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Poster

EDUCATION AND TRAINING PROGRAMME IN SARNET NETWORK ON SEVERE ACCIDENTS

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ABSTRACT

Forty-two organisations from 21 countries network their capacities of research in SARNET (Severe Accidents Research NETwork of excellence) to resolve the most important remaining uncertainties and safety issues on severe accidents (SA) in existing and future water-cooled nuclear power plants (NPP). SARNET2 started in April 2009 for 4 years in the 7th Framework Programme (FP7) of the European Commission (EC), following a first project in FP6. It includes a large majority of the European actors involved in SA research plus a few non-European important ones. The “Education and Training” programme in SARNET2 is mainly focusing on raising the competence level of the university students and young researchers engaged in SA research and in the organization of Information/training courses for staff in NPP or regulatory authorities (but also for researchers) interested in SA management procedures.

1. Introduction

Despite the accident prevention measures adopted in NPPs, some accident scenarios, in very low probability circumstances, may result in a SA, as shown in the recent Fukushima Daiichi event, with core melting and dispersal of radioactive materials into the environment, thus constituting a hazard for the public health and for the environment. Significant progress has been achieved since the 1980’s thanks in particular to the EC FPs, but several issues still need research activities to reduce uncertainties and consolidate SA management plans [1], [2]. Facing the reduction of the national budgets on SA, it was judged necessary to better coordinate the national efforts to optimise the use of the available expertise and the experimental facilities in order to resolve the remaining issues for enhancing the safety of existing and future NPPs. In April 2004, 51 organizations involved in R&D on SA, including research organizations, safety authorities, technical safety organisations (TSO), industries, utilities and universities, decided to network in SARNET, in the framework of FP6, their capacities of research in the SA area in a consolidated manner [3]. A second phase of the network has started in April 2009, again supported by EC in the FP7 (SARNET2 project) for 4 years and coordinated by the French Institut de Radioprotection et de Sûreté Nucléaire (IRSN).

2. The SARNET2 network

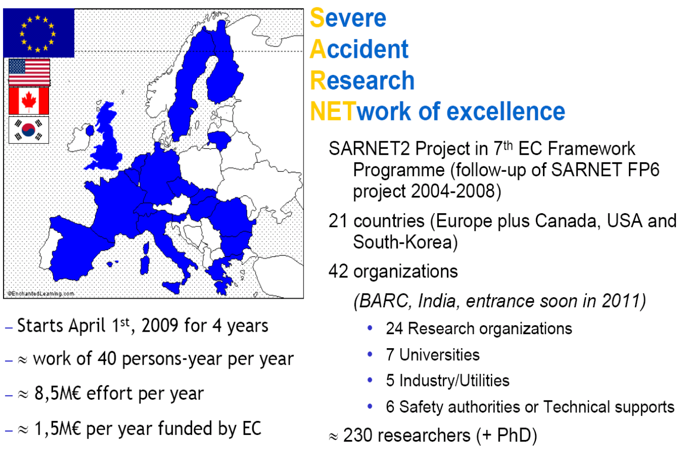

Fig.1: Characteristics of SARNET2 project

Forty-two partners from Europe, Canada, Korea and the United States, participate in the SARNET2 consortium (Fig.1). This project has been defined in order to optimize the use of the available means and to constitute a sustainable consortium in which common research programmes and a common computer code (ASTEC) are developed. One of the main objectives is to establish, after the SARNET2’s end, a self-sustaining organization in the field of SA research through activities in networking, integration, knowledge management, exchange of information, dissemination of results and training in order to keep the competence in SA management alive I The ASTEC integral code [4], plays a key role in the network by capitalizing SA knowledge through new physical models that are produced by the network. The Joint Programme of Activities (JPA) is broken down in 8 Work-Packages (WPs) pertaining to the 3 following types of activities:

a) Integrating activities, aiming at strengthening links among the partner organizations,
b) Joint research activities,
c) Spreading of excellence (described in detail in this paper).

About 300 papers related to SARNET work in the last 5 years have been presented in conferences or published in scientific journals. The dissemination of information is also done through periodic newsletters or participation to public events. At mid-term of the project, the paper in reference [5] presents a few recent outcomes of joint research done by the network members.

2.1 Integrating Activities

2.1.1 ASTEC code assessment and improvements (WP4)

IRSN and German Gesellschaft für Anlagen und ReaktorsicherheitmbH (GRS) jointly develop ASTEC to describe the complete evolution of a SA in a nuclear water-cooled reactor, including the behaviour of engineered safety systems and procedures used in SA Management (SAM). The new series of versions V2 aims at covering all European NPPs, including BWR and CANDU reactors and the new Gen.III LWR designs. IRSN and GRS also assure the code maintenance and the support to the code users, notably through Users Club meetings. Twenty-eight organizations collaborate on the development and assessment of the successive ASTEC versions. The assessment activity mainly consists in covering a broad matrix of reactor applications, aiming at the most important SA scenarios for 4 types of reactors (PWR, BWR, VVER and CANDU). In complement to these reactor applications, ASTEC assessment continues through calculations of experiments, such as the integral Phébus FP [6] ones and of real plant accidents such as TMI2.

2.1.2 Information Systems (WP3)

A public web site (www.sar-net.eu) is open in order to provide information on the SA research field to the general public. For the communication among all network members, the e-collaborative Internet Advanced Communication Tool (ACT) is used.

The goal of the DATANET database is to collect the available SA experimental data in a common format in order to ensure their preservation, exchange and processing, including all related documentation. The data are both previous experimental data that partners are willing to share and all new data produced within SARNET. DATANET is based on the STRESA tool [7] managed by JRC Institute for Energy in Petten (NL).

2.2 Joint Research Activities

Six safety issues have been selected with high priority and analysed in 4 WPs. The experimental efforts are mainly devoted to two of these issues, for which a real progress toward the closure of the issue is expected: "corium/debris coolability" and "molten core-concrete interaction (MCCI)".For all these issues, the same method is adopted: review and selection of available relevant experiments, contribution to the definition of test matrices, synthesis of the interpretation of experimental data, benchmark exercises among codes, review of models, synthesis and proposals of new or improved models for ASTEC. Indeed a key integration aspect is the set-up of the technical circles, each covering a specific detailed topic. They bring experimenters and modellers closer together, concerning test definition, interpretation and model development. Additional studies are being performed in order to bring research results into reactor applications.

2.2.1 Corium and debris Coolability (WP5)

The major motivation is to solve the remaining uncertainties on the possibility of cooling structures and materials during SA, either in the core or the vessel bottom head or in the reactor cavity, in order to limit the accident progression. This could be achieved by water injection either by ensuring corium retention within the vessel or at least slowing down the corium progression and limiting the flow rates of corium release into the cavity. These issues are covered within SAM for current reactors, and also within the scope of the design and safety evaluation of future reactors. The current PSA (Probabilistic Safety Assessment) level 2 studies still show very large uncertainties in the results of the core reflooding phase. The following 3 key situations and processes are analyzed in WP5:

a) Reflooding and coolability of a degraded core,
b) Remelting of debris, melt pool formation and coolability,
c) Ex-vessel debris formation and coolability.

2.2.2 Molten Corium Concrete Interaction (WP6)

The addressed main situation is the reactor pit initially dry but with the possibility of water injection later during MCCI. The work programme is complementary with the OECD/NEA (Nuclear Energy Agency) MCCI project [8]. Recent experiments [9] have provided new results that questioned the reliability of the available models and their extrapolation to reactor conditions. As an example, it becomes clear that new effects have to be taken into account to be able to describe the ablation anisotropy observed in case of silica-rich concrete and the different behaviour of limestone common sand concrete. This anisotropy was also present in the ablation of Chernobyl silica-rich concrete. The intention is thus to gain sufficient experimental data in order to determine which phenomena are responsible for the observed isotropy/anisotropy of the concrete ablation.

2.2.3 Containment issues (WP7)

The considered issue is the threat to the containment integrity due to two types of highly energetic phenomena: steam explosion and hydrogen combustion. Steam explosion may be caused by ex-vessel fuel-coolant interaction (FCI) due to a pressure vessel failure and pouring of the corium in the flooded reactor cavity. Hydrogen combustion (deflagration and detonation) may be caused by ignition of a gas mixture with high local hydrogen concentrations, which may be due to the imperfect mixing of containment atmosphere. Phenomena linked to these threats are considered as well. Essential insights and results from this research should be applicable to actual NPPs.

2.2.4 Source Term (WP8)

The overall objective is to reduce the uncertainties associated with calculating the potential release of radiotoxic fission products to the environment. It concentrates on iodine and ruthenium, given their high radio-toxicity, noting that the ruthenium release is enhanced in oxidising atmospheres, such as those that may follow air ingress into the reactor coolant system (RCS). The research treats the transport of these elements through the RCS and their behaviour in the containment. Of particular importance is the prediction of volatile iodine and ruthenium species in the containment, forms that are hard to remove by containment sprays, or by filtration while venting the containment. Full advantage is taken of cooperation with international programmes such as Phébus FP, International Source Term Programme (ISTP) [6] and programmes of OECD/NEA/CSNI, to avoid duplication of experiments, to help consistency of the programmes and to identify remaining needs.

3. The SARNET2 education and training programme

The “Education and Training” programme, included in the WP2 “Spreading of Excellence”, is focusing on:

a) Raising the competence level of the university students (Master and PhD) and young researchers engaged in SA research. Towards this purpose, in the streamline of what was done in SARNET FP6 project, education courses are developed on SA phenomenology. Links with the European ENEN association (European Nuclear Education Network) have been strengthened. Four one-week educational courses, the last one in Pisa (I) in January 2011, were organised since 2005, gathering 40 to 100 persons.
b) Information/training courses for staff in NPP or regulatory authorities (but also for researchers) interested in SA management procedures; here the emphasis will be also in identifying what these procedures are based on and why they are effective.
c) Final review and editing (in 2011) of the text book on SA phenomenology, written in the SARNET framework. It covers historical aspects of water-cooled reactors safety principles, and phenomena concerning in-vessel accident progression, early and late containment failure, fission product release and transport. It contains also a description of analysis tools or codes, of management and termination of SA, as well as environmental management.

Further activities are the periodic European Review Meetings on Severe Accident Research (ERMSAR) and the mobility programme under which university students and researchers go to internship programmes.

4.1 The SA Courses

These short courses focus on disseminating the knowledge gained on SA in the last two decades to Master-PhD students, young engineers and researchers. During SARNET FP6 project, three short courses (1 week) on Severe Accidents were organized:

a) SA phenomenology including some description of SAM.
b) SA progression (analysis, data and uncertainties) to give the order of magnitude of physical phenomena occurring during a SA progression to researchers and engineers working in industry and regulatory organizations.
c) Nuclear reactor SA analysis: application and management guidelines, focused more on SA methodology (models, codes), analyses and SAM.

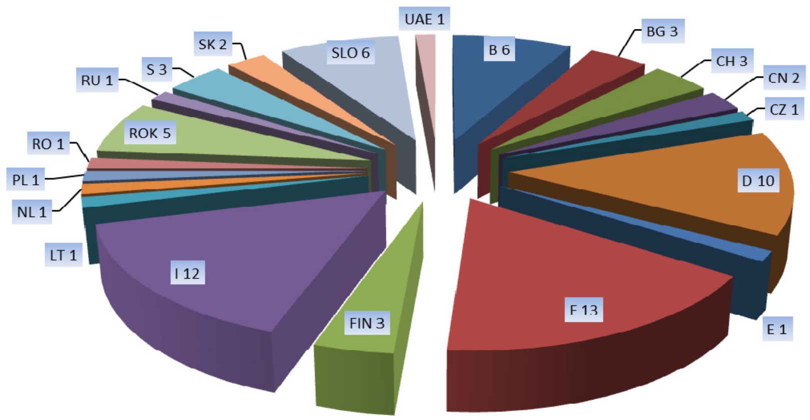

Fig.2: Nationalities of the participants to the Pisa 2011 course

The first SARNET2 *"Severe Accident Phenomenology Short Course"* was organized in January 2011 by CEA and Pisa University and hosted by Engineering Faculty of Pisa University, with the participation of about 100 students from 20 countries (Fig. 2). This was again a 1-week course on phenomenology because the goal was also to refresh participants memories after 5 years and SARNET new outcomes, with a program covering SA phenomenology and progression in current water-cooled Gen.II NPPs, but also the different design solutions in Gen.III ones. The purpose was to describe Gen.III designs addressing SA (i.e. the "in-vessel" melt retention concept or the "ex-vessel" core catcher concept). SA phenomenology has been described through its progression in the core and in the lower head up to vessel failure, followed by the ex-vessel accident progression, with the loadings which can cause early containment failure (i.e. Direct Containment Heating, hydrogen combustion in containment, steam explosion) and the late containment failure (i.e. MCCI, coolability, etc.) The source term with fission products release from the core and transport in the RCS and containment have been specially emphasized. Lecturers were experts from 8 different countries, with large skills and knowledge on Gen.III NPPs and on the progression of a SA. The presence of lecturers from industry was utilized to describe how the different plants would react during a SA, keeping in mind that an introductory course would not allow lengthy discussions or computer simulations. The course was open to university students with a strong discount fee and contributed for 3 ECTS (with a written work) as an advanced course for master students, with a strong link among SARNET2, ENEN & European Master of Science in Nuclear Engineering (EMSNE).

4.2 The Mobility programme

The Mobility Program (MOB) aims at training young researchers and students through delegation in SARNET research teams, in order to enhance the exchanges and the dissemination of knowledge. A total of 33 mobility actions (with average duration of 3 months) were completed at the end of the SARNET FP6 project. Most of the delegates were from Eastern Europe going to laboratories and universities in Western Europe and a large fraction of the delegates were women. The dominant area of training was on ASTEC code. In SARNET2 a financial support covering partially the delegation cost (maximum of 1500 €/m) is provided. To apply for mobility support, the following conditions shall be fulfilled: organizations shall be SARNET2 members (or only the host one for master/PhD students), the work to be performed shall be relevant to SARNET2 objectives and be part of the JPA, the delegation shall contribute to the transfer of knowledge/know-how. The allocation of funds is subject to the final delivery of a delegation report describing the main technical achievements. The number of mobility actions is one of the several integration indicators defined in order to assess the progress of the SARNET2 project and the success of integration. However, a successful MOB program needs partners' efforts to highlight research projects which could be of interest to researchers or students and to disseminate the understanding of the benefits of this MOB program. In this context an attractive idea has been to arrange for university delegates to perform a master thesis and/or to take courses in SA technology in the EMSNE framework, funding the master thesis stages in the SA field to be performed to obtain the 20 ECTS necessary for EMSNE achievement. In this MOB programme, the long term goal is to build and strengthen teams which would engage together in a certain activity of the excellence network.

4.3 Conferences

Four ERMSAR conferences have been organized successively in France, Germany, Bulgaria and Italy as a forum to the SA community. They are becoming one of the major events in the world on this SA topic. The 4th ERMSAR Conference was hosted by ENEA in Bologna (Italy) on May 11-12, 2010. It gathered 98 participants from 24 different nationalities (8 non-EC countries and 15 EC ones).The network partners presented papers on their joint work, including some first conclusions of the work done in the first period. The 5th conference is planned to be held in March 2012.

5. Conclusions

After a first phase of four and a half years, the SARNET network of excellence continues from April 2009 for four years more. It aims both at solving the latest pending issues for current NPPs safety and at consolidating the sustainable integration of the European SA research capacities. Efforts will continue on the transfer of knowledge to younger generations through the education and training activities. The work done on the ASTEC assessment and improvements will reinforce its position of European reference SA code. It will allow preservation of knowledge produced by thousands of person-years of R&D and dissemination to end-users, and also making Europe a leader in SA computer code. Links with OECD/NEA and other programmes co-funded by the EC will be maintained and reinforced, in particular with ENEN on education and training courses for students, and SNETP (Sustainable Nuclear Energy Technological Platform).

Acknowledgments

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ACTIVITIES OF JAPAN NUCLEAR HUMAN RESOURCE DEVELOPMENT NETWORK (JN-HRD)

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ABSTRACT

Japan Nuclear Human Resource Development Network (JN-HRD Net) was established November, 2010, supported by cooperative partnership among 50 related organizations in charge of nuclear HRD from industries, academia and government, in an integrated manner to promote effectively and efficiently various HRD actions and projects in Japan. With these activities, JN-HRD will serve to 1) develop nuclear-related social infrastructure, 2) lead young students to be nuclear-oriented, 3) secure a stable source of manpower who will support Japan's nuclear industry in the future. Also, JN-HRD intends to promote the global HRD network in cooperation with IAEA and other related organizations.

1. Introduction

Japan Nuclear Human Resource Development Network (JN-HRD Net) was established in November 2010 in order to conduct and promote various national and international HRD activities in strategic and integrated manner, effectively and efficiently.
The establishment of this JN-HRD Net was first recommended by the Council on Nuclear HRD (2007-2010) after two and half years investigation on mid and long term HRD strategies in Japan. With continued discussion under the Establishment Committee for Nuclear HRD Network in response to the call from government (Cabinet Office "CAO"; Ministry of Education, Culture, Sports, Science and Technology "MEXT"; Ministry of Economy, Trade and Industry "METI"; Ministry of Foreign Affairs "MOFA"), the JN-HRD Net, an all-Japan framework based on mutual beneficial relationship among nuclear-related organizations from industries, academia and the government was established. Figure 1 shows the overall scheme of JN-HRD Net.

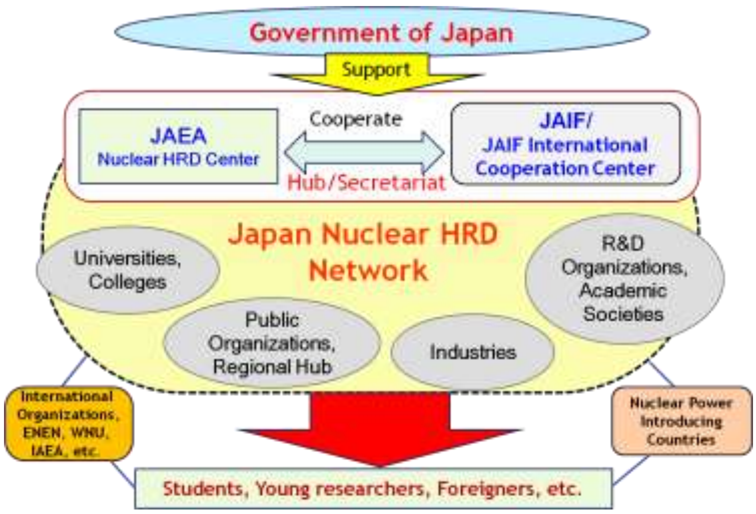

Fig.1 Overall Scheme of Japan Nuclear HRD Network

The main activities of the JN-HRD Net are; 1) Establishment and enhancement of cooperative partnership among nuclear-related organizations at home and abroad, 2) Mutual support for participating organizations on their HRD activities, 3) Reinforcement of National and international public relations, 4) Enhancement of international network in close cooperation with international organizations, 5) Planning and operation of inter-organ HRD activities, and 6) Support and cooperation on nuclear HRD for countries introducing nuclear power.

2. JN-HRD Net activities

2.1 Actualization of JN-HRD activities

The Steering Committee, consisting of representatives of participating organizations/ institutions, from industries, academia and the government, formulate the basic policy and outline of the JN-HRD Net. Under those policies, planning, discussion and review of the overall JN-HRD activities are carried out in the Working Group, also consisting of all-Japan members. The actual HRD activities will be submitted and coordinated in the Sub-Working Group, for individual or aligned activities, to realize effective and efficient human resource development. The members of the Sub-Working Group mainly consist of those actually implementing the related activities. The framework of JN-HRD Net is shown in Figure 2.
The HRD activities implemented will be reported and reviewed for feedback studies to plan, initiate and carry out the next year HRD activities.

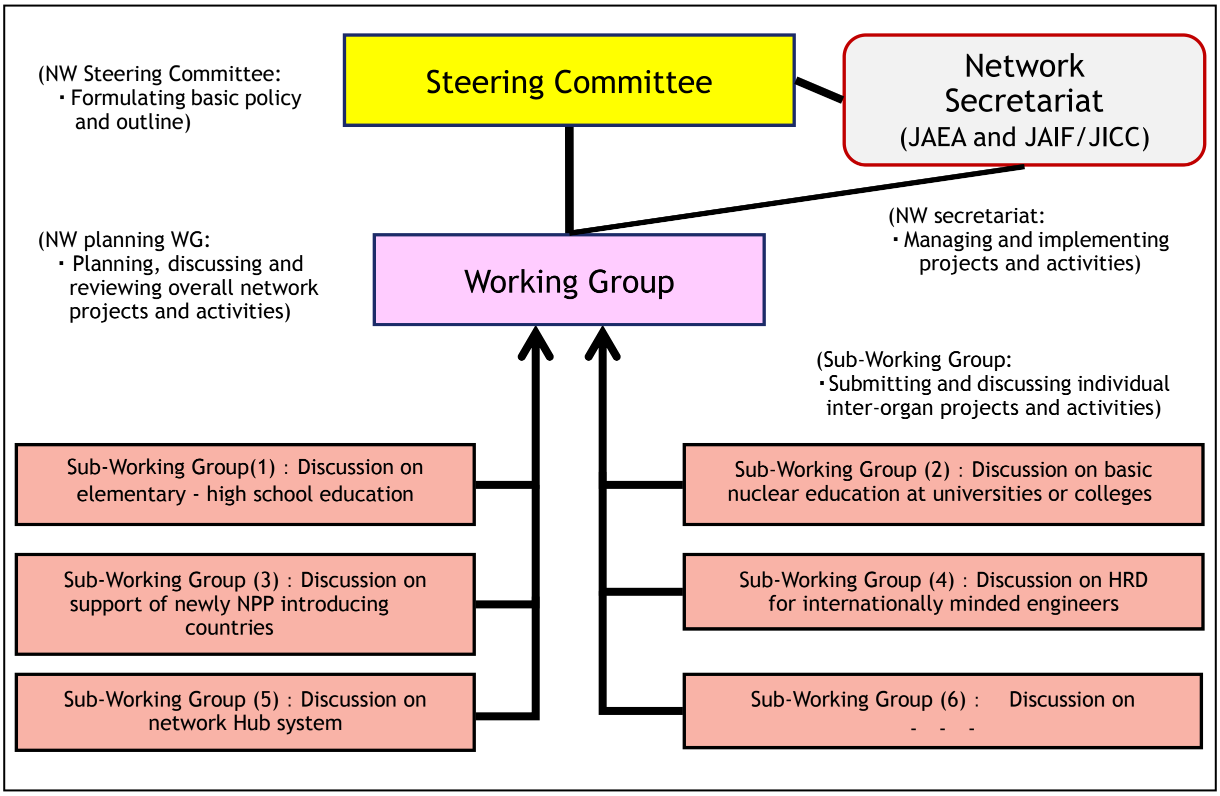

Fig.2 Framework of JN-HRD Net

2.2 Current JN-HRD Activities

Currently, JN-HRD-Net has five important subjects on nuclear HRD and each subject is now being discussed at Sub-Working Groups for implementing the related activities:

1) To reinforce the action toward elementary, junior- and high school educations to encourage students to proceed to a higher grade school to study science and engineering including nuclear field.

2) To reinforce the basic education on nuclear technologies and related subjects at universities and colleges and to rebuild the professional education system on nuclear energy.
3) To train young generations to be internationally minded (talented) persons (ex. Planning of international seminars for young engineers, researchers, students of Japan)
4) To support nuclear HRD in developing countries that plan to introduce nuclear energy in the near future
5) To support transfer of nuclear-related knowledge, skills and experiences (know-how) to the next generations.

