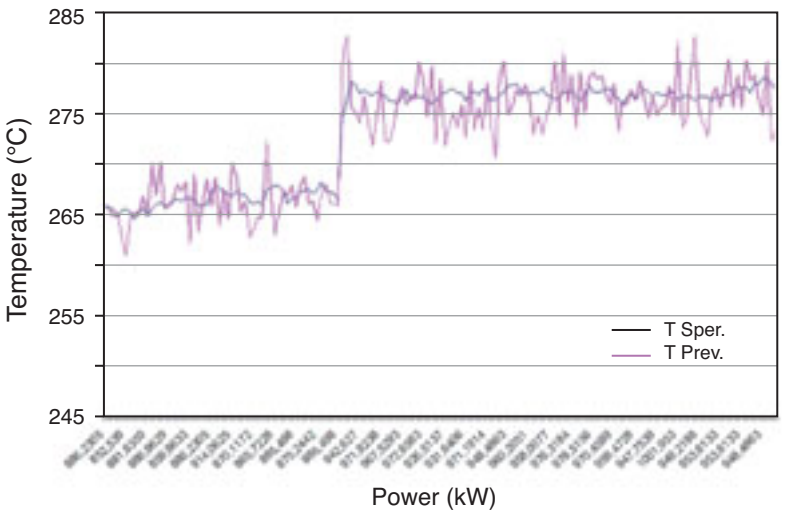

Fig. 12.5 - Fuel temperature: experimental data (blue); simulated data (pink)

steady state was less than that expected and the training method was quite effective. Testing will continue with the data scanning rate increased to improve the answer during status transitions.

The results of the work were presented in November at the Australian Research Reactors International Conference in Sydney.

12.11 Work in Progress

Decommissioning of RB3 Research Reactor. Authorisation by APAT for the decommissioning of the RBR research reactor (Bologna) is still pending even though all the APAT requests have been fulfilled. However preliminary activities have been carried out and a detailed proposal made for the organisational structure with expert personnel for dismantling, characterisation and radioactive waste management. Preliminary procedures consisted of a draft for the dismantling activities, safety provisions and for the radiological characterisation of materials to be cleared according to the EC document Radiation Protection 122 “Practical use of the concepts of clearance and exemption – Part I. Guidance on General Clearance Levels for Practices” (2000).

New Radiochemical Laboratory. A preliminary design and safety assessment has been started for the construction of the new Radiochemical Laboratory at ENEA Saluggia. The objective is to submit the license application within the first half of 2008.

13.1 Publications

Articles

A. TAGLIONI, A. CASTELLANI, M. COLLEPARDI, R. PELLEGRINI, E. PIZZIGALLI: *Hazardous-waste containers in cementitious materials: leakage tests on small-scale specimens and on full-scale prototypes*
Studies and Researches, Ed. by Starrylink, **27**, 11-32 (2007)

A. TAGLIONI, G. MARENCO, R. LARAIA, M. BELVISI: *Development of guidelines within the European legal framework concerning environmental assessment and co-operation procedures*
CITEC 2007 Guidelines

F. CUMO, U. DI MATTEO, G. GUIDI: *A methodological proposal for the identification of energy-environmental performance indicators aimed at the recovering of the air quality*
Inter. J. Environ. Technol. Manag. **7**, 1-2, 85-98 (2007)

F. CUMO, F. GUGLIERMETTI, G. GUIDI: *Best available techniques (BATs) for oil spill containment and clean-up in Mediterranean Sea*
Proc. of Water Resources Management 2007, in Water Resources Management IV, Transactions on Ecology and Environment, Ed. by C.A. Brebbia and A.G. Kungolos, Wit Press Vol. **103**, 527-535 (2007)

F. CUMO, F. GUGLIERMETTI, G. GUIDI: *Evaluation of physiological comfort index for workers wearing personal protective equipment*
Proc. of Environmental Health Risk 2007 (Malta, 27 – 29 June 2007) in Environmental Health Risk IV, Transactions on Biomedicine and Health, Ed. by C.A. Brebbia, Wit Press Vol. **11**, 97–106 (2007)

G. GUIDI: *Life cycle Assessment*
Manuale Europeo di Bioarchitettura, Ed. by Mancosu, Chapter H.1, 2 -12, 17 (2007)

F. CUMO, G. GUIDI: *Radioattività*
Manuale Europeo di Bioarchitettura, Ed. by Mancosu, Chapter C.3, 114-120, 134-135 (2007)

Nuclear Power Legacy in Italy TM IAEA (November 2007), *Technical conditions for long term storage of radioactive waste*

Contributions to conferences

R. BOVE, A. DODARO, A. LUCE, A. TAGLIONI: *Prove di tenuta nella lavorazione e manipolazione di materiali radioattivi*
Presented at the Conferenza Nazionale sulle Prove Non Distruttive, Monitoraggio, Diagnostica (PnD), Milan (Italy) October 11-13, 2007

M. SEPIELLI, M. PALOMBA, A. RATTO, R. ROSA, M. BERNABUCCI: *Neural network application to on-line monitoring of CRDM and thermo-hydraulic condition*
Presented at the HOLMUG Meeting, Olkiluoto (Finland), October 3– 4, 2007

M. SEPIELLI, M. PALOMBA, A. RATTO, R. ROSA, M. BERNABUCCI: *Neural networks application to CRDM and thermo-hydraulic data validation*
Inter. Conference on Research Reactors: Safe Management and Effective Utilization, Sidney (Australia), November 5– 9, 2007