Also, to enhance international cooperation with related organizations of various countries, JN-HRD Net plans to hold an international conference in Japan once a year. (This year "International Conference on Nuclear Human Resource Development in Asia & Pacific - Toward Effective & Efficient HRD Networking" cancelled due to the giant earthquake and tsunami on March 11, 2011.)

And, especially for newly nuclear power introducing countries, new activities are planned in this framework of JN-HRD Net; short term seminars led by Japanese university professors in each country, dispatch of Japanese experts to exchange knowledge and experiences with the engineers of each country, international seminars and training courses in Japan including visit to nuclear power plants and nuclear facilities, and consultation and support to establish nuclear HRD programs in each country, mostly in close collaboration with international organizations, such as IEAE and FNCA.

2.3 Participating organizations/institutions of JN-HRD Net

Fifty-nine nuclear-related organizations/institutions including four Ministries; CAO, MEXT, METI, and MOFA are now registered under JN-HRD Net (as of April, 2011). Figure 3 shows the overview of JN-HRD Net.

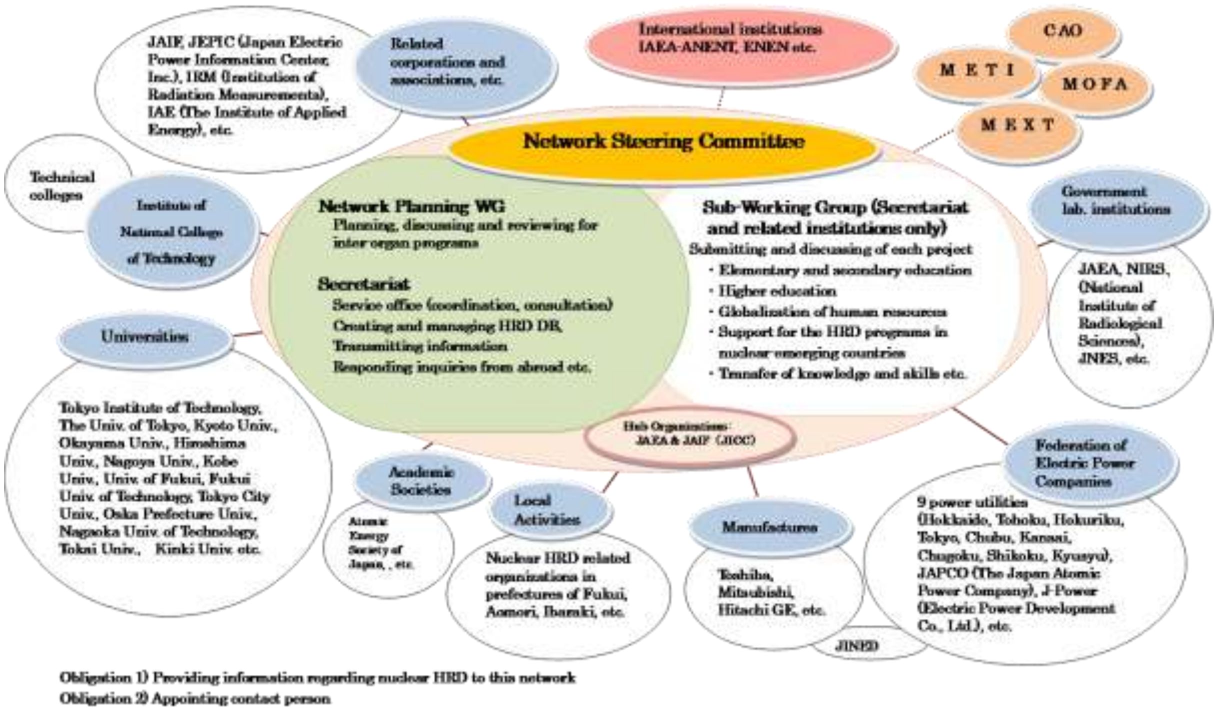

Fig.3 Overview of JN-HRD Net

The registered members include 21 from universities and colleges, 12 from power utilities, 4 from nuclear power plant manufacturers, 4 from research institutes and academic society, 14 from nuclear-related organizations and 4 governmental offices.

2.4 Secretariat

Japan Atomic Energy Agency (JAEA) and Japan Atomic Industrial Forum, Inc. (JAIF) play a central role in coordinating participating organizations/institutions and local networks, and also in conducting inter-organ HRD activities.
The main activities as the secretariat are; to collect information on nuclear HRD activities of Japan and abroad, to assemble a data base system on nuclear HRD, to support activities discussed and planned by the Sub-Working Group, to spread information on the JN-HRD Net and its activities to enhance JN-HRD Net cooperation and play a role of contact office for inquiries about nuclear HRD from organizations at home and abroad. Especially, for countries introducing nuclear power, JAIF International Cooperation Center (JICC) acts as the contact office for inquiries concerning their HRD activities.

3. Summary

Japan Nuclear Human Resource Development Network (JN-HRD Net), an all-Japan framework based on mutual beneficial relationship among nuclear-related organizations/ institutions from industries, academia and the government was established in November 2010. Through our effective, efficient and strategic nuclear HRD activities, we hope to further contribute to the safe and peaceful utilization of nuclear energy.
Unfortunately, Japan is now suffering massive damages caused by the giant earthquake and tsunami. The accident at Fukushima Daiichi, which is heart-breaking for each one of us in the Network, raises question to the utilization of nuclear power. Hence so, with humbleness and courage, we are determined to stay focused and carry on the necessary and important HRD activities to overcome this difficult situation.

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“RESPONCIBLE SCIENCE” AND OTHER ISTC PROGRAMS SUPPORTING INTERNATIONAL COLLABORATION, TRAINING AND EDUCATION IN NUCLEAR SCIENCE AND TECHNOLOGY

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ABSTRACT

The International Science and Technology Center (ISTC) is a unique international organization, established in Moscow in 1994 by Russia, USA, EU and Japan. Later Republic of Korea, Canada and several CIS countries acceded to ISTC. The basic idea behind establishing the ISTC was to support non-proliferation of knowledge related to weapons of mass destruction by re-directing former Soviet weapons scientists to peaceful research thus preventing the drain of dual use knowledge and expertise from Russia and other CIS countries. Presently, the ISTC has 39 member states (27 from EU), representing the CIS, Europe, Asia, and North America. The Partner list includes over 200 organizations and leading industrial companies from all ISTC parties. Numerous science and technology projects were realized with the ISTC support in areas ranging from biotechnologies and environmental problems to all aspects of nuclear science and technology. Many projects were focused on the development of innovative concepts and technologies in the nuclear field including many aspects of nuclear safety.

1. Introduction

ISTC initiated and funded several programs to promoting excellence of projects in science and technology. One of the programs was the Technical Training program. Each training session gets together experts from Russia, CIS and Western countries for lectures, practical exercises and technical tours. Consequently, the ISTC projects have been better focused, managed, and in many cases results of the projects were successfully implemented in practice. The Technical Training program contributed also to improved international collaboration. Examples: trainings for nuclear critical safety, benchmarking, plutonium disposition programs, nuclear submarine decommissioning, molten salts and transmutation technologies, etc (1).
During its 16 years of operation the ISTC has supported a large number of science workshops, seminars and conferences. Several dozens monographs have been published with the ISTC support, such as "Aperiodic Pulse Reactors" (VNIIEF, Sarov), "Boron in Nuclear Engineering" (NIIAR, Dimitrovgrad), "Coupled Pulsed Reactor Systems" (IPPE, Obninsk), "Natural Safety Fast Neutron Lead Cooled Reactor" (NIKIET, Moscow), and others.

2. Survey of the ISTC programs

2.1. Program ” Responsible Science"

Under the new program *“Responsible Science"* with focus on nonproliferation the following activities will be addressed:

- Supporting research and training programs for scientists to obtain and build-up know-how on the scientific and technical aspects of safeguards, export control, and dual-use technology monitoring as part of overall non-proliferation policies under conditions of “nuclear renaissance”. This activity will be conducted in close cooperation with IAEA, based on the signed ISTC-IAEA Memorandum of Understanding;

- Working with universities and other educational institutions to prepare the pilot lectures/programs on “responsible science”, like courses on non-proliferation principles, ethics of dual-use science, international history and approaches. In particular, the program will support Moscow Engineering Physics Institute (MEPhI) in cooperation with Tomsk Polytechnical University, Obninsk OIAtE-MEPhI and nuclear experts to establish a “non-proliferation and responsible science” faculty offering inter-university courses for students and young experts. Under this activity the ISTC will help to prepare the program for this faculty, thus guaranteeing an international profile for this program;

- Promoting international cooperation in this field. ISTC will support initial steps of such cooperation. A concept of International Center of Excellence for non-proliferation sciences will be assessed in this process;

- Support activities of think-tanks and other organizations dealing with nonproliferation activities and raising public awareness in these matters, like Green Cross, Committee of Scientists for Global Security, Center for Policy Studies in Russia (PIR Center), Non-proliferation Association, etc.

Results of the first year activity:

Special sections with the non-proliferation issues were prepared and inserted into the two courses of lectures (partly with multimedia mode, one of courses - in English), given at the Moscow Engineering Physics Institute (in Moscow and Obninsk, for the 4th year students), starting from current School Year (September 2010), namely:

- Modern problems and challenges of nuclear power (Science and technical problems and approaches, Social and political aspects;
- Control and accounting of nuclear materials;
- International Nuclear Legacy (preparation of the training program for specialists working abroad);
- “Development of Nuclear Power with suppressed valuable risks (with protection against proliferation of nuclear materials” (planning of new lectures).

The monograph *“Nuclear Non-proliferation” (G. Pshakin, et al, 260 p., in-English)* was published.

The following monographs (tutorials) are prepared for publishing:

- “Nuclear-physical properties, identifying security of fissile materials against illegal proliferation”;
- “Methods for Nuclear Materials Measurements” (in-English).

New analytical surveys were presented:

- “Development of Nuclear Power with Suppressing of Significant Risks: Aspects of Protection against Proliferation of Nuclear-Hazardous Materials”;
- “Review of Methods for Improving of Nuclear Materials Security, as a Component of the National Non-Proliferation Safeguards”;
- “Analysis of Methods and Approaches to Nuclear Non-Proliferation Risks Assessment” was issued;

Demonstration option of the Internet-portal has been created and demonstrated at the MEPhI internet-site.

The following organizations expressed their interest to collaborate with the project:

- IAEA INSEN program (International Nuclear Science and Education Network);
- Oregon State University and Monterey Nuclear Non-Proliferation Center (USA);
- Nuclear Power Institute, Texas A&M University, USA, and some others.

The ISTC continue collaboration with the PIR-Center in Moscow, including the following actions:

- Conducting of the International Summer School on Global Security 2011;

- Publishing and dissemination of the Security Index journal (Russian and international editions);
- Round Table Discussion on multilateral scientific cooperation in sensitive technologies and culture of non-proliferation, etc.

The international conferences: four papers were presented and accepted by the NESTet Program Committee, Prague, Czech Republic (May 15-18, 2011). The team took part in the IAEA meetings in Vienna and Russia.

To the end of 2011 will be created:

- **Ten training manuals (3 in English), two training modules, three courses of lectures, eight analytical notes and research reports, etc.**

The following frames of this collaboration are accepted:

- **Carrying out joint working meetings, seminars, workshops** – both in Russia/CIS, and abroad.
- **Joint preparation of training/lecturing courses** (planning, scientific basis, references, issuing of monographs and tutorials (in-English), practical training, etc.).
- **Exchange by lecturers/ lectures** (partly may be sponsored by ISTC)
- **Exchange/assistance by info** (via web-portal, etc.)
- **Joint analysis of scientific issues** (risk analysis, NFC protection, etc).
- **Harmonization of legal aspects.**

2.2. The ISTC Program "Severe Accidents Management"

Nearly three dozen projects, related to different aspects of nuclear reactor safety enhancement in case of a severe accident involving the core degradation are being coordinated by the international group of collaborators – the Contact Expert Group for the projects related to Severe Accident Management (CEG SAM). Through its regular meetings (two times a year) and additional topical workshops this program has been closely linked with European FW programs and programs of other countries.

- ***Materials for NPP safe barriers (IVTAN, Moscow, NITI, Sosnovy Bor).*** New protective materials for traps, walls, containment, catcher were tested under shock, thermal and chemical loads at the SA conditions.
- ***Corium study and modeling (NITI, IBRAE, IAE of Kazakhstan).***

A diversified research in-depth of thermo-hydraulic, physical, thermodynamic and chemical processes of interactions of molten uranium corium with reactor vessel, trap or/and other barriers, construction of new or advanced phase diagrams of corium systems with different components of the reactor and concrete shaft, for instance (2):
- Melt corium interaction with different vessel steel specimens;
- Degree of melts superheating;
- Composition of above-melt atmosphere, inert and steam options are proposed for the second phase;
- Fission product release to the PWR containment atmosphere.

The results can be used for:
- Elaboration of computer models, codes and data for corium melt - vessel steel interaction processes;
- Verification of calculation codes modeling free convection processes in the melt pool in terms of physics and chemistry;
- Calculation and safety upgrade of operated and designed reactors VVER, PWR and BWR.

- ***Experimental modeling of quench-type regimes (NIIAR, Dimitrovgrad, IBRAE, MPI, Moscow, GIDROPRESS and NPO LUCH, Podolsk,).***

Destruction processes of VVER-type fuel rods and fuel assemblies were studied and modelled under accident conditions, including reactor core destruction, degradation confines are defined.

The program includes a set of out-of-pile tests with use of simulators of irradiated fuel rods, standard VVER fuel and structural materials. The complex studies of fuel assembly destruction after top and bottom-up quench were carried by the large-scale experimental installation PARAMETER (NPO LUCH, Russia) in cooperation with the European installation QUENCH (KIT/FZK, Karlsruhe) and accompanied by supporting small-scale experiments with fuel element samples irradiated up to high burn-up in RIAR (Dimitrovgrad, Russia). These tasks were solved as complementary to the QUENCH project in KIT, Karlsruhe. Realization of the same methodical approach will allow comparison of the behavior of VVER and PWR materials and design elements as well as to provide the possibility of application of the same approach to develop the numerical codes and determine safety criteria of these reactors.
The PARAMETER experimental program (GIDROPRESS and NPO LUCH) includes study of:

- Thermal-mechanical and corrosion behavior of VVER fuel rod assemblies and structural components (fuel rod cladding, fuel pellets, guiding tube, spacing grids) in simulated conditions of a severe accident development stages and determining their damage parameters, under flooding from top/top and bottom of the lead assembly superheated up to 2000°C.
- Determining an oxidation degree of the VVER fuel rod assembly structural components.
- Interaction and structural-phase changes in the VVER fuel rod assembly materials (fuel cladding, fuel pellets).
- Hydrogen release rates under severe accident conditions including stage of bundle flooding.

Small-scale tests and an integral experiment under quench conditions are carrying out with VVER material in order to build up a database for modeling and verification of codes. The integral fuel bundle experiment will be carried out using non-irradiated materials. The small-scale experiments with irradiated fuel are assumed in order to develop basis for database for irradiated core materials.
The project includes three stages:

- Study of the spent fuel rod segments (RIAR, Dimitrovgrad);
- Integral experiment with model bundle with 31 fuel rod simulators under “quench” conditions (NIIAR and, KIT- Karlsruhe);
- FA Quench Model: Development of models and codes to describe VVER core behavior under “quench” stage conditions (NIIAR, IBRAE, KIT).

Experiments of Moscow Power Institute MPI *“Experimental Investigation of the Thermal and Structural Integrity of the VVER Pressure Vessel Lower Head in Severe Accident”* are devoted to study of thermal hydraulic characteristics of molten pool in the lower head of the reactor vessel.

- ***Math-modeling*** *(IBRAE, Moscow):*

Modeling of reactor core molten materials behavior at consecutive stages of an accident development: from the early stage, when the core is mostly intact and the first zirconium cladding melting occurs, up to the late stage, when the core is completely degraded and a molten pool is formed in lower head of the PRV.
The following processes were studied:

- Melt formation, onset of melt relocation;
- Cladding oxide shell failure,
- Release of U-Zr-O mixture from the cladding breach.
- Candling process: flowing down in the form of drops and rivulets during the first stage of melt relocation;
- Formation of massive coolant channel blockage (slug), its oxidation and downward relocation in the course of the second stage of melt relocation process;

On the basis of received experimental data and developed models, the Russian computer codes SVECHA and SOKRAT (IBRAE, Moscow), as well as relevant European codes were improved and verified.

2.3. Program "Medical physics"

The program includes joint activity of physical laboratories (equipped by accelerator, reactor or other instruments) and bio-medical institutions in favour of novel methods for diagnostics and treatment of human diseases (oncology): neutrons capture therapy (NCT), gamma radiation, electron beam radiation and charged particles.
Manufacture of medical radioisotopes: a pilot line will be installed at the IPPE plant in Obninsk, Russia, for production of micro-dose iodine-125 for prostate cancer drugs.
VNIIEF (Sarov), MEPhI and Cancer Hospital (Moscow) developed and verified models and computer codes for optimisation of doses and beam parameters for each patient.
MEPhI research reactor was modified and specified for neutrons capture therapy applications (3).

3. Survey some of the ISTC research projects

The following information will be presented partly in the review, with special attention on details of corresponding experimental programs, particularly to:

- Fast reactors (cooled by sodium, helium, lead or lead-bismuth);
- Supercritical Pressure Water aspects;
- HTGR – critical modeling, engineering.
- Molten salts (fuel, coolant).
- Study of processes related to severe accidents, creation of barriers).
- MA transmutation aspects (experiments, nuclear data measurements, partitioning).
- Complex nuclear fuel cycle analysis (MOX): efficiency, non-proliferation, and safety.
- Reactor data benchmarking and verification, critical experiments.
- Nuclear Power Plant life management (Reactor pressure vessel and internals control, etc.).

4. Conclusions

Within the last 17 years ISTC was a partner for Russia/ CIS in development of advanced civilian nuclear technologies.
ISTC today:

- The ISTC is the unique official international platform for cooperation between Russian/CIS laboratories and foreign partners;
- The creative working and trust relationship among the vast network of domestic and foreign partners;
- Programmatic Approach and the ISTC Contact Expert Groups – coordination at professional level of planning, management and performing activities, between research groups / projects/ programs in Russia and other CIS Parties (4).

In the frames of new conditions the ISTC is ready to assist further to the Russian/ CIS national programs, particularly for international collaboration in the nuclear fields – like until 2012, and, hopefully, further.

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10 YEARS OF EXPERIENCE WITH NUCLEAR EDUCATION IN THE BELGIAN NUCLEAR HIGHER EDUCATION NETWORK

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ABSTRACT

The Belgian Nuclear higher Education Network (BNEN) organises a master-after-master academic programme in nuclear engineering, through a consortium of six Belgian universities and the Belgian Nuclear Research Centre, SCK•CEN. This condensed (60 ECTS in one year, including a master thesis) programme allows the students to acquire all necessary scientific and technical background and skills to develop a career in the field of nuclear applications. In 2011 the BNEN programme exists for 10 years. In this paper, the evolution over the past 10 years is highlighted and specific attention is given to the use of various research infrastructures within the programme. Exercises and hands-on sessions in the specialised laboratories of SCK•CEN complement the theoretical classes, bring the students into contact with all facets of nuclear energy, and are therefore a clear added value to the programme.

1. Introduction

The post-graduate BNEN programme [1] was formed in 2002 in order to remodel the nuclear education scene in Belgium and catalyse networking between academia, research centres, nuclear industry and other stakeholders. Its primary objective was, and still is, to educate young engineers in nuclear engineering and applications and to maintain and develop high level nuclear engineering competences in the country. Until 10 years, nuclear engineering programmes were in a state of decline, with programmes disappearing due to the lack of interested students. The creation of this master-after-master in nuclear engineering was the response of 5 universities and SCK•CEN to counter this negative trend. During the preparation of the BNEN programme, all partners agreed to strive for top quality goals. BNEN is linked with university research, benefits from the human resources and infrastructure of SCK•CEN and is encouraged and supported by the partners of the nuclear sector. A sixth university joined the consortium in 2006. The university members are now: KULeuven (Leuven), UGent (Ghent), VUB (Brussels), UCL (Louvain-la-Neuve), ULg (Liège) and ULB (Brussels). From the start, the partners did not only focus on the Belgian scene, but worked towards international recognition, targeting a number of international students as well. BNEN served as a role model for ENEN, the European Nuclear Education Network, which now has become an international association of about twenty universities cooperating with the European stakeholders (industry, regulators, research centres), aiming at facilitating mobility in Europe for students in nuclear engineering.

2. Some facts about the BNEN programme

From the start, the consortium partners had the intention to create an academic programme that would educate students in all aspects of nuclear technology and its applications and thus create nuclear engineering experts in the broad sense. Table 1 explains the BNEN programme, which is made up of theoretical, more applied and an interdisciplinary set of modules. All courses are in English and take place at the technical domain of SCK•CEN. The modular structure, teaching in blocks of one to three weeks for each course, is especially suited to attract young professionals and international students. The total workload amounts to 60 ECTS and one should note in particular the substantial weight of the Master thesis, which takes up 25% of the programme. Students have to take 4 ECTS of advanced/elective topics. These courses either deepen or broaden a certain theme. In 2010 topics were (amongst others) nuclear safeguards, accelerators and time of flight experiments and probabilistic safety assessment of nuclear power plants. Topical days organised by SCK•CEN are also recognised as advanced course.

	BNEN Module	ECTS	
BNEN block I	Introduction to nuclear energy	3	First Semester (October to January)
	Introduction to nuclear physics	3	
	Nuclear materials I	3	
	Nuclear fuel cycle and applied radiochemistry	3	
	Nuclear materials II	3	
	Advanced courses	4	
BNEN block II (ENEN block)	Nuclear reactor theory	8	
	Nuclear thermal hydraulics	6	Second semester (February to June)
	Radiation protection and nuclear measurements	6	
BNEN block III (ENEN block)	Operation and control	3	
	Reliability and safety	3	
	Thesis/Internship	15	

Table 1: The BNEN modules, from [2].

The universities in the consortium provide the academic framework: they assign the different professors and issue the BNEN degree to the students. SCK•CEN is responsible for scientific and administrative support, offering the entire infrastructure for the lessons, exercises and laboratory sessions. Several of SCK•CEN's researchers provide valuable contributions to the programme through seminars and practical exercises. From their daily tasks and responsibilities they give an expert view on the subjects that are being taught.

The BNEN programme is open to people holding a 5-year master degree in engineering. People having a master degree in sciences or industrial sciences are accepted upon successful completion of a make-up programme of approximately 30 ECTS. Three different types of students attend the BNEN programme: full-time students (choosing an extra year of specialisation), young professionals (getting an incentive from their employer) and other professionals (looking for a change in career).

From Figure 1, showing the evolution in student numbers, it is clear that the programme has known an increase in students each year. Including students that are registered for isolated courses only, the total number of students exceeds 40 in 2010-2011. A large number of students spread the programme over time, taking more than one year to graduate. For the group of (young) professionals this can be expected, as they have to combine BNEN together with working for a company. Recently, also full-time students tend to take one-and-a-half to two years to complete the programme. This is mainly due to the fact that they choose to focus on the courses in the first year and the master thesis in the second year.

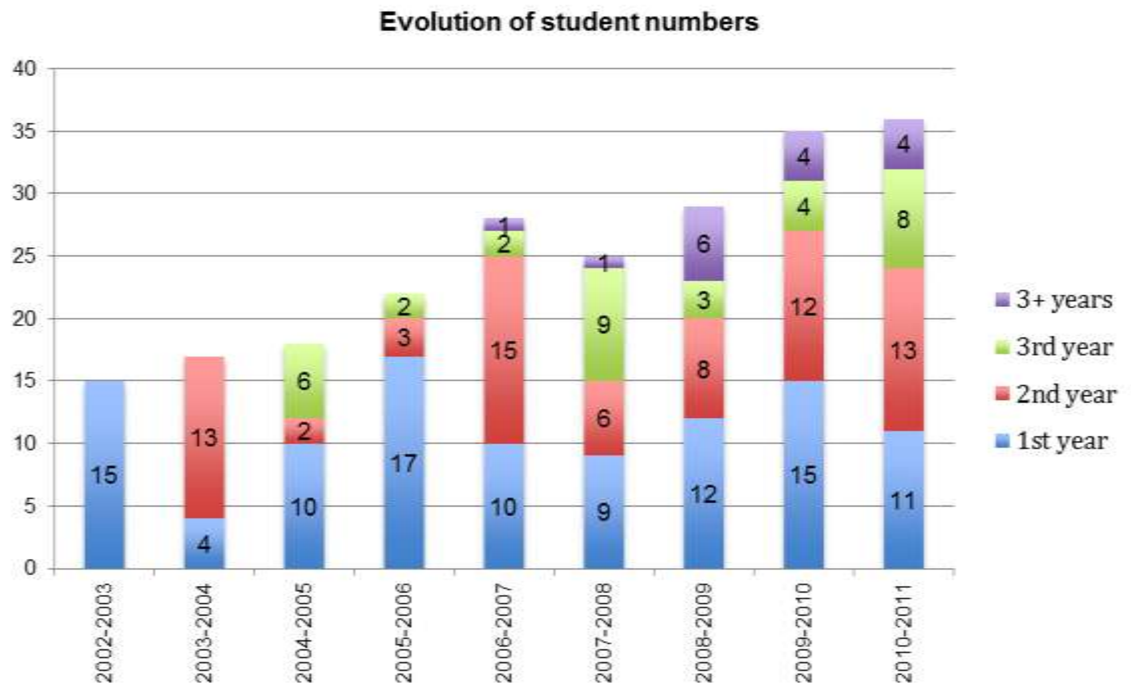

Fig.1: Student numbers

3. Quality assurance

Over the years a continuous effort is being made to improve the overall quality of the BNEN programme. Quality issues, next to general policy issues, are discussed during the BNEN Steering Committee meetings. The Steering Committee consists of a representative of all partners, 2 student members and the BNEN secretary. Furthermore, the BNEN vice-chair is specifically responsible for quality assurance and dedicated quality meetings are held every 2 years since 2007. As a direct result of the quality programme, following actions were taken: all course material is available on a restricted area of the BNEN website, every professor has a “proxy” taking over his/her teaching tasks in case of absence, students give feedback on the courses through an online application, a brand-new classroom – including smart board – is in place since 2010, regular stakeholder meetings are organised to ensure a good interaction with industry, regulators and other interested parties. Currently, the BNEN programme is going through a process of accreditation for which a self-assessment report (SAR) is being drafted based on a SWOT analysis and a number of surveys conducted among the different stakeholders of the BNEN programme.

4. Use of the SCK•CEN research infrastructure

Most of the BNEN courses include exercises and/or laboratory sessions to which attendance is compulsory for the students. For the practical sessions and technical visits the BNEN programme makes use of the various installations at SCK•CEN [3]. In this way, students can get a unique practical experience of all facets of nuclear energy and at the same time they get an introduction to the activities of the research centre.

BR1

The BR1 research reactor is a natural uranium, air-cooled reactor with graphite acting as a moderator, in operation since 1956. Today, it is mainly used as a neutron reference source for reactor physics experiments and as a calibration tool for nuclear instruments and detectors. Working at a maximum power of 700kW, it has very safe operation mode and limited maintenance costs. It is therefore a flexible and useful instrument for training purposes.

In the BNEN programme, the BR1 reactor is used to carry out experiments related to the course ‘Nuclear reactor theory’. During this practical session, the students are effectively working from the reactor control room and get important hands-on experience with a research reactor. The topics covered in this laboratory session are:

- Subcritical approach: estimation of the critical size of the control rods
- Period measurement and control rod worth
- Measurement of the temperature coefficients of uranium and graphite
- Full control rod calibration

BR2

The BR2 research reactor works with highly enriched uranium and pressurised water is used as a coolant and moderator. As a material testing reactor, the BR2 produces a high neutron flux and is regarded as one of the most powerful research reactors in the world. It plays an important role in international research on the behaviour of nuclear fuels and reactor materials for different reactor types, including advanced Generation-IV fast reactors.
Next to this, the BR2 is also one of the main sources in the world for the production of radioisotopes to be used in nuclear medicine (diagnostics and therapy) and doped silicon used in industry.
Complementary to the lessons of ‘Nuclear materials I’ a technical visit to the BR2 installation is included. The BNEN students first receive a presentation on the background and functionalities of BR2, after which they enter the reactor building. They visit the two control rooms (one for the cooling system and the other one for the core reactivity) and can witness the Cerenkov radiation at the reactor pool. The combination of nuclear and reactor physics, materials science and dosimetry, makes this technical visit a valuable part of their education.

Laboratory for High and Medium Activity (LHMA)

The study of irradiated reactor materials and nuclear fuels requires specific experimental conditions to ensure safety for researchers. The LHMA is equipped with a number of shielded cells, called hot-cells. These large boxes are shielded with lead and use robotic arms to manipulate radioactive samples from a distance. Using mechanical, chemical and microstructural instruments, the researchers analyse the damage to, and the ageing processes of, materials as a result of ionising radiation. BNEN students visit the LHMA during a laboratory session on mechanical testing in the ‘Nuclear Materials II’ module. They assess the mechanical properties of structural materials by performing tensile, Charpy impact (toughness) and Vickers (hardness) tests. For safety reasons, students perform tests on non-irradiated samples. However, for one of the tests a hot cell is used, allowing the students to experience the particularities of manipulating a sample using the robotic arms.

Radiation protection & nuclear measurements

The laboratory sessions on ‘Radiation protection and nuclear measurements’ use many of the facilities available at SCK•CEN. During the practical exercises on liquid scintillation counting and alpha/gamma spectroscopy, students have to determine the identity and quantity of radioactive emitters that are presented in -to them- unknown samples and deal with detector calibration and efficiencies. Next to this, practical sessions on dosimetry and radiation dose calculations are organised. In addition, the VISIPLAN 3D software [4] is used to illustrate the ALARA principle. With this SCK•CEN planning tool a model in a 3D environment is made to simulate for example maintenance works in a hot zone from which the students can then calculate the dose maps and suggest improvements to reduce the dose received by the workers.

HADES

During the course ‘Nuclear fuel cycle and applied radiochemistry’ a technical visit to the underground laboratory HADES is planned. HADES stands for High Activity Deposition Experimental Site. At 225m under ground, scientists study the possibility of geological disposal of highly active long-lived radioactive waste in a Boom clay layer. The construction of the underground laboratory demonstrated that it is technically feasible to dig out shafts and galleries in a clay layer. The students get an overview of the construction phases of the laboratory and the experiments that are being performed.

VENUS

VENUS was a zero-power critical facility for light-water reactor physics research, mainly focused on code and nuclear data benchmarking and validation. Students visited the facility up till 2009. At that time SCK•CEN started the transformation of the facility into the new VENUS-F facility: a lead based zero-power critical and sub-critical facility. In critical mode, the same type of experiments can be done as before, but now in a fast neutron spectrum (in support of Generation-IV reactors). In sub-critical mode, an external neutron source is provided by a GENEPI accelerator that sends deuterium on a tritium target. This combination is a zero-power Accelerator Driven System to study the coupling of particle accelerator, target and sub-critical core. Commissioning of the new facility is on-going and visits will again be possible in 2012.

5. Conclusions

After almost a decade of successful operation and on-going improvements, the Belgian Nuclear higher Education Network has progressively become a major actor on the Belgian and European nuclear scene. BNEN gives the partner universities the possibility to offer a high quality academic programme in nuclear engineering without having to fear for insufficient student numbers. Every year it delivers a new class of top-level nuclear engineers, ready to ensure safe operation of current and future nuclear power plants, research infrastructures, waste treatment and disposal facilities. The use of the research infrastructures of SCK•CEN for the practical sessions is an important and indispensible asset. SCK•CEN also offers students the link between academics and a possible future scientific career in research. BNEN graduates can continue their research at SCK•CEN, becoming a PhD candidate or working on one of its innovative projects as a nuclear engineer. A future challenge for the BNEN programme will be the upcoming accreditation process. It will, however, be a valuable exercise that will only benefit the programme of this master-after-master in nuclear engineering.

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INTERNATIONAL NUCLEAR HUMAN RESOURCE DEVELOPMENT AND COOPERATION IN ASIAN COUNTRIES AT JAEA/NUHRDEC

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ABSTRACT

Since the new introduction and construction of nuclear power plant is increasing, especially in Asian countries, mostly due to energy security, low cost and global environment issues, a number of countries are facing with emerging need to develop nuclear human resources. Nuclear Human Resource Development Center (NuHRDeC) of Japan Atomic Energy Agency (JAEA) has conducted nuclear education and training since its establishment in 1958. Nuclear human resource development (HRD) is clearly identified as one of JAEA's missions. NuHRDeC is conducting Instructor Training Program (ITP) launched in 1996 to contribute to the development of nuclear human resources in Asian countries. The purpose of ITP is to develop a self-sustainable instructors in nuclear sectors in Asian countries. The main specialized fields of the ITP are reactor engineering, environmental monitoring and nuclear emergency preparedness. The characteristic feature of ITP is that the curricula places emphasis on the practical exercise with well-equipped training facilities, experimental laboratories and the expertise of lecturers mostly from JAEA. As a part of ITP, NuHRDeC has been conducting Safeguards Training in cooperation with IAEA, Plant Safety Training and Administration Training Courses. As an international cooperation in Asia, NuHRDeC collaborates with HRD Project of Forum for Nuclear Cooperation (FNCA). Currently the project focuses on Asian Nuclear Training and Education Program (ANTEP), a network system by utilizing existing nuclear training and education resources in member states to meet each country's HRD needs. NuHRDeC also contributes to IAEA Asian Nuclear Safety Network (ANSN) by providing an information in nuclear safety. Recently Japan has become a member of IAEA Asian Network for Education in Nuclear Technology (ANENT) and aims to further contribute to HRD in Asia. In the newly established all-Japanese HRD network, NuHRDeC plays an important role as Secretariat in cooperation with Japan Atomic Industry Forum. It should be mentioned that the recent accident at Fukushima may affect the future nuclear trend to some extent, but that the necessity and advantages of nuclear science and technology, and hence the importance of nuclear human resource development, will basically be unchanged.

1. Introduction

Nuclear human resources development (HRD) in Japan has been identified as one of the most important issues these years in nuclear society, mostly due to the decrease of nuclear engineers in industries and students in universities with the coming peak of replacement of nuclear power reactors around 2030, and also to the difficulties of technical transfers between old and young generations. Nuclear Human Resource Development Center (NuHRDeC) was established in 1958. Japan Atomic Energy Agency (JAEA), established by the integration of JAERI and JNC in 2005, clearly identifies nuclear HRD as one of its missions. NuHRDeC's activities are conducted in line with governmental policy and programs, and aims at comprehensive nuclear education and training program. NuHRDeC's program consists of; 1) education and training for national nuclear engineers, 2) cooperation with universities and 3) international training and cooperation as shown in Fig.1. The main feature of NuHRDeC's training programs is that the curricula place emphasis on the laboratory exercises with well-equipped training facilities, including research reactors, expertise of lecturers mostly from JAEA, and the usage of accumulated know-how on education and training obtained in over 50 years. The wide spectrums of cooperative activities, including international training mostly for Asian countries, and international cooperation with international organizations have been extensively conducted[(1)-(5)].

Fig. 1 Outline of JAEA-NuHRDeC Activities

In Asian non-nuclear power countries, nuclear education and training have been conducted in the field of non-power fields, such as medical, industrial or agricultural applications. However in recent years the new introduction or construction of nuclear power plant is increasing, mostly due to energy security, low cost and global environment issues. In this context a number of Asian countries are facing with emerging need to develop nuclear human resources in all levels from young generation to top management. NuHRDeC has been conducting international human resource development for Asian countries both in radiadion application and nuclear power fields. NuHRDeC has also been conducting international cooperation under the frameworks of Forum for Nuclear Cooperation in Asia (FNCA) by Japan Atomic Energy Comission, and Asian Nuclear Safety Network (ANSN) and Asian Network for Education in Nuclear Technology (ANENT) of IAEA. The present paper describes the status and future direction of international human resource development and cooperation in Asian countries at JAEA/NuHRDeC.

2. International Human Resource Development in Asian Countries

Currently several international training programs have been conducted under the scheme of Instructor Training Program (ITP) since 1996. As a part of ITP, short training courses for safeguards, nuclear plant safety and administration are conducted for more than 20 Asian countries. The accumulated number of trainees since 1959 in international training is close to 3,500 as shown in Fig. 2.

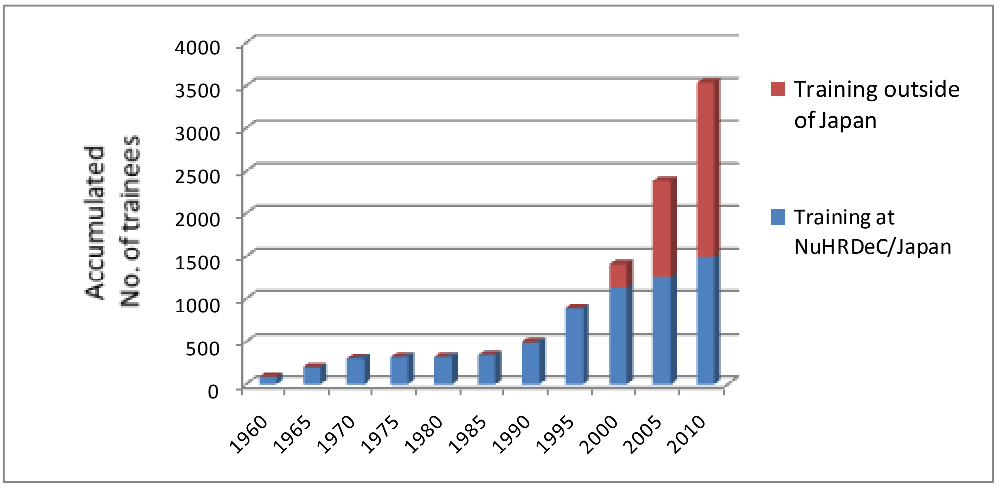

Fig. 2 Accumulated number of trainees in international training courses

2.1 Instructor Training Program

Instructor Training Program (ITP) has been conducted to contribute to the development of human resources in Asian countries seeking peaceful use of nuclear energy under MEXT (Ministry of Education, Culture, Sports and Technology)'s special budget. The purpose of ITP is to develop a self-sustainable instructors in nuclear sectors of industry, government and academia in Asian countries, who are expected to disseminate the nuclear knowledge and technology in their countries. ITP consists of 1) training in Japan, and 2) dispatch of Japanese experts to the local training courses for technical advice in Asian countries. The main specialized fields of the ITP are reactor engineering, environmental monitoring and nuclear emergency preparedness (Fig. 2). The curricula and facilities for ITP have been improved to meet each Asian country's needs. Currently the ITP is applied to 7 Asian countries; Indonesia, Thailand, Vietnam, Bangladesh, Kazakhstan, Malaysia and Philippines.

Fig. 3 Instructor Training Program on Reactor Engineering

2.2 Safeguards Training Course

The Safeguards Training Course is conducted in cooperation with IAEA, inviting about 20 trainees from about 10 Asian countries concluding a safeguards agreement based on the non-proliferation treaty. Trainees are mostly from administrative offices or research institutes. The 2 weeks' course is to join the intensive on-the-job training, consisting of safeguards technology in Japan, IAEA safeguards technology, supplementary protocol, IAEA system of accounting and physical protection. The course place emphasis on practices, discussion and laboratory exercises to enhance understanding on the safeguards.

2.3 Nuclear Plant Safety Training Course

The purpose of the Nuclear Plant Safety Training Course is to train nucear trainers and leaders in Asian countries, which are going to introduce nuclear power in future. Targets of the course are nuclear engineers in nuclear research and development institutes, governmental organizations and universities from about ten countries. Four week course is provided twice a year, inviting totally about 20 trainees. The couse includes lectures in various fields, excersises on reactor operation and maintainance, and facility visit to nuclear facilities, including nuclear power plants.

2.4 Administration Training Course

Administration Training Course was initiated in 2010 to train management-level officers in administrative organization or research institutes. The purposes of the course is to contribute to nuclear development, to establish intellectual network and to contribute to safety assurance of nuclear activities in each country through learning wide range of nuclear knowldgement and sharing information on nuclear policy. In 2010 eleven trainees participated in the course from 9 countries.

3. International Cooperation in Asian Countries

NuHRDeC has been conductiong several international cooperation in Asian countries, such as HRD project for Asian countries under the framework of Forum for Nuclear Cooperation in Asia (FNCA), and IAEA's Asian Nuclear Safety Network (ANSN) and Asian Network for

Education in Nuclear Technology (ANENT). Also NuHRDeC plans to conduct new cooperation activities under the frame of newly established Japan Nuclear HRD Network (JN-HRD Net).

3.1 FNCA Related Activities

Since 1999, NuHRDeC has cooperated to promote HRD project for Asian countries under the framework of Forum for Nuclear Cooperation in Asia (FNCA) by the Japan Atomic Energy Commission. Currently the project focuses on ANTEP (Asia Nuclear Training and Education Program), a network system by utilizing existing nuclear training and education resources in FNCA member states, i.e., training and education programs, nuclear research facilities and experts to meet each country's HRD needs. Recently, FNCA is promoting information exchange on HRD for the introduction of nuclear power plant among the member countries. To facilitate the information exchange, NuHRDeC has developed a database of detailed HRD programs and useful information; such as experience on building nuclear power plant, good practices, public acceptance and regulation, which is important especially for the countries to newly introduce nuclear power.

Fig. 4 Concept and function of ANTEP (Asian Nuclear Training and Education Program)

3.2 Cooperation with IAEA

NuHRDeC contributes to IAEA's Asian Nuclear Safety Network (ANSN) activities by providing a variety of information, including textbooks in the field of nuclear safety. It is noted that Japanese Government has recently participated in IAEA's Asian Network for Education in Nuclear Technology (ANENT). As the relevant correspondence of Japan, NuHRDeC plans to contribute to ANENT by providing educational materials and opportunities, such as remote learning or laboratory exercises using facilities in future.

3.3 Cooperation in JN-HRD Net

Japan Nuclear HRD Network (JN-HRD Net) was established in November 2010 in order to conduct and promote national and international HRD activities in strategic and integrated manner, effectively and efficiently in close collaboration with international organizations. Figure 5 shows the overall scheme of JN-HRD Net. NuHRDeC plays an important role in hub as Secretariat of JN-HRD Net in cooperation with Japan Atomic Industry Forum (JAIF). One of the main activities of JN-HRD Net is the promotion of support and cooperation mostly for nuclear power introducing countries. In response to this, new activities have been initiated in JN-HRD Net for newly nuclear power introducing countries mostly in Asia, such as short term course in each country, dispatching experts to each country for training engineers, training courses held in Japan, including visit to nuclear facilities, and consultation on nuclear HRD programs, mostly in close collaboration with international scheme and organizations, such as IAEA and FNCA.

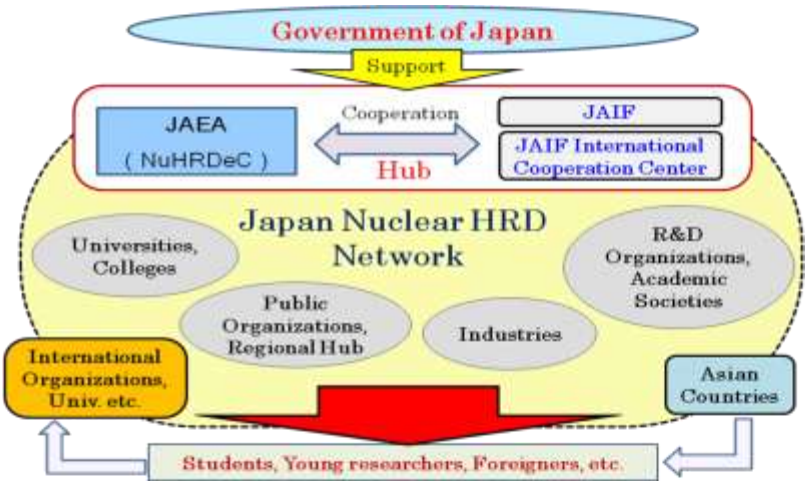

Fig. 5 Japan Nuclear HRD Network

4. Summary

(1) JAEA/NuHRDeC aims at comprehensive nuclear human resource development (HRD) and cooperative activities both in Japan and abroad. NuHRDeC has conducted extensive HRD and cooperation efforts in response to the needs in Asian countries, especially to the emerging needs for newly introducing nuclear power.
(2) Instructor Training Program (ITP) is the major education and training shceme to develop a self-sustainable instructors in nuclear sectors in seven Asian countries. Currently the main specialized fields of the ITP are reactor engineering, environmental monitoring and nuclear emergency preparedness. Additionally short training courses for safeguards, nuclear plant safety and administration are conducted for more than 20 Asian countries.
(3) The wide spectrum of cooperative activities have been pursued in Asian countries with international scheme and organization, such as with FNCA/HRD Project, IAEA/ANSN and IAEA/ANENT. In the newly established all-Japanese HRD network, JN-HRD Net, NuHRDeC plays an important role as Secretariat of JN-HRD Net in cooperation with Japan Atomic Industry Forum.

Lastly it should be mentioned that the recent accident at Fukushima Daiichi due to giant earthquake and tsunami on March 11, 2011 may affect the future nuclear trend to some extent, but that the necessity and advantages of nuclear science and technology, and hence the importance of nuclear human resource development, will basically be unchanged.

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A Fully Integrated Approach to Education, Skills Development and Training for the UK Nuclear Industry

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ABSTRACT

At its peak, nuclear power in the UK provided over a quarter of the total electricity generation in the UK. Today the UK nuclear industry is on the cusp of a renaissance and there is a need to understand the skills requirements to support all elements of the current and future fuel cycle. The paper will explain the formation of a UK taxonomy to support the Labour Market Intelligence on which these forecast of skills requirements is based.

The results of the research, based on this taxonomy to forecast the UK nuclear industry skills needs, for all elements of fuel processing, electricity generation, decommissioning, new build and the defence programmes will be described. Recognising the international nature of the nuclear industry, collaboration with European and OECD groups to produce broader nuclear role taxonomy has also been undertaken and progress to date will be reported.

Behind the basic taxonomy Cogent SSC working in concert with industry group and the National Skills Academy Nuclear has developed industry agreed role profiles, articulating competences. and These role profiles cover the technical competences, regulatory compliance requirements along with business and functional and behavioural needs. This leads to the development of qualifications and training standards to provide the underpinning industry agreed education and training. This activity provides an example of cooperation across industry as these role profiles support the National Skills Academy Nuclear Skills Passport which is described in a separate paper.

1. Introduction

At the national level, how can education and training requirements be quantified and verified? And, to what extent can governments and employers, in free labour markets, ensure a pipeline of suitably qualified and experienced people to support energy infrastructures? These are well-worn questions for a highly regulated and safety conscious sector; questions which the recent events at Fukushima in Japan will test further.

This paper illustrates how a Nuclear Skills Taxonomy linked to independent training standards and independent accreditation of training provision is the cornerstone for a national Nuclear Industry Training Framework and an national Nuclear passport capturing education, training and experience in the sector; effectively, a voluntary license to practice.

In addition, two important national initiatives between the Nuclear sector and Higher Education testify to a fully integrated approach.

2. A Nuclear Taxonomy for HR

A taxonomy of 13 job contexts was agreed with the sector and <u>all nuclear operating companies</u> in the UK returned HR data and projections against these contexts. The peer-reviewed *Power People* report demonstrates the power of the taxonomy in quantifying and analysing the national workforce. The *Next Generation* report illustrates projected future skills needs. Examples are given below.

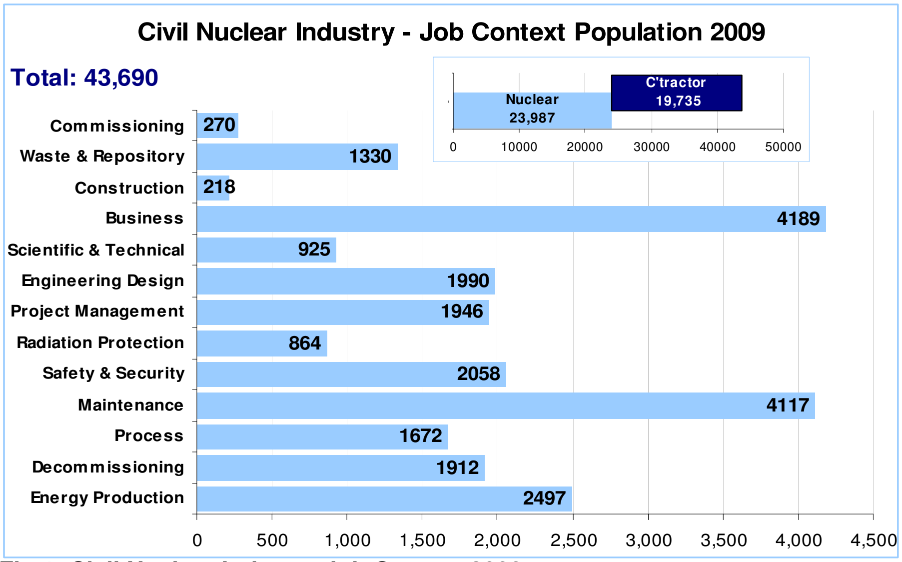


Fig.1: Civil Nuclear Industry-Job Context 2009

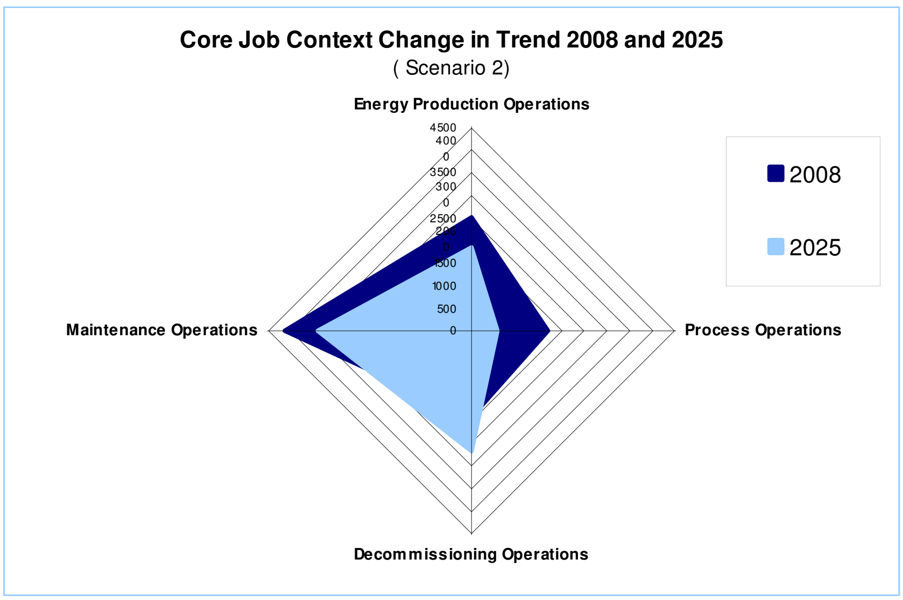


Fig.2: Core Job Context- Change in trend 2008-2025

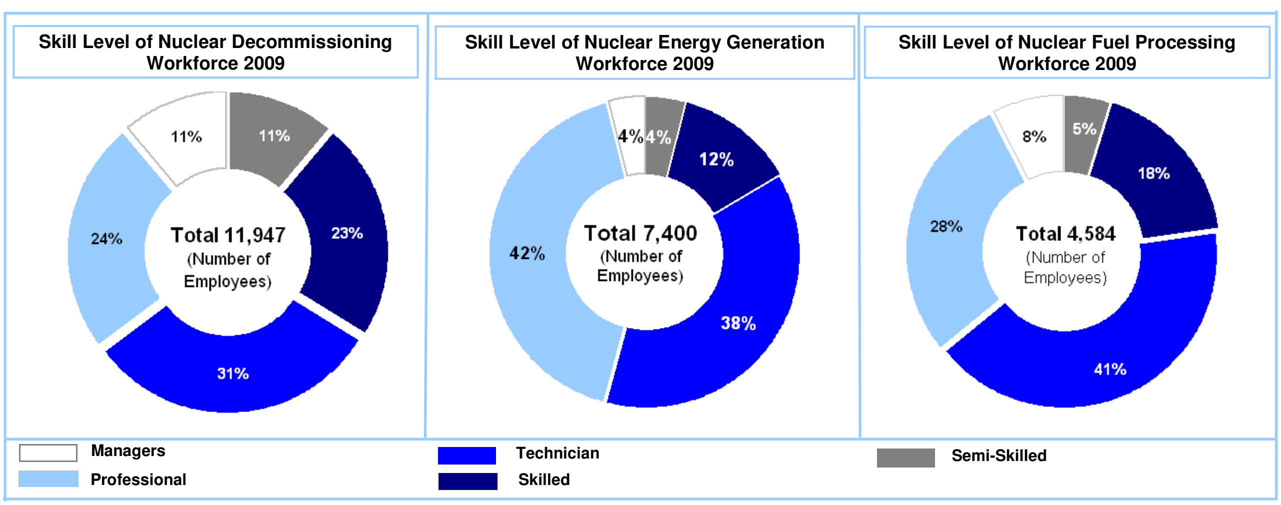


Fig.3: Skill Level of Civil Nuclear Workforce UK

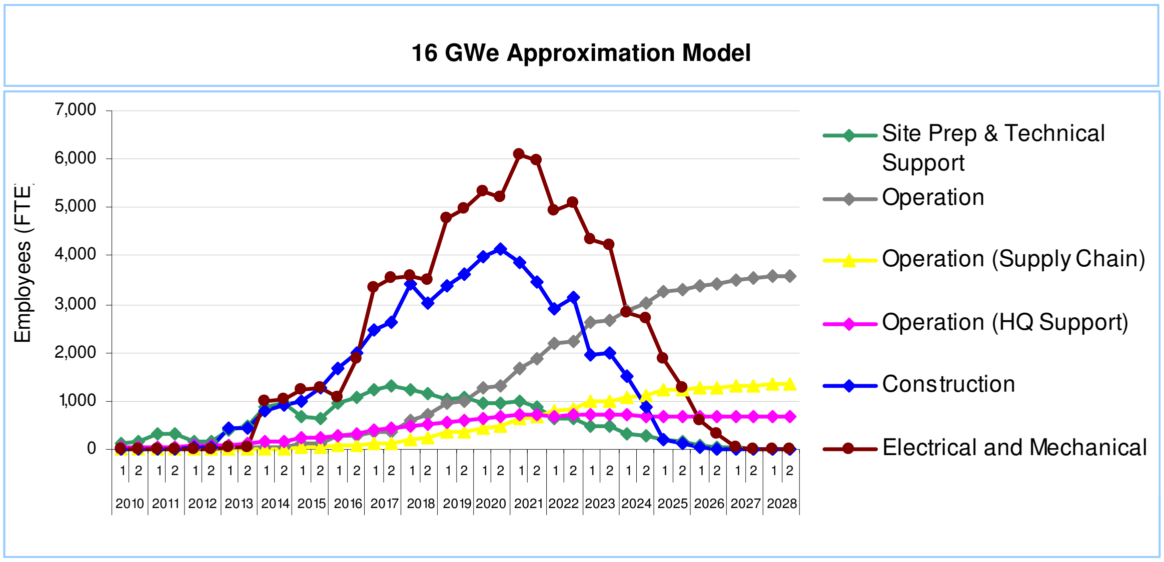


Fig.4: 16GWe Workforce Approximation Model

3. A Nuclear Industry Training Framework

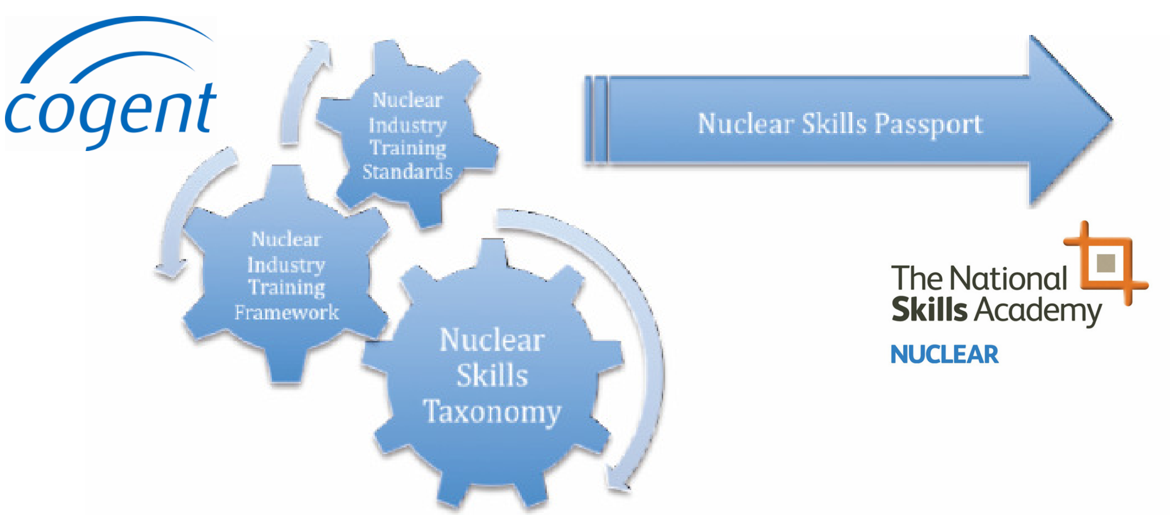
The Nuclear Industry Training Framework (NITF) encompasses all nuclear job contexts, qualifications and industry standards for a site-licenced company. Shaped by Cogent with the industry and for the industry, the NITF is the starting point for employers for skills gap analysis. The taxonomy provides a common framework for NITF on competences, qualifications and training. The NITF identifies recognized education and 4 training in four areas: Technical Competence, Regulatory Compliance, Business Improvement, Functional and Behavioral Skills.

4. Nuclear Industry Training Standards

Guided by the taxonomy and the NITF, Nuclear Industry Training Standards (NITS) have been developed for the job contexts in collaboration with industry groups and relevant trade, professional or training associations.

5. The UK Nuclear Skills Passport

Founded on the NITF and the NITS is the Nuclear Skills Passport of the National Skills Academy. The Passport evidences individual and organisational competence. The Passport is underpinned by a database driven IT platform which provides verification of accredited training. In the UK the Passport is voluntary, but it has been identified by nuclear operators as highly desirable for their supply chain.



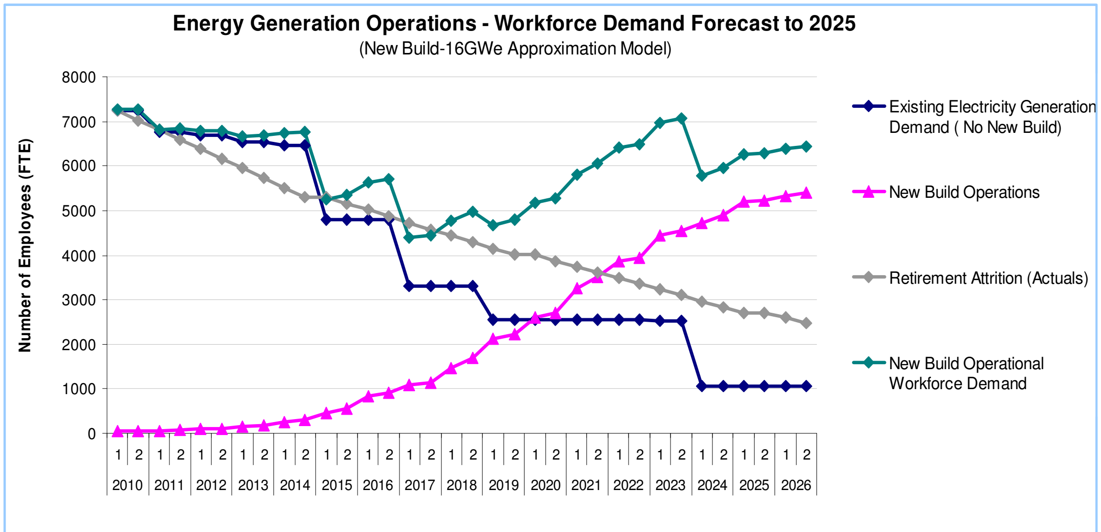


Fig.5: Energy Generation Operations Workforce Demand Forecast to 2025

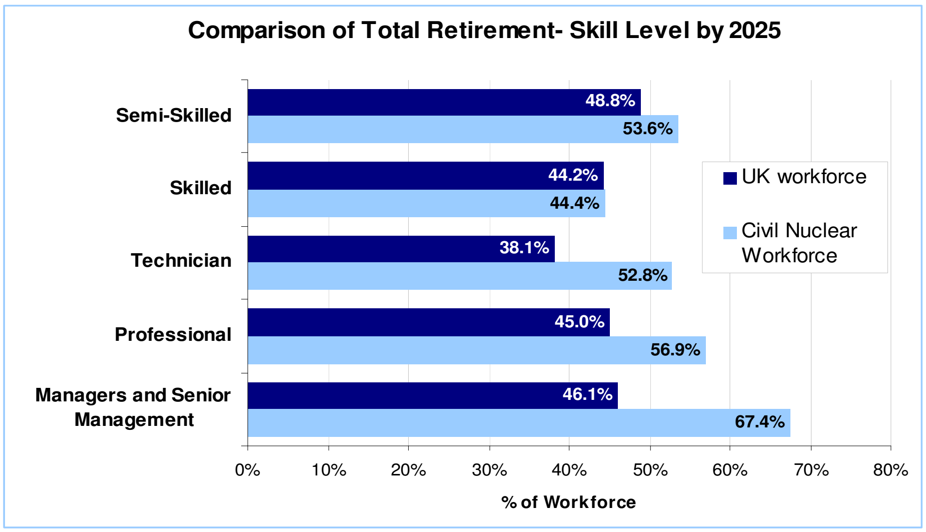


Fig.6: Comparison of Total Retirement by 2025

Working Higher - Education comes to the Workplace

This initiative integrates academic and applied learning in an industrial context. It is the result of a partnership between nuclear employers, the University of Central Lancashire and regional providers to develop innovative and flexible delivery models for the FdEng Nuclear Engineering. Delivery is through three themes: principle knowledge; functional skills and specialist knowledge. At least 50% of the learning is context driven in the workplace.

http://www.cogent-ssc.com/working-higher/nuclear/

Nuclear Island Constructionarium –the Workplace comes to Higher Education

Employers in partnership with Higher and Further Education tackle the critical future workforce demands of new build through the development of a programme for off-site scaled down construction. Focusing on the nuclear reactor core, the programme enables students, lecturers and employers to experience, embed and challenge nuclear behaviors and competencies, construction techniques, project and team leadership skills first hand.

http://www.cogent-ssc.com/Higher_level_skills/index.php

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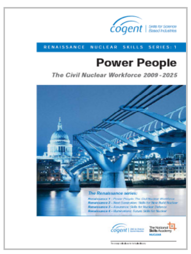
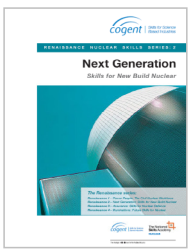
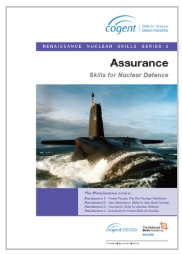
Renaissance Nuclear Series







THE UTILIZATION OF IPR-R1 TRIGA NUCLEAR RESEARCH REACTOR FOR EDUCATIONAL PURPOSES IN BRAZIL

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ABSTRACT

The Nuclear Technology Development Centre (CDTN), a research institute of the Brazilian Nuclear Energy Commission (CNEN), offers the Training Course for Research Reactor Operator (CTORP). This course is offered since 1974 and about 250 workers were certificated by CDTN. The CTORP is a three-week practical training course using the IPR-R1 TRIGA reactor which emphasizes basic nuclear reactor neutronic principles. Subjects such as the neutron multiplication factor, criticality, reactivity worth, period, poisoning, delayed neutrons and control rods are discussed in such a manner that even someone not familiar with reactor physics and kinetics can easily follow it. A few equations are used and several tables and graphs illustrate the text. A proposal to expand the training activities at the IPR-R1 TRIGA reactor is presented here, in order to meet the current demand for education and training in the nuclear area. Research projects programs would be created in the postgraduate course at CDTN. In addition to the normal reactor physics topics addressed by CTORP, new items as thermal hydraulic and instrumentation should be added and discussed in more detail. Among the new items that should be studied, may be cited: reactor thermal power calibration, fuel and water temperatures, heat transfer, fuel thermal conductivity, temperature coefficients, Design Basis Accident, etc. Validation and verification of modern neutronic and thermal-fluid dynamics computer code, such: Monte Carlo, WIMS, RELAP and CFX. Theoretical and experimental burn-up calculations and an introduction to reactor control and safety system based on the microprocessor.

1. Introduction

Rising concerns about global warming and energy security have spurred a revival of interest in nuclear energy, leading to a “nuclear power renaissance” in countries the world over. In Brazil, the nuclear renaissance can be seen in the completion of construction of its third nuclear power plant and in the government's decision to design and build the Brazilian Multipurpose research Reactor (RMB). The role of nuclear energy in Brazil is complementary to others sources. Presently two NPP are in operation (Angra 1 and 2) with a total of 2000 MW_e that accounts for the generation of approximately 3% of electric power consumed in Brazil. A third unity (Angra 3) is under construction. Even though with such relatively small nuclear park, Brazil has one of the biggest word nuclear resources, being the sixth natural uranium resource in the world and has a fuel cycle industry capable to provide fuel elements.

Brazil has four research reactors in operation: the MB-01, a 0.1 kW critical facility; the IEA-R1, a 5 MW pool type reactor; the Argonauta, a 500 W Argonaut type reactor and the IPR-R1, a 100 kW TRIGA Mark I type reactor. They were constructed mainly for using in nuclear research, education and radioisotope production. The Nuclear Technology Development

Centre (CDTN) offers the Training Course for Research Reactor Operator (CTORP) using the IPR-R1 TRIGA reactor [1]. This paper describes the Brazilian experience in application of CTORP and presents a proposal to expand the training activities at the IPR-R1 reactor, in order to meet the current demand for education and training in the nuclear area.

2. The IPR-R1 reactor

The IPR-R1 TRIGA reactor at Belo Horizonte is a typical TRIGA Mark I light-water and open pool type reactor. The fuel elements in the reactor core are cooled by water natural convection. The heat removal capability of this process is great enough for safety reasons at the current maximum 250 kW power level configuration. However, a heat removal system is provided for removing heat from the reactor pool water. The basic parameter which allows TRIGA reactors to operate safely during either steady-state or transient conditions is the prompt negative temperature coefficient associated with the TRIGA fuel and core design. This temperature coefficient allows great freedom in steady state and transient operations. The IPR-R1 was designed for training in reactor operation, neutronic and thermal-hydraulic researches and isotope production, but has been used practically only for characterization of samples by neutron activation analysis technique. Figure 1 shows two photographs of the pool and the core with the reactor in operation.

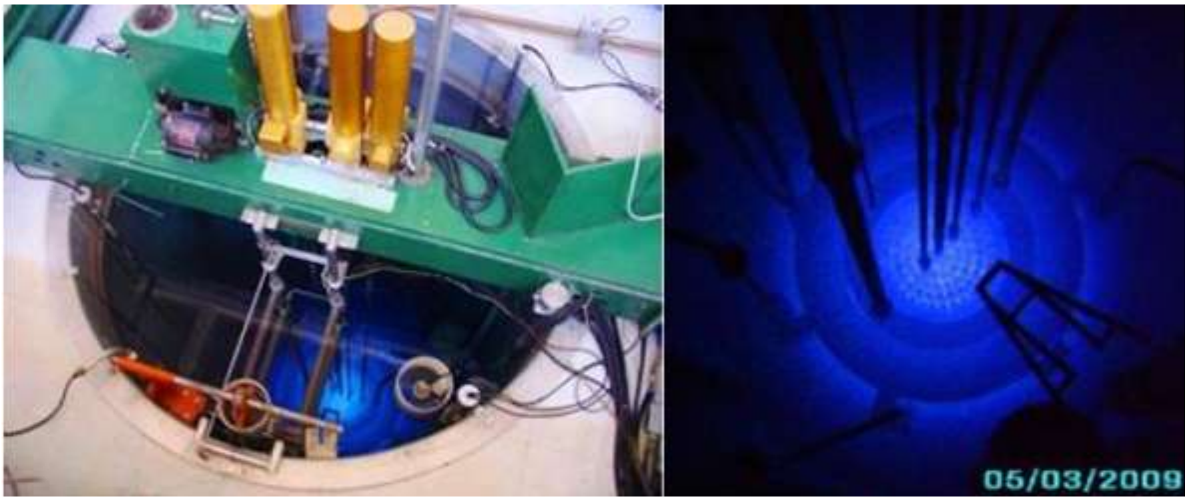

Figure 1. The IPR-R1 TRIGA nuclear reactor

3. The Operator Training Course on Research Reactors (CTORP)

One of the requirements for the commissioning of the Angra 1 Power Station, the first Nuclear Power Plant in Brazil, was the training program for future nuclear reactor operators [2]. In general, training programs in countries with experience in the nuclear area included training in research reactors operation or in reactor simulators [3], [4]. Among all the Brazilian research reactors, the IPR-R1 TRIGA was chosen to be the most appropriate for operators training. In the middle seventies, the Operator Training Course on Research Reactors CTORP [1] was structured with the aim of filling part of the reactor operators training for Angra 1, which started its commercial operation in 1985. Since then, CTORP has been given 25 times and has certified around 250 professionals for the Brazilian nuclear sector.

The content of this training program was first drawn by experts from the Nuclear Utilities Services Corporation, an American company, working in behalf of FURNAS, the reactor operator, together with Brazilian staff from the Radioactive Research Institute – IPR (later its name changed to Nuclear Technology Development Centre – CDTN). During several days, the requirements for the training program were quoted with the experimental installations available at CDTN, and adaptations were provided, either to adjust the texts to the existing equipment or to make them match the practical character intended for the training.

The CTORP is a three-week practical training course using the IPR-R1 TRIGA reactor which emphasizes basic nuclear reactor neutronic principles. Subjects such as the neutron multiplication factor, criticality, reactivity worth, period, poisoning, delayed neutrons and control rods are discussed in such a manner that even someone not familiar with reactor physics and kinetics can easily follow it. The experiments are divided into three categories: Reactor Experiments, Laboratory Experiments and Radiological Protection Experiments. The CTORP is applied indiscriminately to professionals with high school and also with higher levels. For this reason, this course avoids the application of differential and integral calculus, using only elementary mathematics. A few equations are used and several tables and graphs illustrate the text. This approach does not diminish the level of the course. The physical concepts which could be masked by a more elaborate mathematical treatment are better understood and assimilated by the trainees. Additional requirements of the program for the first applications were that the operators had some experience in the operation of thermal power stations and that they should get in advance the written description of the experiments to be made at the TRIGA research reactor of CDTN. During the practical classes, special attention is given to each trainee to participate effectively in the experiment, and everyone in the class is expected to participate in the discussions.

After the first week and the second one, the trainees do written tests to measure their progress in learning the fundamental principles. At the end of the three week course a written and an oral examination will be administrate to each student to evaluated the overall knowledge of the student at the end of the program. The practical test is necessarily applied by two experts who did not teach in the course. This procedure aims to avoid any prejudgment that could occur due to the student-teacher interaction during the course.

The final evaluation of the trainees is done on the basis of individual questionnaires, partial tests and final exams. Approval is given to trainees who obtain final grade equal or greater than 70 %. Another important point in the philosophy of this course is the student-instructor relationship. It is our intention to treat all students as equals, regardless of their company position or academic background. Further, although the students will perform many startups and other operations on the reactor control console, it is essential to remember that the licensed reactor Senior Operator is fully responsible for the reactor at all times and no action affecting the reactor shall be performed without his knowledge and consent.

The CTORP so far has been applied 25 times, and about 250 trainees received Research Reactor Operator certificates. The efficiency and success of the course have been confirmed over the years by the good performance of the workers in the later stages of the training program.

4 Proposal for a program in reactor technology using the IPR-R1 TRIGA

Nuclear Technology Development Centre (CDTN) was the first nuclear research institute in Brazil. In the sixties there was the pioneer project conducted by a research group called Thorium Group. The aim of the project was development a thorium fueled reactor. This project realized several progresses in conceptual design (fuel technology, reactor physics, thermal hydraulics, reactor vessel and materials). With the decision of the Brazilian Government to build a Westinghouse PWR (Angra1) in a turn key bases, the Thorium Group discontinued the activities in the early seventies. However, the human power and knowledge developed under the frame work of this initiative were very useful for the future Brazilian nuclear program [5]. Until the late 80s CDTN provided reactor technical support for Brazilian nuclear power plants.

During the last decade there was a recovery of several areas of research in CDTN research institute, leading to the creation of the Postgraduate Program in Science and Technology of Radiation, Minerals and Materials. In the course programme there isn't nuclear reactor technology. With the conclusion of Angra 3, the design and construction of the RMB and the resumption of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology.

It is proposed here the expansion of training activities in the IPR-R1 TRIGA reactor. Research projects programs would be created in the CDTN postgraduate program. CDTN is now an academic environment and it is an ideal place for reactor operation education. Students of the postgraduate course at CDTN, not an expert in nuclear energy, would be practice on reactor technology, enabling them to know the terminology referring to this field and to follow the renaissance of this area.

In order to perform a research program and training in postgraduate students, using the IPR-R1 reactor, is in progress the update of its instrumentation for monitoring of operational parameters. The new system would be microprocessor based, and would utilize large LCD displays that are typical of state-of-the-art control rooms. So, the graduates would find the same type of control system of a typical reactor control room.

A digital system is being developed to monitor, store and simulate the behavior of operating parameters. Figure 2 shows two user-friend interface of the system, in two computer video screens. In the foreground can be seen the calibration curve of a control rod. The graphical interfaces will provide greater reliability and transparency in IPR-R1 TRIGA reactors operations. Besides allowing online reactor parameters visualization and transmission through the internet or in the networks, the data can be stored and made available for exercises.

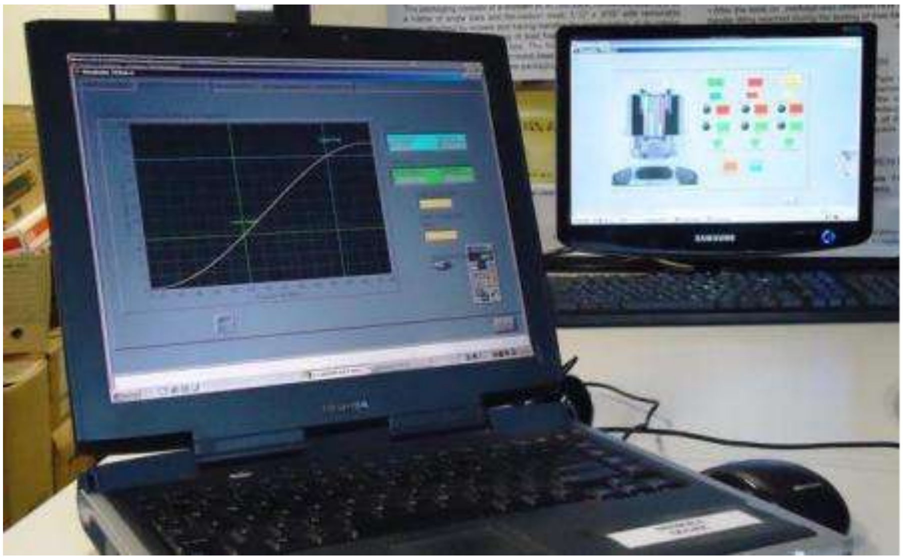

Figure 2. Digital system for simulation of IPR-R1 TRIGA neutronic parameters

In addition to the normal neutronic and radiation protection topics addressed by CTORP, new items as thermal hydraulic and instrumentation should be added and discussed in more detail, mainly in the postgraduate program at CDTN. Among the new items that should be studied, may be cited:

- Validation and verification of reactor physics and kinetics computer codes, such as: MCNP, WIMS-D and TRIGLAV-W.
- Validation and verification of thermal-fluid dynamics computer codes, such as RELAP and CFX.
- Development of codes, including coupling of neutronic and thermal-hydraulic codes.

- Calculation of various research reactor physics parameters and models.
- Basics of burn-up calculations and experiments.
- Core optimization.
- Safety requirements, strategic planning and IAEA standards for research reactors.
- Design Basis Accident (DBA).
- Reactor thermal power calibrations and heat transfer.
- Fuel and water temperatures, and heat transfer.
- Reactor instrumentation, digital control and safety system based on the microprocessor.

5. Conclusions

With the revival of the Brazilian nuclear program, it is anticipated a large demand for training in nuclear technology. The IPR-R1 TRIGA research reactor at Nuclear Technology Development Center (CDTN) was used in the past for education, particularly for the needs of the Brazilian nuclear power plants operators training. This paper proposed the expansion of training activities at the IPR-R1 reactor. Research projects programs would be created in the postgraduate course at CDTN. In addition to the normal neutronic topics addressed by CTORP course, new fields as thermal hydraulic and instrumentation should be added and discussed in more detail. In order to perform a research program and training using the IPR-R1 reactor is needed the update its instrumentation for control of operational parameters.

6. Acknowledgements

The Research Support Foundation of the State of Minas Gerais *(FAPEMIG)* and the Brazilian Council for Scientific and Technological Development *(CNPq)* have supported the purchase of some equipments for the IPR-R1 TRIGA reactor modernization, through research projects.

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AN EDUCATIONAL INITIATIVE BETWEEN THE UNIVERSIDAD POLITÉCNICA DE MADRID AND SPANISH YOUNG GENERATION IN NUCLEAR (JÓVENES NUCLEARES): THE SEMINAR OF NUCLEAR SAFETY IN ADVANCED REACTORS

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ABSTRACT

Jóvenes Nucleares (Spanish Young Generation in Nuclear, JJNN) is a non-profit organization and a commission of the Spanish Nuclear Society (SNE). The Universidad Politécnica de Madrid (Technical University of Madrid, UPM) is one of the most prestigious technical universities of Spain, and has a very strong curriculum in nuclear engineering training and research.
Finishing 2009, JJNN and the UPM started to plan a new and first-of-a-kind Seminar in Nuclear Safety focused on the Advanced Reactors (Generation III, III+ and IV). The scope was to make a general description of the safety in the new reactors, comparing them with the built Generation II reactors from a technical point of view but simple and without the need of strong background in nuclear engineering to try to be interesting for the most number of people possible.
After a great effort from JJNN with the support of the UPM, the Seminar took place in April 2010 at the Industrial Engineering School (ETSII). The lessons were conducted by young professionals, experts in the field, that belong to the Young Generation of the Spanish Nuclear Society and to companies and institutions related with the nuclear energy.
The Seminar was structured in four sessions. In each of them, a comparison between previous and new technologies was done, regarding safety perspective.
The first day there was an introduction lesson to PWR safety and just after a lesson of AP1000 safety, to clearly see the advances in safety systems in the new technologies. Same comparison took place between the BWR - ABWR/ESBWR and PWR – EPR in the other sessions.
For the Generation IV reactors there were a specific lesson, longer that the others to cover all the specific characteristics of these kind of future reactors. A special lesson about the ADS (Accelerator Driven Systems) took place to emphasize the importance of this new development in the nuclear energy sustainability.
The seminar was very popular, with nearly 70 assistants each day, from the university, nuclear companies and research centers. After each session there were very interesting and animated discussions between the lecturers and the public that demonstrated the interest of the assistants for the subjects taught.
Both, the UPM and the SNE, strongly supported the seminar: the opening session was conducted by the Vice-Chairman and Nuclear Engineering professor of the UPM, Emilio Mínguez and the closing session was conducted by the president of the Spanish Nuclear Society, Mr. José Emeterio Gutiérrez.
A really important fact is that in 2011, the Seminar starts to be an official subject of the UPM, which will help to develop the lessons and the materials.
The assistants were asked for a highly detailed feedback of each one of the lessons and those opinions have helped to improve the program for the 2011 Seminar.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares) is a commission of the Spanish Nuclear Society (SNE), whose main goals are to spread knowledge about nuclear energy among the society.

One of the scopes of the seminar was to make a general description of the new reactors from the point of view of the safety and in reference with the operating reactors. The course lasted four days and was divided in two lectures of one hour each day, except the last day that consisted of a two hours lecture.

In the first and second lecture a review of the principal systems of a Westinghouse and a KWU PWR of and their design differences was done, including their different behavior against transients. Those characteristics were compared with the AP1000 ones, to clearly seen the advances in the new design.

The same analogy was done in the following two lectures with the BWR of GE and ABWR and ESBWR of GE. The third day two lectures were given, the first one was about operation and the safety systems of the EPR of AREVA. The second one was an introduction to the ADS and the physics of transmutation. In the last lecture of two hours, an introduction to the new Generation IV designs was done from the point of view of the advances in nuclear safety that this new generation incorporates.

The objective of the seminar is to show clearly the advances that have been obtained in the section of safety with the new reactors, from a technical but simple point of view and without needing great previous nuclear engineering knowledge.

2. Seminar Development

The opening session was chaired by the Vice-rector of the Universidad Politécnica de Madrid and full-professor of Nuclear Technology Dr. Emilio Mínguez and by the Spanish Young Generation in Nuclear president in that moment, Miguel Millán.

Figure 1. Seminar opening session

The Seminar was highly crowded every day, with more than 70 daily attendees. There was a very active audience participation with animated debates after every lecture. The closing session was presented by the president of Jóvenes Nucleares and the president of the Spanish Nuclear Society, D. José Emeterio Gutiérrez.

After the brief speech of each president, the diploma ceremony started with the documentation given to the audience. To finish the closing act, it took place a Spanish wine, courtesy of the University.

Figure 2. Seminar Closing Session

3. Surveys results

The participation filling the surveys was estimated into 50% of the attendees. It is a satisfactory result due to the voluntary aspect of the surveys.

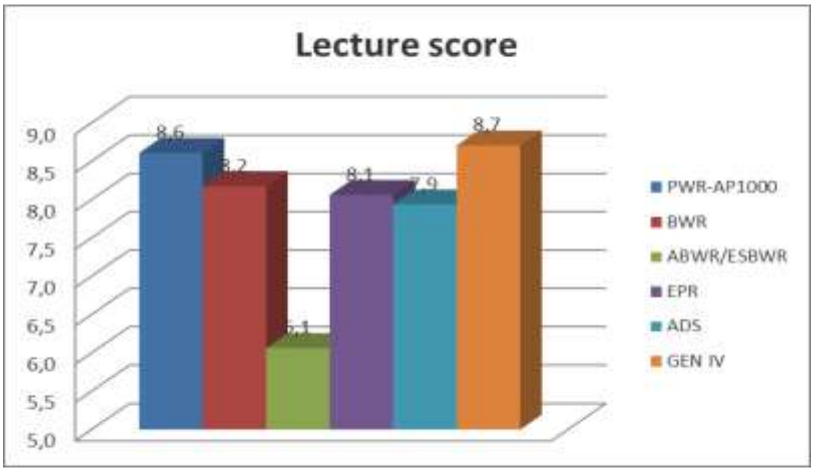

Figure 3. Lecture score

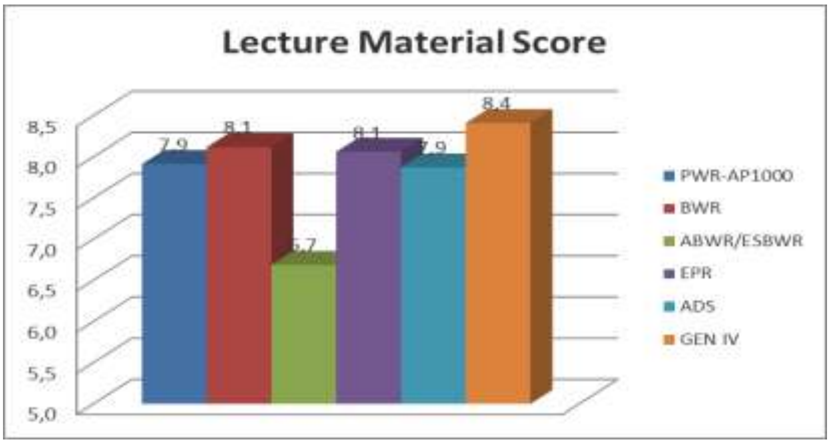

Figure 4. Lecture Material Score

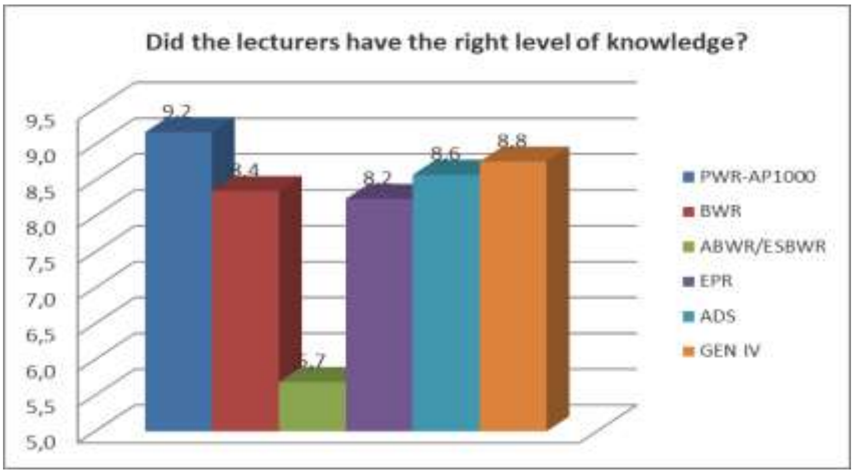

Figure 5. Lecturers level of knowledge score

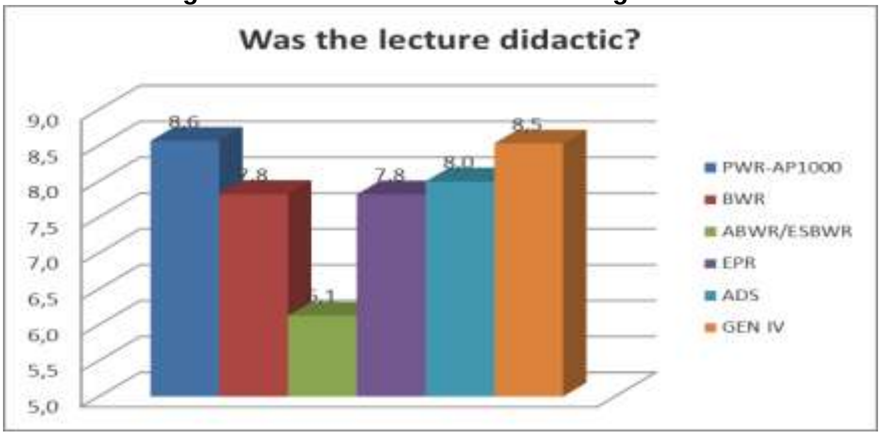

Figure 6. Didactic of the lectures score

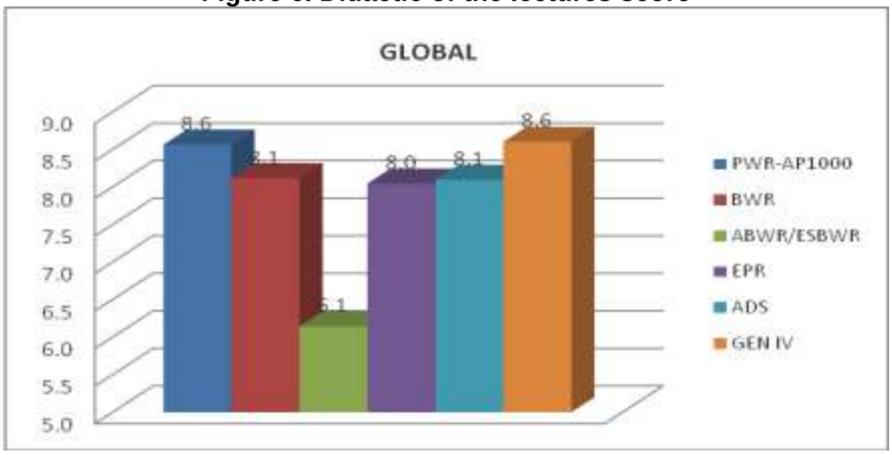

Figure 7. Global Score

The surveys had two different parts: in the first one, some fields were scored from 0 to 10, see Figures 3 to 7, and the second part was a free text one, where the attendees could write down their suggestions and comments about the Seminar.

As a first conclusion of the surveys, the score of the lectures, the lecturers and the lectures material was satisfactory. More important than that, as it was one of the main scopes of the Seminar, the lectures were valuated as didactic. This was highly difficult to get, as the level of knowledge of the audience was very varied.

4. Lessons Learned

From the multiple and very valuable comments from the attendees, some of them have been extracted, as they are lessons learned for the on forward Seminar sessions. For example:

- The Seminar should last more to describe with more details the lectures.
- The timetable should be respected.
- It is important to have all the material available at the beginning of the lecture, to follow it and take notes during the presentation.
- The Seminar should be valuated with UPM ECTS.
- It is recommendable to have a more specific introduction of the PWR of Westinghouse, separated of that one about PWR of KWU, as they are too different from each other.
- ABWR and ESBWR are too different to be in the same lecture.
- The time dedicated to the new reactors should be longer that the old reactor´s time.
- The detailed systems drawings are too complex to be seen by the audience.
- It could be interesting to see more images of the reactors under construction.
- The technical videos are very good, but some of them are too corporative.

The following comments describe the most valuated aspects of the Seminar:

- The ambient and the subjects were very interesting. It was a good point to present different reactors to compare them during the same session.
- Good quality of the debates answers and questions.
- High attendance and audience collaboration.
- Interesting state-of-the-art subject
- The lectures were clear enough for somebody that did not know all the concepts.

5. Conclusions

Once all the surveys were processed and all the comments were classified, some improvements were implemented in the 2011 edition of the Seminar:

- The Seminar lasted more hours (15 h) and it was valuated with ECTS
- The structure was changed to 1h of the old reactor + 1.5 h of the new one
- There was one lecture for PWR-W and another for PWR-KWU
- There was one lecture for ABWR and another for ESBWR
- All the documentation was given at the beginning of the Seminar.
- A first day lecture about “Introduction to Nuclear Safety” was created.
- A new lecture of High Temperature Reactors was created.

In this 2011 edition, the Seminar is still alive, open to comments and evaluated with surveys, to make it better year after year.

HELPING TO CLOSE THE GENERATIONAL GAP IN NUCLEAR: THE SEMINARS AND CONFERENCES OF SPANISH YOUNG GENERATION IN NUCLEAR (JÓVENES NUCLEARES)

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ABSTRACT

As in each country of Europe with nuclear power, there is a clear gap between those generation that have built the power plants in the eighties and the new generations with less than ten years of experience in the nuclear field.

From its creation, Spanish Young Generation in Nuclear (Jóvenes Nucleares) has as an important scope to help transferring the knowledge between those generations in the way that it can be possible. Some years ago, JJNN have started organizing seminars periodically trying to cover as many areas as possible in the nuclear engineering field, and some of them outside the industry but related with it.

Over the last years there have been some really interesting topics, from the communication in the nuclear industry like "How to manage with the journalists?" and "Communication in crisis", through the energy seminars like "The Spanish Electricity Market" to the seminars about the present and the future of the nuclear energy, for example "Past, present and future of the nuclear fuel cycle in Spain", "Uranium for the Nuclear Renaissance", "The firsts AP1000 in China" and "The Nuclear Renaissance in UK". All of the seminars were taught by experts on the issue and the most part of them were very experience people of the industry in order to share their knowledge with the young public that assisted to the seminars, more than 40 people in average, some of them nearly 100.

It has been done also a cycle of seminars called "Chernobyl 2009" with some of the most relevant professionals and researchers of Spain. The seminars included in the cycle were "The base of the original RBMK design. Implications on the Chernobyl-4 accident, introduced improvements", "Effects on the population of the Chernobyl accident", "Chernobyl vs. TMI: searching the root cause" and "Facts and Hypothesis of the Chernobyl "experiment""

The experience of these seminars is highly positive, both for the experienced speakers and the young audience. It is being possible through these seminars to bring the knowledge of the two generation closer and to answer all of these questions that only those who have built the reactors are able to answer.

Based on that idea, it will start in 2011 a new cycle of seminars based on the experience of the Spanish nuclear power plants construction, to bring light and share lessons learned with the generation that will build the new reactors in Spain in the future.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares) is a commission of the Spanish Nuclear Society (SNE) which main goals are to spread knowledge over the society about nuclear energy.

Over the last years there have been some really interesting conferences organized by Jóvenes Nucleares, covering topics from the communication in the nuclear industry like "How to manage with the journalists?" and "Communication in crisis", through the energy seminars like "The Spanish Electricity Market" to the seminars about the present and the future of the nuclear energy, for example "Past, present and future of the nuclear fuel cycle in Spain", "Uranium for the Nuclear Renaissance", "The firsts AP1000 in China" and "The Nuclear Renaissance in UK". All of the seminars were taught by experts on the issue and the most part of them were very experience people of the industry in order to share their knowledge with the young public that assisted to the seminars, more than 40 people in average, some of them nearly 100.

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In this paper, some of these conferences will be presented, as well as how they help transferring knowledge between generations.

2. Conferences

Jóvenes Nucleares has a long tradition of interacting with the media, that is why the topic of two really interesting conferences promoted by Jóvenes Nucleares was “communication”. To get over the subject, it was a need to find somebody enough talkative and friendly to connect with the audience and this person was Piluca Nuñez, communication director of the Spanish Nuclear Forum. In the first conference, *“How to manage with the journalists?”* she talked about the difficulties that the nuclear energy has in terms of public acceptance. She reminded that one of the problems is the lack of adequate information in the media, which is not always enough clear and reliable. The main goal was to learn how to communicate effectively with the journalists to give the adequate message to them.

Figure 1. Piluca Nuñez at the “How to deal with journalists?” conference

In the presentation some examples and experiences were related to show how difficult can be to give a message of calmness when everybody is trying to find a message of alarm, which is very typical in this field. The conclusion was that is very important to have the message clear before starting the communication to avoid boring or confusing the interviewer with technical explanations that could be not so clear for the people outside the nuclear field.

In the second conference called “*Communication in crisis”,* she focused the attention on how to be efficient in the communication during a crisis, which is especially relevant and useful nowadays. The conference was very popular and well appreciated by the audience, with many interesting questions.

Some years ago, the Spanish electricity market became a free-basis one and Jóvenes Nucleares saw the need of inform to the people about the new situation. In the conference called “The Spanish Electricity Market”, the lecturer Víctor Niharra Hernández, from the Spanish Market Operator, explained the audience with simple words but very clear how the market is composed.

Figure 2. Víctor Niharra at “The Spanish Electricity Market” conference

The lecturer talked about the different laws of the market and the comparing between the Spanish Electricity market and some European ones. After the lecture, there was an animated discussion with the lecturer.

As the nuclear Renaissance is becoming a fact, Jóvenes Nucleares though that it could be convenient to do a series of conferences to inform the public about the different aspects of the nuclear new age.

The first conference “UK and the Nuclear Renaissance” was based on the new ideas of construction in Europe from the perspective of one of the utilities that are going to build plants in the UK, the international Spanish company Iberdrola. The lecturer, Manuel Prieto Urbano, started the lecture talking about the beginning of this new age in UK with the energy planning of the Government in 2008, with the decision of starting the dismantling of the old power plants and the construction of new ones in the next decades.

Figure 3. Manuel Prieto at “UK and the Nuclear Renaissance” conference

The main part of the conference was based on the Generic Design Assessment process, which is the licensing basis of the new reactors, very different one from the old licensing ones.

Finally, he spoke about the different energy planning of the political parties, trying to guess if a Nuclear Renaissance is possible in Spain.

The second conference of the “New Age” was about the AP1000 construction in China and the Spanish collaboration though Westinghouse Electric Spain. The lecturer, Miguel Palazuelos, spoke about the challenges and success of the Chinese four unit construction and the lessons learned for the future constructions in Europe and the USA. As the construction is modular based, the making of the equipment and the site works are parallel, so the planning is going very well and it is expected to finish on time.

The third conference was called “Uranium for the Nuclear Renaissance”. In this conference, the lecturer, Francisco Tarín from ENUSA, the Spanish fuel company, spoke about the uranium resources that are actually available and the future perspectives.

Figure 4. Francisco Tarín at “Uranium for the Nuclear Renaissance” conference

The key issue was the fact that with this planned development, it will be enough fuel for the future, as there are many unexploited resources that will be used if the uranium is more expensive in the future.

In the last series of thematic conferences, Jóvenes Nucleares faced the big challenge on every debate about nuclear energy. In a project called “Chernobyl 2009”, four different conferences were planned plus a trip to Chernobyl paid by Jóvenes Nucleares.

The conferences were: “Chernobyl vs. TMI2” by Juan Manuel Blanco, “Facts and hypothesis of the Chernobyl “experiment”” by Luis E. Herranz, “Chernobyl: effects on the population” by Eduardo Sollet, “RBMK reactor design and the Chernobyl accident” by Agustín Alonso

Figure 5. Jóvenes Nucleares at Chernobyl

3. Conclusions

The experience of these conferences is highly positive, both for the experienced speakers and the young audience. It is being possible through these seminars to bring the knowledge of the two generation closer and to answer all of these questions that only those who have built the reactors are able to answer.

Based on that idea, in 2011 it will start a new cycle of seminars based on the experience of the Spanish nuclear power plants construction, to bring light and share lessons learned with the generation that will build the new reactors in Spain in the future

THE STATUS OF NUCLEAR EDUCATION IN ROMANIA

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ABSTRACT

There is only one NPP in Romania, named Cernavoda NPP, having two units CANDU 6 type in operation and another two same type units prepared for restart after 20 years structure conservation in different stages. For this NPP a good infrastructure was created including training operators' centre and energetic lyceum in the town. For the next two units must have new multidisciplinary teams for operation. Only the University Polytechnic of Bucharest, Energetic Faculty had section or programs regarding nuclear energy. AREN as scientific NGO is involved on developing yearly programs in order to promote understanding and knowledge of safety and radioprotection regarding the restarting the Cernavoda U3+U4 at every level of society so to obtain public acceptance and trust in operating team. AREN as ENS member disseminate the nuclear information and prepare update information about nuclear field focusing to NPP and issued "NUCLEAR ENERGY" magazine. AREN also has a participation to some European programs regarding education, training and permanent instruction.

1. Introduction

1.1 Nuclear energy in Romania preliminary actions

Romania began on 1960 his nuclear program by option process regarding type of reactor and some meetings between a Romanian team of specialists in nuclear physics and American and Canadian specialists and authorities. This activity was very difficult to do because the cold war and political pressure made by "Big Russian Brother" had limit of Romanian actions. Also the international configuration and restriction regarding using enriched uranium for power and prohibited enriched uranium facility supply to the Eastern European countries guided the Romanian specialists group to make a proposal to government controlled by communist party to choose a reactor type using natural uranium as fuel. Some disastrous natural events till 1969 delayed the nuclear power type reactor option. From 1970 Romanian team of specialists recommended to adopt CANDU PHWR as national type reactor. In the same time technical discussion done with the Soviet Union for implementing in Romania the VVER 440 MWe reactor and a long time was spent regarding safety and containment systems. As is knew this type of reactor was built on Loviisa site but having Westinghouse containment and safety systems. So in our country from 1970 started the construction the heavy water pilot facility near Ramnicu Valcea town and Energetic Nuclear Reactors Institute having a Triga research reactor a natural nuclear fuel pilot using the yellow cake from Feldioara factory near Brasov town. In the same period the Polytechnic University Bucharest-Faculty of Energy shared a section dedicated to nuclear engineering and many other high school included in their programs education in nuclear field. The difficulties were regarding by lack of nuclear knowledge and hard access to the specialized nuclear documentation, programs and regulations. The grants offered by IAEA Vienna for education of specialists involved in design, construction and management of the nuclear projects at Argonne Laboratory offered a good opportunity for better understanding of real safety care. Basically can be concluded that in the first period of founded first national nuclear power program was used only US CFR part 50 and part 100 as applying rules and some first information regarding CANDU type reactor implemented in Canada.

1.2 Nuclear power plant in Romania

The first Romanian NPP was located at 180 km east of Bucharest, in Constantza County at about 2.5 km SE from Cernavoda town, on the north side of the Danube-Black Sea Channel where merged to Danube River. This NPP was planned to be equipped with 5 units of CANDU 6 reactor type and ANSALDO–GE turbine of 706.5 MWe maximum power per unit at 15^0 C cooling water temperature. The on site work began in 1979 by excavation earth, temporary building and infrastructure. The erection of NPP was too long regarding regular schedule due to financial aspects and distortions by political intrusions. First nuclear unit is in commercial operation from 1996 and second nuclear unit from 2007, both covering now around 18-20% from yearly electric power of Romanian consuming.

Fig 1. Romania map of nuclear companies

The remaining units were stopped in different stages of construction and putted under conservation procedures, more or less. Romanian government announced in 2008 his decision to restart the works on site for Units 3+4 by private and state funds agreement. Now the build up and put in operation time of this units depend of financing and education/training the new workers involved in construction, fabrication, equipment setting and testing in order to obtain the permit for every step from nuclear authorization body. The existing Heavy Water Plant (ROMAG PROD) sited near Drobeta Turnu Severin town close to Danube River, in operation from 1987, supply heavy water having isotopic concentration min. 99.78 % wt. D_2O for normal operation reactor units. Nuclear Technology and Engineering Centre (CITON) assure nuclear engineering and design, Nuclear Research Institute (ICN) assure R & D support, Energetic Faculty and Faculty of Physics trains graduated nuclear engineers and physicists. The nuclear fuel bundles are supplied by Nuclear Fuel Factory (FCN) sited in the same area with ICN, close to Pitesti town. The yellow cake for FCN is supply by preparation factory Feldioara by processing of uranium ore extracted from Romanian mines. All main support for Cernavoda NPP is assured from national resources can be concluded. In the above Fig 1 there are showed the main supporting units including the training and education centre. The status of civil works of Cernavoda Unit 3+4 can be deducted from below Fig 2 and also are showed the Unit 1 and Unit 2 in operation.

Fig. 2 The artistic picture of four units Cernavoda NPP

2. Romanian education in nuclear field

2.1 Nuclear heritage

The decision of site for first nuclear NPP CANDU at Cernavoda was much disputed but Romanian and Canadian specialists decided finally to be the best solution. Before this decision the education of Romanian specialists involved in nuclear power plant projects and in National Nuclear Program was based from cropping the copies of US CFR, ASME & ACI Codes, nuclear power plant safety description, magazines, journals or other publications. Also drafts copies of Safety Guides issued by IAEA Vienna were a real help for understanding nuclear safety philosophy. Translation in Romanian language the specific technical nuclear words, sometime create some contradiction between engineering designers groups or/and university didactic groups. The technical documentation support gave us by AECL after licence agreement was in charge offered to Romanian specialists first detailed data, manuals and standards in order to understanding and increase the knowledge about CANDU 6 work preparation, erection, mounting, equipment testing and preoperational phases. So after 10 years from starting point of Cernavoda NPP other teams worked to select new sites for new CANDU power plant on inner rivers. During this period the technical discussion regarding Russian VVER reactor type was passed to the last priority. But from education point of view this pre project documentation had good effects in order to understanding and knowledge the radioprotection and safety nuclear power plant aspects and importance of people acceptance by good education and information spread.

2.2 1990 milestone

The events from December 1989 gone to the wind of discontinuity, sharing and delays of works, fabrication and equipment supply in regular schedule of Cernavoda NPP building units. Situation itself creates a great gap in developing of education and training for many reasons. A lot of workers having a high skill in nuclear was turned to the other projects or retired by aging. Many companies, institutes and universities reduced their staffs which were oriented to classic building or emigrated after 1990 even the high qualified persons in nuclear engineering, design and operation. A little revival was for Unit 2 one of difficulties regarding European cooperation consists into difference between NPP reactor types from western countries and CANDU type reactor. Must underline CANDU type of reactor is single in the eastern countries region who meets all IAEA safety recommendations and requirements. A real helps for Cernavoda Unit 1 and Unit 2 operators were bring from the joins to CANDU Owners Group (COG) and World Association of Nuclear Operators (WANO) by exchanging of information. Cernavoda NPP has a training and public relation centre building having a command room simulator CANDU 6 in order to make operators training, technical staff training and many programs for education of other category of persons. This centre has basically main importance in NPP operating and maintenance continuous training.

Fig 3 NPP Cernavoda site and training building centre pozition

After Romanian govern announcement regarding restart the works for Unit 3+4 from Cernavoda NPP all companies, institutes, university and others tried to cover the lack of education, training and population information.

3. Present and future in Romanian nuclear education

3.1 Civil society in action

In the context of most frequent changes of priorities in Romanian society and politics parties the Romanian Nuclear Energy Association (AREN) NGO founded in 1990, adhered to European Nuclear Society one year later, tried to maintain the level of good information and/or education of people involved in nuclear or population by spread all nuclear information gained from NUCNET and from other sources by bilateral agreement. Also AREN organized at every 2 years international energy nuclear symposium and his member participated/ attended other international conference regarding nuclear energy field and radioprotection. AREN has a strong cooperation with Romanian Radioprotection Society (SRRp), affiliated to IRPA, in order to have very good information regarding nuclear energy and radioprotection fields. AREN has yearly programs in order to organize the following:

a. Nuclear Energy Days:
   i. Schools children contest designs/drawings (painting) shared by 4 age category regarding their perception of nuclear power on life;
   ii. Schools children contest essays regarding their perception about nuclear;
   iii. Itinerary exhibition with awarded paintings and essays;

iv. “Ionel Purica” award accorded to personality having most contribution on nuclear field developing;

b. “Nuclear Energy” magazine issued periodical;
c. Information campaign about real aspects regarding nuclear of peoples, local and governmental authorities;
d. NUCNET bulletins distributions;
e. WiN conferences and discussions regarding nuclear energy with school children shared in 2 two groups, primary school and lyceum (teenagers), in 4 sessions per year;
f. Participation to the European program “Implementing Public Participation Approaches in Radioactive Waste Disposal”;
g. Co organizer of yearly conferences of AREN’s societies members;
h. Selection and organize of scholar group from one of Bucharest lyceum to take a part to « Les Ateliers de la Radioprotection » at Grenoble, France, in conection to ENETRAPII program;
i. Participation at other international conferences an spread the information collected, now focused on Fukushima NPP highest level accident;
j. Develop and speed up the connection and distribution of educational booklet regarding nuclear energy;
k. Nuclear book issued having as authors AREN’s members,
l. Collaboration with ROMATOM and SRRp in order to promote soon the program of education of nuclear safety culture,

3.2 University support

Polytechnic University of Bucharest participates to the European universities or institutes to education program development.

- The Energetic Faculty has in his program the education by International master’s degree and doctorates in nuclear engineering, radioprotection and safety;
- Postdoctoral training at universities having international reconnaissance in nuclear sciance or laboratories like Argonne National Laboratory training personel in nuclear planning, construction, instalation, testing, design, chemical, reactors engineering and others disciplines postdoctoral training and education;
- Participate at ENETRAP II by extending network to develop European high-quality "reference standards" and good practices for education and training in radiation protection (RP), specifically with respect to the radiation protection expert (RPE) and the radiation protection officer (RPO) and harmonization of practice and methods.

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INTRODUCING NUCLEAR ENERGY TO HIGH-SCHOOL STUDENTS: THE SPANISH YOUNG GENERATION IN NUCLEAR (JÓVENES NUCLEARES) LECTURES

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ABSTRACT

One of the main goals of Spanish Young Generation (JJNN) is to spread knowledge about nuclear energy, not only pointing out its advantages and its role in our society, but also trying to correct some of the ideas that are due to the biased information and to the lack of knowledge.
With this goal in mind, lectures were given in several high schools, aimed at students ranging from 14 to 18 years old. This paper explains the experience accumulated during those talks and the conclusions that can be drawn, so as to better focus the communication about nuclear energy, especially the one aimed at a young public.
In order to evaluate the degree of knowledge and information on a specific topic of a given group of individuals, statistical methods must be used. At the beginning of each lecture (and sometimes at the end, in order to evaluate the impact of the talk) the students were submitted to a short survey conducted by Spanish Young Generation. It consisted in eight questions, dealing with the relation between the main environmental issues (global warming, acid rain, radioactive waste…) and nuclear energy. The answers can be surprising, especially for professionals of the nuclear field who, since they are so familiar with this topic, often forget that this is just the case of a minority of people. A better knowledge of the degree of information of a given group enables to focus and personalize the communication. Another communication tool is the direct contact with students: it starts with their questions, which can then lead to a small debate. If the surveys inform about the topics they are unaware of, the direct exchange with them enables to find the most effective way to provide them the information. Of course, it depends a lot on the public attending the talk (age, background…) and on the debate following the talk: a good communication, adapted to the public, is necessary.
Therefore, the outcome of the performed exercise is that Spanish teenagers have still a lack of knowledge about nuclear energy. We can learn that items that are evident for nuclear young professionals are unknown for high school teenagers.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares) is a commission of the Spanish Nuclear Society (SNE) which main goals are to spread knowledge over the society about nuclear energy.

One of the difficulties is not only pointing out its advantages and its role in our society, but also trying to correct some of the ideas that are due to the biased information and to the lack of knowledge.

With this goal in mind, lectures were given in several high schools, aimed at students ranging from 14 to 18 years old. This paper explains the experience accumulated during those talks and the conclusions that can be drawn, so as to better focus the communication about nuclear energy, especially the one aimed at a young public.

2. The lectures and the surveys

In each one of the high schools, the lectures are conducted by a JJNN member which normally is a young worker of the nuclear area. It helps to reduce the gap in the communication between high school students and the lecturer, as the knowledge transfer is known to be more effective as the age difference is lower.

The lectures are based on general information about nuclear energy. First of all, the lecturer provides some basic concepts about nuclear physics and how the electrical energy is produced from uranium. Then, the idea is to bring the audience a broad vision of every field in nuclear energy: nuclear safety, radiation protection, waste management, etc.

The most popular questions of the students are normally those which involve nuclear accidents such as Chernobyl and, unfortunately from March, Fukushima and waste management. The students are eager to learn the real data and precise information about these popular areas and how reliable the news they have heard are.

In order to evaluate the degree of knowledge and information on a specific topic of a given group of individuals, statistical methods must be used. At the beginning of each lecture (and sometimes at the end, in order to evaluate the impact of the talk) the students were submitted to a short survey conducted by Spanish Young Generation.

It consisted in eight questions, dealing with the relation between the main environmental issues (global warming, acid rain, radioactive waste…) and nuclear energy.

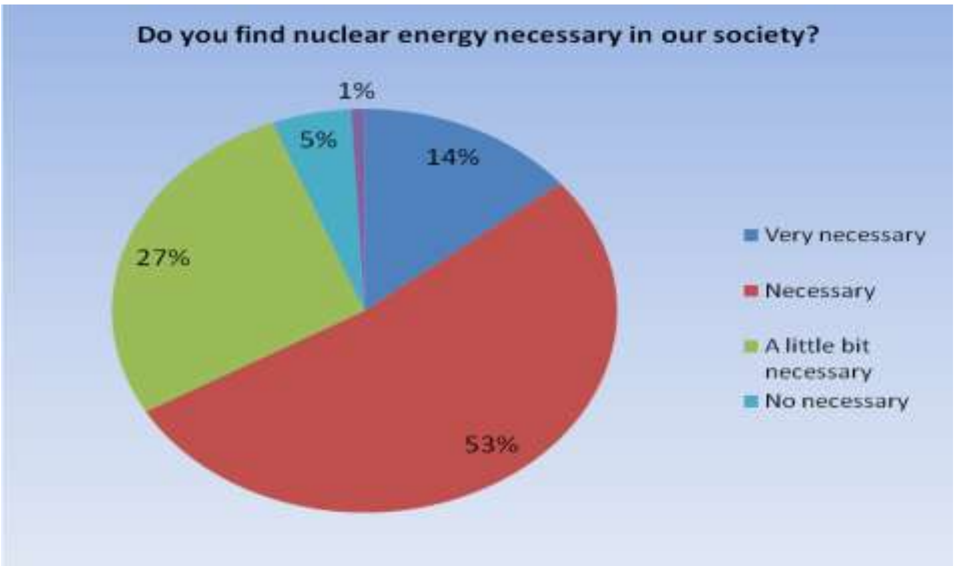
Some of the answers can be surprising; especially for professionals of the nuclear field who, since they are so familiar with this topic, often forget that this is just the case of a minority of people. A better knowledge of the degree of information of a given group enables to focus and personalize the communication.

Another communication tool is the direct contact with students: it starts with their questions, which can then lead to a small debate. If the surveys inform about the topics they are unaware of, the direct exchange with them enables to find the most effective way to provide them the information.

Of course, it depends a lot on the public attending the talk (age, background…) and on the debate following the talk: a good communication, adapted to the public, is necessary.

3. Statistical results of the surveys

In this section, the results of most relevant answers to the survey are shown.



- **Figure 1. Answers to the question: Do you find nuclear energy necessary in our society?**

The results are surprising since Spanish people have always been against nuclear energy

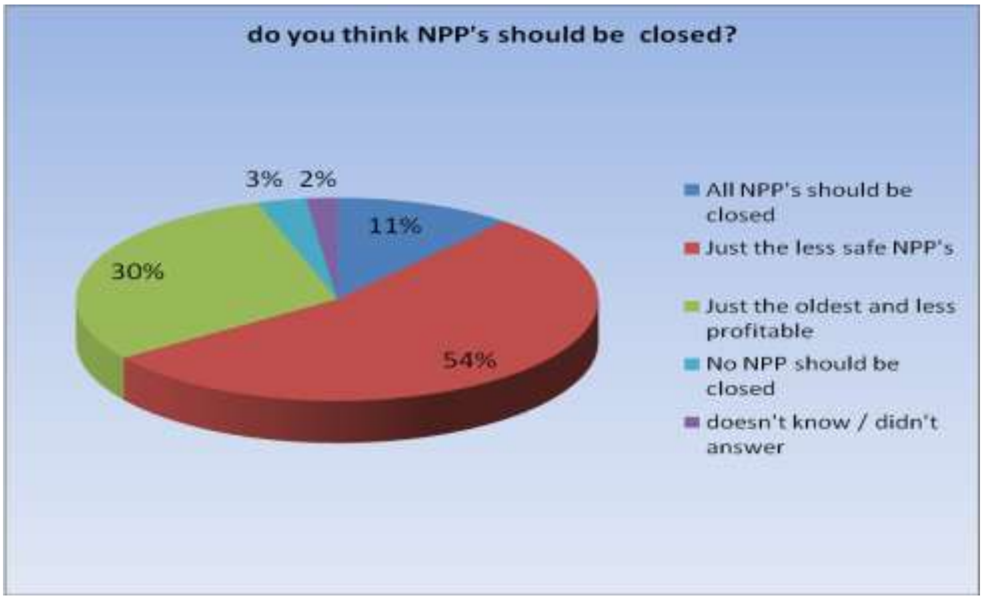


Figure 2. Answers to the question: do you think NPP's should be closed?

Most of the students attach importance to nuclear safety, more than plant profitability

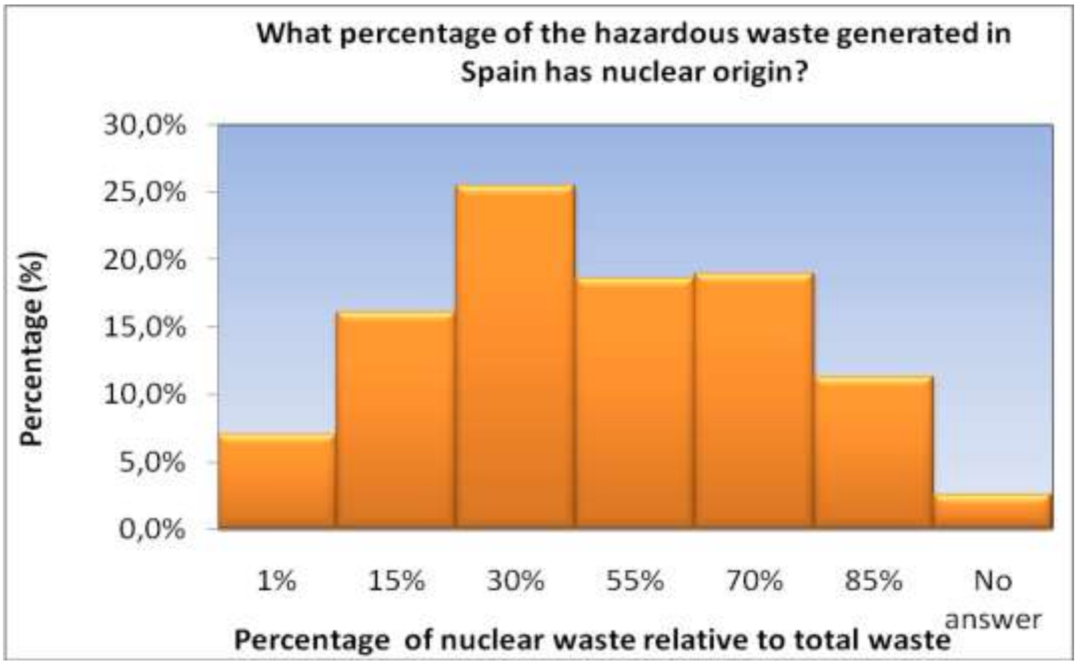


Figure 3. Answers to the question: what percentage of the hazardous waste generated in Spain had nuclear origin?

The answers show a wide range of students' opinions; it is important to highlight that less than 8% of the students answered this question correctly.

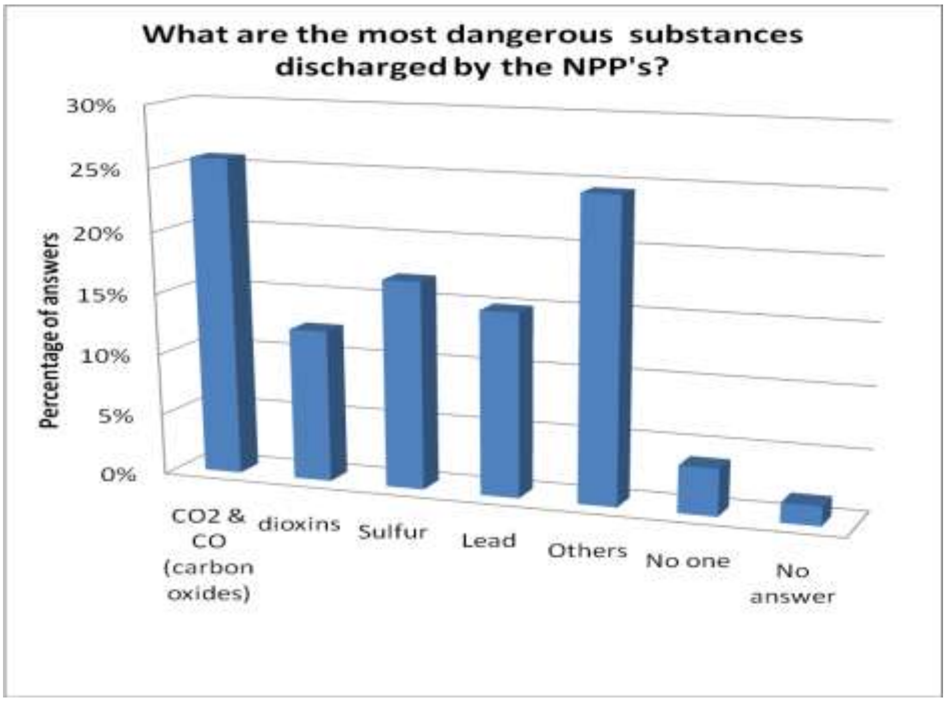


Figure 4. Answers to the question: what are the most dangerous substances discharged by the NPP's?

The ignorance about what kind of substances can discharge a nuclear plant is fairly widespread and wrong nonsense answers are also typical.

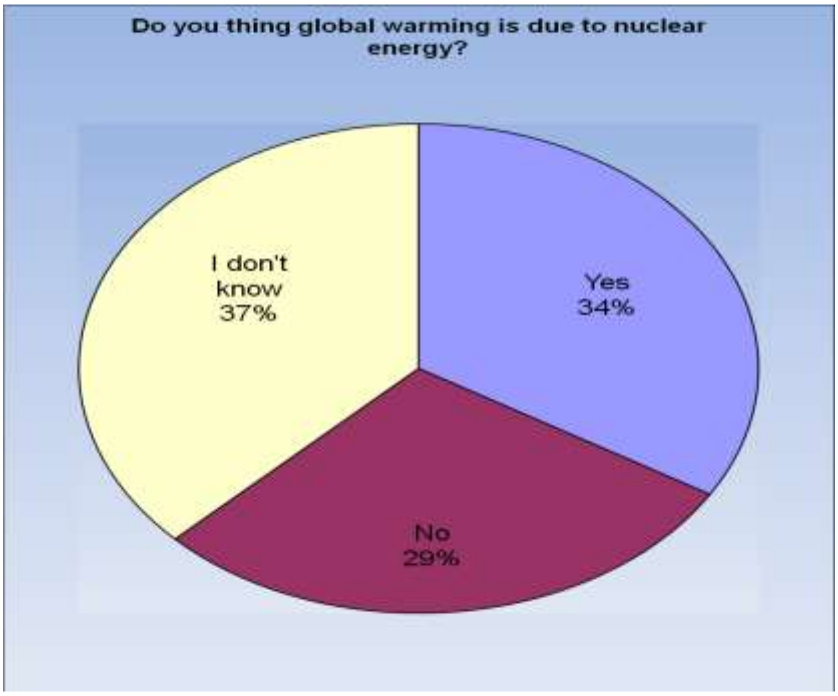


Figure 5. Answers to the question: Do you thing global warming is due to nuclear energy?

Only a third of the students are sure that nuclear energy has nothing to do with climate change.

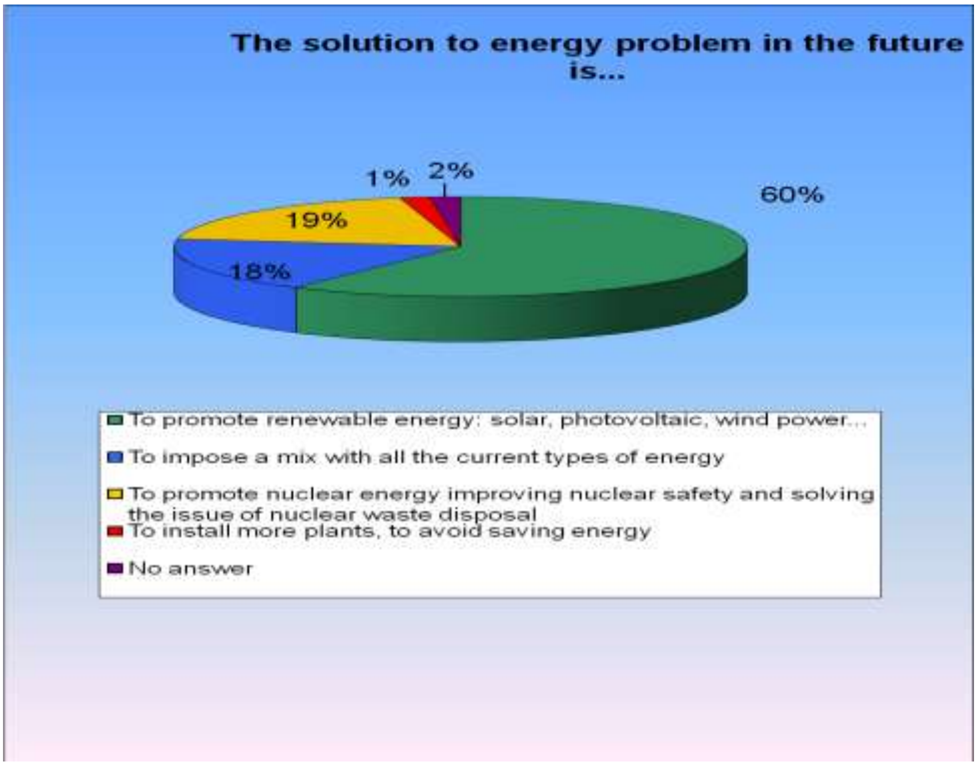


Figure 6. Final question: choose the statement that would solve the issue of energy in the future

Most students want to increase the weight of renewable energy to solve the energy problem of the future

4. Conclusion

Therefore, the outcome of the performed exercise is that Spanish teenagers have still a lack of knowledge about nuclear energy. We can learn that items that are evident for nuclear young professionals are unknown for high school teenagers.

It is considered that the sample of 354 teenagers of different Spanish high schools is big enough to draw preliminary conclusions.
Nevertheless, in order to make the sample more representative of the Spanish teenagers' perception of nuclear energy, it is necessary to have more opinions and more answers to the surveys.
The main conclusions are the following:

- Spanish teenagers think that nuclear energy is necessary in our society.
- Nuclear safety has more importance for them than plant profitability.
- There is an obvious lack of information about the quantity of hazardous waste generated by nuclear power plants.
- Spanish teenagers still believe that nuclear power plants are responsible for some environmental problems that are obviously not related with nuclear power plants
- The Spanish teenagers that are opposed to nuclear energy usually justify their position by accusing nuclear energy to be responsible of all environmental problems: acid rain, oil sick, greenhouse effect…

WEB-BASED SIMULATION TOOLS FOR DISTANCE TEACHING OF NUCLEAR ENGINEERING AT UNED

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ABSTRACT

Nuclear engineering education is often performed by professionals also devoted to research in numerical simulation. However there is usually a large gap between the simplified theory and models taught to students and the realistic simulations performed for research applications. This gap is partially due to the high complexity of advanced simulation codes, which makes them unfit for graduate student level. The nuclear engineering division of the UNED distance teaching university has developed a set of web-based educational tools, which range from simple models to simplified interfaces to production codes, in order to study a broad range of systems from simple to realistic.

This paper presents in more detail the educational tools and teaching strategy implemented at UNED for the courses of Nuclear Technology and Radioprotection.

1 Introduction

UNED (Universidad Nacional de Educación a Distancia) is a Spanish state owned university focused on distance teaching. It was founded in year 1975 and nowadays it is the largest Spanish university with more than 200.000 students. The educational offer covers from humanistic studies to engineering, and grade to doctoral studies, all of them officially recognized in Spain. There is also a wide offer of informal (continuous) education courses. The main feature of UNED is that its educational methodology has always been focused on distance teaching. The teaching strategy is centered in a main campus in Madrid, where all faculties are sited. The faculties produce the teaching guidelines and examinations. Besides this central site, and depending on the amount of local students, there is about one hundred of university offices scattered around Spanish and foreign territory (Europe, North and South America). Local professors support the guidelines marked from the university central site, providing a closer contact to the student located far away from Madrid.

Despite of the possibility for a personal contact with professors, special text books for distance teaching are produced that try to make the student aware of his own progress in his study. Professors in the university main site are also available to students using the existing technology for telecommunications: previously the phone and nowadays extensive use of internet. Internet provides an optimal channel for both static and dynamic content, like virtual classes or teleconferences.

UNED has lately developed its own distance teaching platforms for distance teaching using internet with the aid of a web browser.

- aLF [1]: it is a distance teaching educational platform that hosts the course materials, exams and communication with the student, becoming the central tool for interaction between students and educators.
- Intecca [2]: is a web-tool that allows the setup of deferred or live virtual classes requiring only a web browser and a webcam. It allows for the interaction of several participants with video and audio connection.

The development of educational material has lately been oriented to making use of the new online capabilities that UNED has provided its students and therefore teaching personnel is encouraged through project calls to explore the use of innovative educational strategies.

2 Nuclear engineering education at UNED

Nuclear engineering education is part of the teaching plan of several engineering degrees at UNED. The educational plan of nuclear engineering is designed with an introductory subject of “Fundamentals of Nuclear Engineering” that describes the main fields of interest for our students, which are: nuclear physics, nuclear reactors, medical and industrial applications of radiation, radioprotection and advanced and future fission and fusion reactors. This subject is designed to attract people to the nuclear engineering specialization line, where these blocks can be studied in more detail.

Nuclear engineering education at UNED includes not only theoretical study through our textbooks, but also laboratory work, visits to technical centers and web-based simulation exercises. Despite of being a distance teaching university, laboratory work and technical visits are officially considered within UNED educational framework. Students are summoned to the university main site for a week of laboratory work of all applicable subjects in order to minimize the travelling expenses.

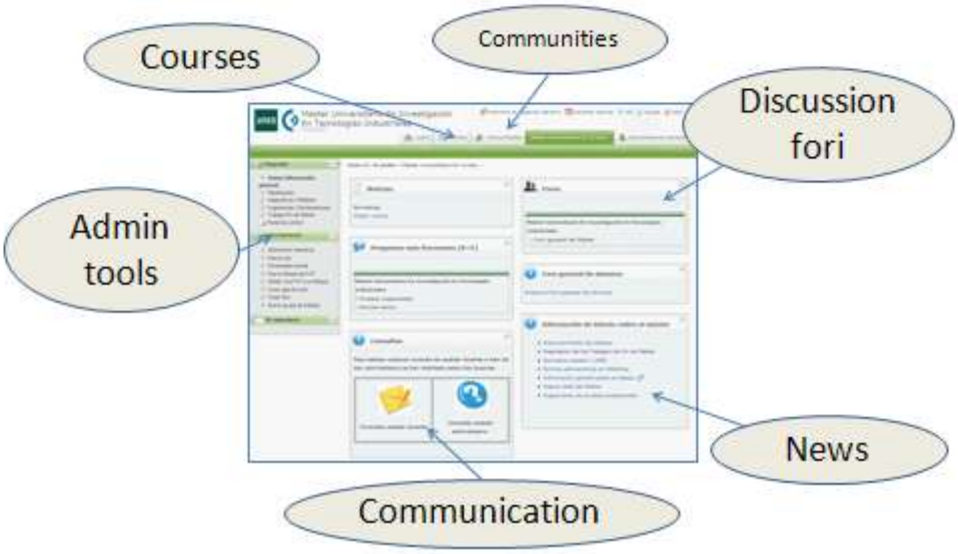

Figure 1 Educational modules in aLF [1]

The interaction between teaching staff and student is based on the aLF educational platform that was previously introduced (Figure **1**). This platform contains several applets that can be optionally used in every course. Every course is customized according to the needs of the educator and students.

3 Simulation tools for nuclear engineering education

Most of the teaching staff of nuclear engineering at UNED has a vast experience in numerical simulations in nuclear physics and engineering, both in the field of nuclear fission and fusion. The idea of building a set of simulation codes for educational purposes arose and was supported by the university within its innovative education program. The strategy of development of computing tools involved two kinds of codes in increasing order of complexity.

- Simple codes to explain theory in an interactive way, basically solving simple differential equations and relating the results to the appropriate physics.
- Adaptation of complex research codes to education by means of simplifying the input interface and producing intuitive graphical output data. The idea here is to let student understand real material behaviors in nuclear engineering, going beyond the idealistic models while keeping the results easy to understand based on appropriate theory.

In all this cases all that the student needs is internet access, a reasonably modern web browser and login data that is provided to them at the beginning of the course. All educational simulation tools, even the simplest, have been designed using the same operating pattern:

1) The student contacts the web server [3], authenticates and fills in the input data.
2) The case is automatically sent to run in the computers of the nuclear engineering group.
3) Output data is post-processed to generate graphical and tabular data for the student.

The main disadvantage of this method is that the student needs constant internet connection in order to perform the tasks, though this is not currently a big problem. The main advantage of this way of operation is that the student never has access to the computational codes and nuclear data which reduces the transferred data and respects privacy issues regarding software. All of the codes run instantly in the same computer that hosts the web server, producing results in real time. All these educational tools are used with the aid of a physics and instructions manual and exercise book (outdated published version [4]).

The following subsections describe in more detail, and with increasing level of code complexity, the simulation tools currently available to our students.

3.1 Analysis of disintegration chains

This first code is a simple simulation tool to understand the different kind of equilibrium which may occur between a radioactive isotope and its daughter. The code implements Bateman analytic expression for a two isotope chain and the results are shown in graphical manner showing the concentration evolution in a characteristic time dependent on the half-lives.

All the required input data is provided by the student and therefore no nuclear data libraries are needed to obtain the results. However the nuclear data of some relevant isotope pairs (i.e. typical neutron poisons) has been hardcoded into the web-form for the student to select.

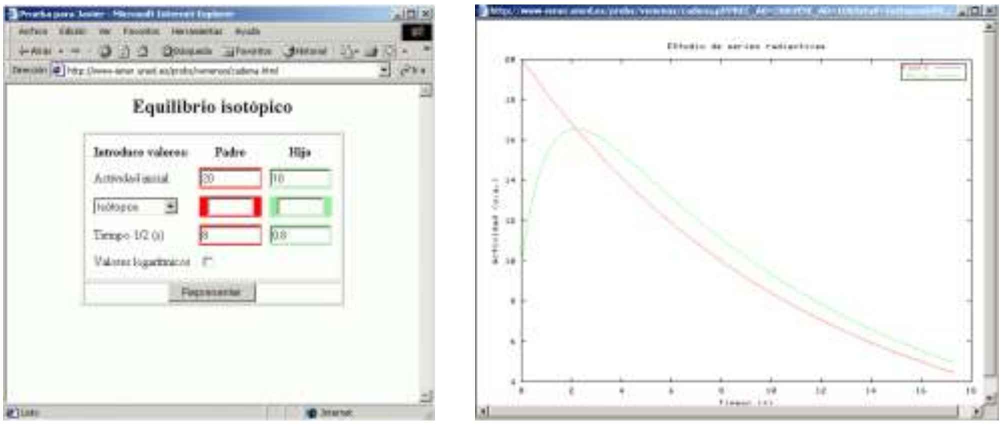

Figure 2 Snapshots of input and output screens in PHRAD

Several exercises are suggested to the student, covering the possible equilibrium situations depending on the relative values of the isotope half-lives.

3.2 Neutron poisoning in nuclear reactors

This exercise is focused on the production and evolution in nuclear reactors of certain isotopes with high absorption cross section. The concentration of these isotopes has a relevant impact on the system reactivity and this dynamic can be studied in a very simplistic way to complement the theoretical studies. The application is based on a zero-dimensional reactor model with an assumed thermal spectrum.

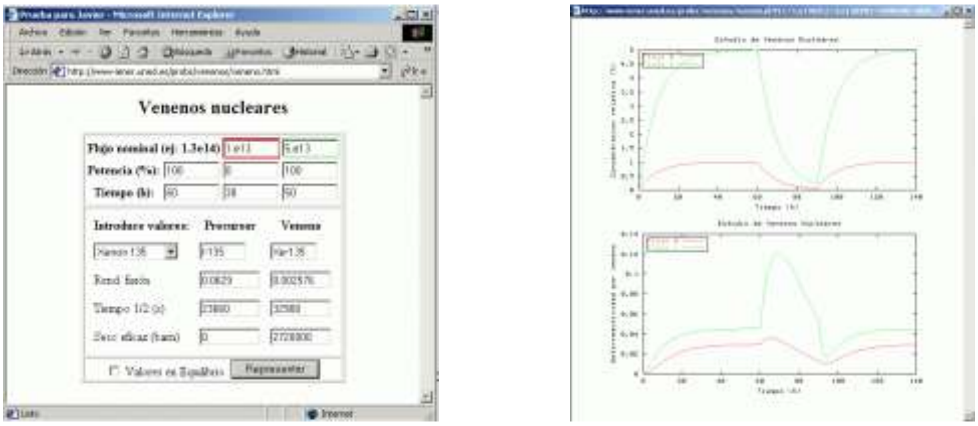

Figure 3 Input and output data in APFVENIN

The students have to define the reactor nominal neutron flux and power evolution in time, and selecting from a list of most relevant neutron poisons. In output, the program displays a graphical analysis of the evolution in time of both poison concentration and impact on reactivity (Figure 3). The student may here learn interactively the evolution of neutron poisoning during power transients and the effect of neutron flux level on the sensibility of the reactivity to those changes. For sake of increased interactivity, a Java version of this program is under development using the easyJava framework, part of the Open Source Physics program [5]. This update allows the student to vary the reactor power during runtime and obtain instant results on the time evolution of the poison isotope concentration.

3.3 Graphical analysis of neutron cross sections

This web-tool, named AGRSEIN, is the first computational tool of our set that actually uses nuclear data libraries for its operation. AGRSEIN is based on the NJOY code for analysis and manipulation of nuclear data libraries. This web-based frontend allows the student to choose data from different libraries, materials, reactions and temperatures to perform quantitative analysis and comparisons.

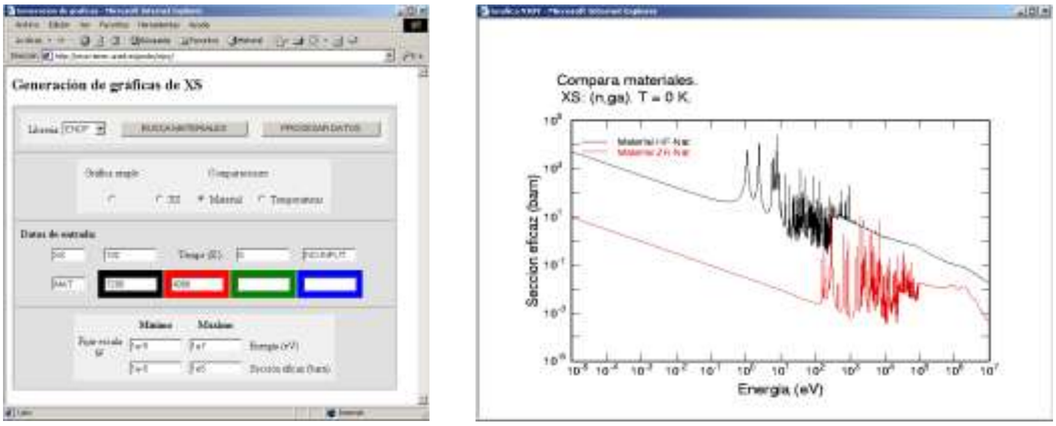

Figure 4 Input and output data in AGRSEIN

The graphical study of neutron cross sections helps to understand many concepts from nuclear physics and technology as well. The set of exercises associated to this program covers these concepts and poses the student the question of why some materials are suitable for use in nuclear systems and some are not.

The AGRSEIN code works in the same operational way as the other codes, with an immediate response from the web server. The resulting graphs present the requested single or comparison plots that can be directly copied into the students' reports (Figure 4).

3.4 Evaluation of radiation shields

The MCBLIND web tool is the most complex educational system currently available to the students of nuclear engineering at UNED. This code allows evaluating the effectivity of one-dimensional radiation shields in slab or spherical geometry. The material composition of the shield can be chosen from a preset of used materials, and it can be composed of two layers of different materials and thicknesses. The incoming radiation flux is selected from different particles and arbitrary energy. The output of the calculation includes the transmission probability of the incoming radiation, uncollided and total fluxes, secondary particle (photon) escapes and ambient dose equivalent on the other side of the shield (Figure 5).

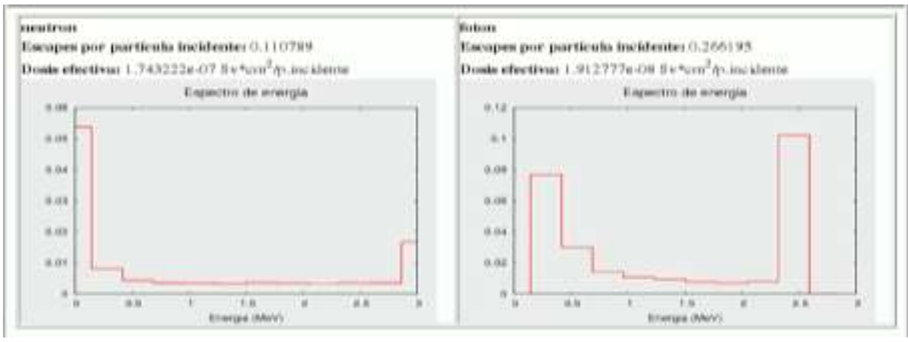

Figure 5 Shield outgoing yields and spectra from MCBLIND

This program is based on a Monte Carlo particle transport code and nuclear data libraries, which provides good accuracy of the results. Once the input has been defined and submitted by the user, the code iteratively generate several input files for the transport code in order to establish the optimal set of variance reduction parameters to produce accurate results even in the presence of large attenuation factors. A typical case may involve up to six internal transport runs, taking up to 30 seconds to produce the final results.

In order to produce reasonable results in less than a minute run, the calculated particle spectrum cannot have very good resolution, which is actually a problem in order to study the moderation spectrum due to elastic or inelastic scattering, or the line sources of photons due to nuclear reactions. In order to overcome this problem, there is a possibility to launch "high resolution runs" with detailed spectrum resolution, which are sent to run to the computer cluster execution queue. These runs may have to wait for hours before entering the machine and take several minutes to run. This is why the results are not shown to screen but processed into a PDF document and automatically sent to the student's email address.

4 Conclusions

Nuclear engineering education at UNED is designed making use of the web technologies not only for interaction between professors and students but also to provide a set of web simulation tools to interactively experiment with the studied theory in different fields of nuclear engineering. These tools range from very simplistic analytical models to research production codes especially adapted for educational purposes. The set of tools is to be expanded to study the fuel burn-up in fission reactors and activation inventory evolution.

5 Acknowledgements

This work has been partially performed within the framework of ENEN and ENEN-III projects.

6 References

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[2] Intecca web site http://intecca.uned.es
[3] Nuclear engineering at UNED. http://www-inuclear.uned.es
[4] J. Sanz, F. Ogando, A. Rodríguez, "Ingeniería Nuclear: Prácticas de simulación computaciona vía internet", Ed UNED, 10536CP01A01 (2003).
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[6] Understanding NJOY, http://t2.lanl.gov/njoy/theindex.html

UTILIZATION OF NUCLEAR RESEARCH FACILITY «GIACINT» FOR EDUCATION AND TRAINING

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ABSTRACT

As a part of the Joint Institute for Power and Nuclear Research – "Sosny" of the National Academy of Sciences of Belarus there is a higher education centre for preparation of engineers and researchers in the field of a nuclear science and technology, including nuclear reactor theory and operation. Training strategy is to complete theoretical courses and training courses on simulators with the experimental work carried out on research nuclear facility «GIACINT». We state a question of application of this research nuclear facility for carrying out of the training courses including the theory and practice. We give the description of modification of this nuclear facility, which can be used in the educational purposes, and also some data about the experiments which are carried out on the facility in the course of training.

1. Introduction

The Joint Institute for Power and Nuclear Research – "Sosny" of the National Academy of Sciences of Belarus (JIPNR – Sosny) has a wide experience of development, a construction, testing, operation and experimental researches on research nuclear facilities. It has been created in 1965 year. At execution of large-scale designs on development, designing and operation of different nuclear power facilities (mobile NPP "Pamir-630D", experimental-industrial NPP BRIG-300, etc.) experience on nuclear power engineering (including nuclear reactors physics and technique) which can be used by engineer and researcher training has been acquired. At present JIPNR-Sosny is take part in scientific support of NPP construction in Belarus. Preparation of specialists in field of nuclear power engineering became the important problem. JIPNR – Sosny became the leading research institute on this problem from the National Academy of Sciences of Belarus. For this purpose at Institute the Training center for a professional training of the top experts in the nuclear power engineering and workers in NPP technologies, nuclear power regulation, quality and safety policy, NPP operation has been created. The Computing center is created also, operations on making of an analytical NPP trainer (includes reactor facility and the basic technological systems) are conducted. Training strategy is guided on supplementing theoretical and training courses to the experiments on research nuclear facilities. For these purposes research nuclear facility (critical stand) «GIACINT» can be used.

2. Critical stand «GIACINT» characteristics

Critical stand «GIACINT» is destined for basic research on the physics and safety of neutron-multiplying systems and applied research in a substantiation of development of new generation of different nuclear energy sources. It provides the experimental base for the development of fundamental and applied nuclear power engineering, including:

- fundamental research on the nuclear reactor physics and a radiation protection, criticality of fissile materials and criticality safety;
- applied research in a substantiation of development of new generation of reactor facilities of different destination;
- provisions of teaching and methodical experimental base for training specialists in field of nuclear power engineering and application of ionizing radiation.

At critical stand "GIACINT" a practical training on measuring of neutron-physical characteristics of neutron-multiplying systems, reactor surveillance systems, nondestructive check of products with fissile materials, dosimetry and radiometric surveillance systems for training of experts in nuclear power engineering and ionizing radiation utilization which are trained at universities of the Republic of Belarus can be conduct. The given teaching and methodical experimental base also can be used for the international schools on training and retraining of experts in research nuclear facilities and fissile material storages operation.

Critical stand «GIACINT» consists from the critical assemblies, control and protection system, hydraulic system, emergency caution system, temporary (operative) storage of nuclear fuel, radioactive materials and a radioactive waste, etc. At critical stand «GIACINT» critical assemblies with water or zirconium hydride moderator and without a moderator are assembled. There are sets of the fuel rods and the fuel assemblies containing uranium with various enrichment on uranium-235 (10, 21, 36, 45, 75 and 90 %), reflector assemblies and blocks (on the basis of zirconium hydride, beryllium, polyethylene, stainless steel, etc.) and control and safety rods of the control and safety system (on on the basis europium oxide, boron carbide (including enrichment to 85 % on a boron-10), cadmium, etc.). On fig. 1 and 2

Fig 1. Critical assembly
with a water moderator

Fig 2. Critical assembly
with a zirconium hydride moderator

are given photos of critical assemblies with water and zirconium hydride moderators.

The critical assembly with water moderator represents uniform hexagonally lattice (pitch 21.0 mm) of rods in a water moderator. Fuel rods settle down in upper and bottom aluminium spacer grids (the bottom edge of the upper grid and an upper edge bottom grid coincide, accordingly, with top and bottom of core) and lean on a steel support plate. Over fuel rods the steel plate is located. The critical assembly has physically "infinite" side and butt water reflectors.

The fuel rod consist of the fuel core, a clad, top and bottom clamps, a spring and trailer details — top and bottom caps. The fuel rod clad is executed from a stainless steel and has external diameter 6,2 mm and thickness 0,4 mm. The fuel core consists of tablets in diameter 5,2-5,3 mm and height 5-7 mm executed from $U(21\%)O_2$. The general length of the fuel core is 500 mm. The fuel core takes places and fixed in the clad by means of a spring, clamps and trailer details. The rod is made leakproof, all inside hollows are filled by helium under pressure 1 atm. Hermetic sealing is carried out by welding the top and bottom caps to the clad. Total fuel rod length is 651 mm. On the fuel rod clad with step 100 mm the stainless steel wire is wound.
This critical assembly has two safety rods (AZ1, AZ2) and four control rods (KO1, KO2, PP1 and PP2). AZ1, AZ2 and KO1 rods located in a core and represent a cluster from three

composite rod elements. Each element consists of two parts: lower, containing debugged fuel rod, and upper, containing rod with boron carbide (absorber). Reactance decreases at ejection (down) from the core three fuel rods and insertion for their place of three absorbers. KO2, PP1 and PP2 rods located in a side reflector and represent a cluster from two composite rod elements. Each element consists of two parts: lower, containing plexiglas rod, and upper, containing rod with boron carbide. Reactance decreases in this case at ejection (down) from the core two plexiglas rods and insertion for their place of two absorbers. The absorber consists of a cylindrical stainless steel shell diameter 6,2 mm and thickness of 0,4 mm, top and bottom stainless steel caps diameter 5,4 mm and length 84 and 67 mm accordingly and B_4C in density 1,3 g/sm^3 on height of 500 mm. Rod with boron carbide is executed by the hermetic. Total length of rod is 651 mm.

Loading chart of critical assembly with a water moderator with 161 fuel rods is figured on fig.3. The core charge is equal 3,294 kg of uranium-235.

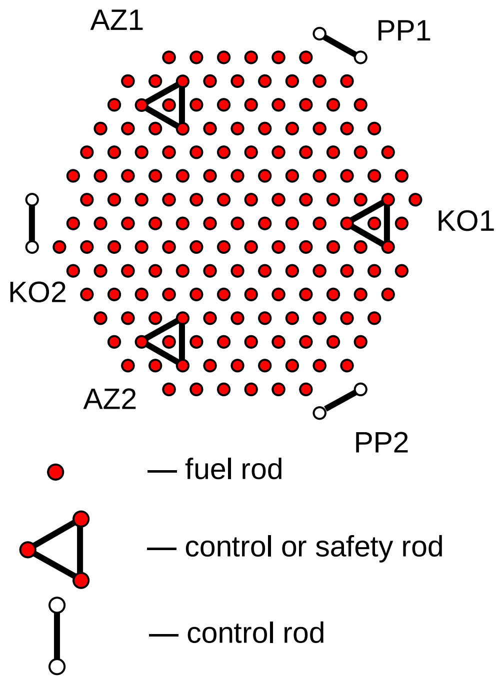

Fig 3. Loading chart of critical assembly with a water moderator

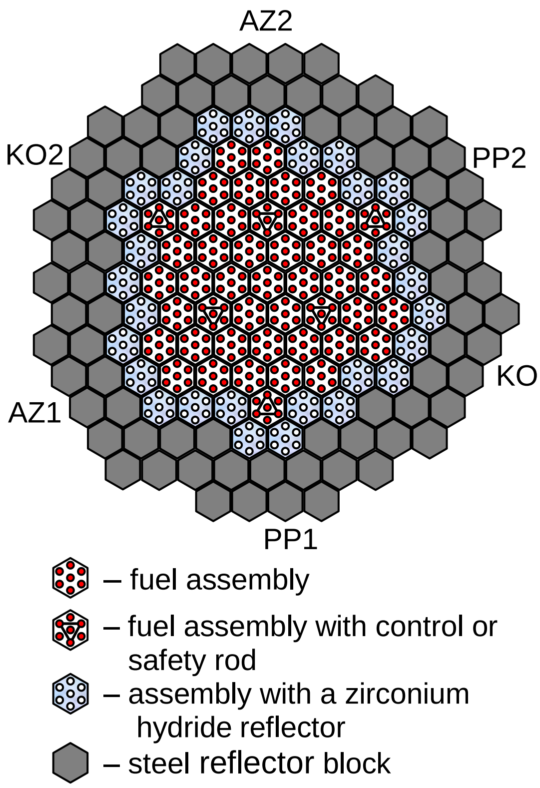

Fig 4. Loading chart of critical assembly with a zirconium hydride moderator

The critical assembly with zirconium hydride moderator represents uniform hexagonally pitched (45.0 mm) lattice of fuel assemblies. Round the core one row of zirconium hydride reflector assemblies and two rows of steel reflector blocks with are located. Assemblies and blocks on steel support spacer plate are installed. From above on assemblies and blocks steel blocks of top reflector are installed.

The case of the fuel assembly represents hexagonally stainless steel pipe with size turnkey 44 mm and wall thickness 0,4 mm. The hexagonally pipe is connected with bottom nozzle which on steel support spacer plate are installed. The top nozzle serves for capture at the transfer operations and installations steel blocks of top reflector. Inside hexagonally pipe are established 12 hexagonally blocks of moderator from zirconium hydride $ZrH_{1.9}$ height 50 mm of everyone with size turnkey 42,85 mm. In moderator blocks with pitch 14,5 mm on a triangular lattice of are located seven holes with diameter 8,2 mm in which channel stainless steel pipes with external diameter of 8 mm with wall thickness 0,25 mm are placed. In this channel pipes seven fuel rods are located. Fuel rods for this critical assembly — same as well as for critical assembly with water moderator.

This critical assembly has two safety rods (AZ1, AZ2) and four control rods (KO1, KO2, PP1 and PP2). Each rod is placed in the separate fuel assembly and represent a cluster from three composite rod elements. Each element consists of two parts: lower, containing fuel rod, and upper, containing rod with boron carbide (absorber). Reactance decreases at ejection (down) from the fuel assembly three fuel rods and insertion for their place of three absorbers.

Loading chart of critical assembly with a zirconium hydride moderator with 46 fuel assemblies is figured on fig.4. The core charge is equal 7,169 kg of uranium-235.

Fig 5. Control board of the critical stand "GIACINT"

The control and protection system of critical stand «GIACINT» in all operating modes of the critical assembly since the first core charging of fissile material provides emergency protection on power level, a period of power doubling, and also the control of power level, a period of power doubling, reactivity, gamma radiation dose rate, moderator level in a critical assembly tank (for critical assembly with a water moderator), moderator temperatures in tanks of hydraulic system (for critical assembly with a water moderator). On fig. 5 the photo of a control board of critical stand «GIACINT» is given.

The hydraulic system of critical stand «GIACINT» is used only for critical assembles with water moderator and intended for storage water moderator, the dosed moderator supply with certain speed in a critical assembly tank, working or emergency moderator discharge from a critical assembly tank, and utilization moderator after its use. As water moderator is used the distillate or a water solution of boric acid.

3. System for acquisition, processing and storage experimental data

At critical stand «GIACINT» there is system for acquisition, processing and storage experimental data meant for measurements of neutron-physical characteristics of critical assemblies analysis on the given stand.

The system for acquisition, processing and storage experimental data can be used at carrying out of following experiments at the critical stand:

- loading of critical mass (plotting of loading charts and inverse account curves);
- measurement of control and safety rod efficiency of control and protection system;
- control and safety rod calibration;
- definition of reactivity margin;
- measurement of reactivity effects;
- measurement of radial and axial energy release distribution on a core;
- measurement of the absolute power of the critical assembly;
- measurement of the kinetics parameter (β_{eff}/l);
- nondestructive check fuel rods and fuel assemblies with fissile material;
- validation neutron detectors, etc.

The system is created on the basis of the local network of PC, a subsystem of signal preprocessing and data acquisition, the experimental assemblies and devices.

4. The experiments spent during training courses

Training courses are intended for a wide range of participants: students of universities, the personnel of research reactors (raising the level of one's skill), experts in the field of the theory and operation of nuclear reactors (reactor operator, researchers, engineers, officer of regulating authority, managerial employee), and also teachers of universities and colleges. Depending on a trainee contingent and the educational purposes training course on various aspects of nuclear reactors for general notion and demonstration of reactor operation, or for detailed studying of various aspects of reactor operation can be offered.

At critical stand «GIACINT» within the bounds of training courses experiments by definition of the above-named neutron-physical characteristics of critical assemblies can be made. We will view two experiments, executed within the bounds of training courses at JIPNR-Sosny.

4.1 Measurement of control and safety rod efficiency of control and protection system

For measurements is used digital reactimeter which consists of current neutron detector (current 10^{-12}-10^{-4} A), high voltage power supply unit, current-voltage converter, multifunctional analog-digital input-output module with ADC and timer and personal computer.

Control and safety rod efficiency is defined as critical assembly reactivity with introduced into a core rod or rod group, compensating reactivity margin of the critical assembly. Measurement data is given in table 1.

Control and safety rods	Efficiency, $ß_{eff}$	
	Critical assembly with a water moderator	Critical assembly with a zirconium hydride moderator
PP1	0,28 ± 0,01	0,70 ± 0,02
AZ1	2,04 ± 0,08	2,72 ± 0,14

Tab 1: Control and safety rod efficiency of critical assemblies with water and zirconium hydride moderator

4.2 Absolute power measurement

The absolute power of the critical assembly can be measured by the Feynman-alpha method based on the analysis of neutron fluctuations. For measurements it is used experimental assembly which composed of slow neutron counter (counting rate < 10^5 imp./s), high voltage power supply unit, preamplifier and pulse former, multifunctional analog-digital input-output module with pulse counters and gated oscillator and personal computer.

Experiments were performed on the critical assembly with water moderator. The absolute power was equal 4 mW. Calibration of power monitoring channels of the critical stand has been carried out on the basis of this result.

5. Conclusion

JIPNR-Sosny provides training of engineers and researchers in the field of the theory and practice of nuclear reactor operation. Training strategy is guided on supplementing theoretical and training courses to the experiments on research nuclear facilities. For these purposes critical stand «GIACINT» can be used. Such approach offers huge advantages. For trainees the experimental work on research nuclear facilities give unique possibilities to gain knowledge or raise the level of one's skill in field of reactors physics and kinetics and to develop the interest in this field of the science and technics.

THE KEY ROLE TRANSFERRING KNOWLEDGE OF NUCLEAR ESPAÑA, THE SPANISH NUCLEAR SOCIETY MAGAZINE

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ABSTRACT

The magazine of the Spanish Nuclear Society (SNE), “Nuclear España” is a scientific-technical publication with almost thirty years of uninterrupted edition and more than 300 numbers published. Their pages approach technical subjects related to the nuclear energy, as well as the activities developed by the SNE, especially in national and international meetings.

The main part of the magazine is composed by articles written by known specialist of the energy industry. One of the top goals of the magazine is to help on transferring the knowledge from the generation that built the nuclear power plants in Spain and the new generation of professionals that have started its nuclear career in the last years. Each number is monographic, trying to cover as many aspects on an issue as it is possible, with collaborations from the companies, the research centers and universities that helps to have complementary points of view. On the other hand the articles help to deep in the issue´s topic, broadening the view of the readers about the nuclear field and helping to share knowledge across the industry.

The news section of the Magazine picks up the actuality of the sector as a whole. The editorial section reflects the opinion of the SNE Governing Board and the Magazine Committee on the subjects of interest in this field. On the other hand, the monthly interview sets out the professional outstanding opinions.

With a total of eleven numbers per year, three of them have a noticeable international character: the one dedicated to the operative experiences on the Spanish and European nuclear power plants, the monographic issue devoted tothe Annual Meeting of the SNE and the international issue, which covers the last activities of the Spanish industry in international projects. Both first are bilingual issues (Spanish-English), whereas the international edition is published completely in English.

Besides its diffusion through all the members of the SNE, the Magazine is distributed, in the national scope, to companies and organisms related to the nuclear power, universities, research centers, representatives of the Central, Autonomic and Local Administrations, mass media and communication professionals. It is also sent to the utilities and research centers in Europe, United States, South America and Asia.

1. Introduction

The magazine of the Spanish Nuclear Society (SNE), “Nuclear España” is a scientific-technical publication with almost thirty years of uninterrupted edition and more than 300 numbers published. Their pages cover technical subjects related to the nuclear energy, as well as the activities developed by the SNE, especially in national and international meetings.

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2. The Magazine History

The NUCLEAR ESPAÑA magazine is intimately linked to the development of the nuclear power in Spain, and it was born like an expression of the Spanish Nuclear Society, founded on 1974. To better understand the role played by *Nuclear España* in the Spanish society since the first issue published in July of 1982 to the present time, it is perhaps opportune to remember some historical data previous to its appearance.

The nuclear age began in Spain in 1951 with the creation in 1951 of the Spanish Nuclear Research Centre, JEN (today CIEMAT), and the construction, seven years later, of the first experimental reactor (3 MW) that was dedicated to the production of isotopes and education. In 1968 the first commercial nuclear power station starts up, Jose Cabrera (Zorita) (160 MWe) and the second, Santa Maria de Garoña (466 MWe), in 1971. This period was covered by the bimonthly magazine “Energía Nuclear”, published by the JEN.

Just at the time of the appearance of *Nuclear España*, the situation that lived the nuclear sector was difficult for several reasons, for example the campaign of attacks and murders undertaken by a terrorist group that forced to stop the construction of the Lemóniz nuclear power plant. In fact, number 1 of *Nuclear España* dedicated one double page to denounce this situation.

Figure 1. First number of Nuclear España in July 1982

On the other hand, the Spanish Government had interest for the fast start of operation of the second generation (GEN-II) of nuclear power plants which were under construction. This was due to the energy crisis that the world was going through, with a very expensive dollar and, therefore, very high petroleum cost.

Indeed a year before, in 1981, Almaraz 1, the first GEN-II nuclear power plant, started operation. In parallel, the other groups were under construction and they started up just a short time later. On the other hand, the Spanish Nuclear Society (SNE), founded on 1974, was looking for a mean that served to set out the works and the experiences of the professionals. Several attempts were raised, but they failed for the huge necessary dedication. At the end of 1981, the Society decided to address the project in a professional manner: a committee of members was constituted contracting the services of a publishing company for the edition work.

The magazine started at the beginning of 1982 with the first president of the Publications Commission, Rogelio de Haro, at the moment engaged in Westinghouse-Spain. The first steps were hard. It was necessary to define the format and the content of the magazine, to look for advertising support that finances the edition and to combine the interests of the publisher with those of the SNE.

Finally, thanks to the effort of the professionals who participated in the Committee and the commitment of Senda Ediciones, the publishing company selected for the edition work, the magazine was a success. After six months the first number was published. Later on, the priority was to give continuity to the magazine. Little people thought that it was going to follow ahead more than 300 numbers.

The present situation of the electrical sector is very different from the one from 1980. In those years it was a regulated sector very atomized, at the present time, the liberalization of the market has derived in a concentration of the sector companies and an important presence of foreign companies. Regarding the nuclear industry, as a result of this process of concentration of the electrical sector, the number of propietary companies is handicapped considerably. Before 1982, the electrical sector was supporting strongly the nuclear energy. Nevertheless, after the moratorium, its position has evolved towards a more passive attitude, with no new nuclear projects in mind.

The first task that assumed the present Commission of Publications president, José Lopez Jiménez, a veteran from CIEMAT, was the renovation of the Commission with the incorporation of new members. It was a smooth transition, of the still pioneering ones, like Professor Luis Gutiérrez Jodra, Carolina Ahnert and others, to the new professionals of the nuclear sector, but maintaining a core of remarkable veterans like Luis Palacios. In so short period of time, important changes have undergone. At this moment, the Commission has thirteen members, and its basic mission is the planning and management of the NUCLEAR ESPAÑA magazine edition.

Figure 2. Two examples (year 1982 and 2006) of special monographic numbers on education & training

As an important milestone, in February of 2009 the SNE Governing Board presented the Strategic Plan in the society General Assembly outlining the action lines of the Society for the next years. In the Plan document it is remarked that the Magazine is “the essential organ of communication of the Society and one of his main assets”.

The mentioned Strategic Plan, that updates the mission and the objectives of the SNE, puts special accent in the communication and the Magazine. The constitution of the Communications Commission and the creation of the figure of the Society spokesman are two new features that have a direct relation with the Magazine.

Regarding this Plan, there are some actions that will allow to improve the Magazine capacities as vehicle of scientific and technological diffusion, proposing to extend its distribution in places like universities, companies, political parties, professional unions, schools, companies, Chambers of Commerce, associations, specialized magazines editorials, etc. This work of diffusion will be coordinated with the new Commission of Communication and the Society spokesman.

Some new features have been incorporated since the introduction of the Strategic Plan. The first one is the addition of the editorial article that will reflect the position of the SNE on current subjects and of the technical editorial that summarizes the content of the monographic number. Another new feature that the Magazine has incorporated recently is the new fixed section titled `the nuclear thing in the media'. This section tries to inform about the main news appeared in Spanish newspapers on power and nuclear topics.

Other subjects of special importance for the Magazine are the annual planning of the topics for the monographic issues, revision of articles and management of all the information that is lately included in the issue. In the last years, NUCLEAR ESPAÑA has published a great quantity of papers showing updated information about a variety of topics like new reactors, long term operation, the market and the energy costs, and many more.

To maintain the quality, the same in content than in edition, is a constant challenge that the Publication Commission faces. The primary target is to produce an attractive issue, taking into account the most recent developments in the nuclear sector and showing them in a way easy to understand for people not directly related with the mentioned topic. This is done also trying to maintain the standards of quality and rigor. Also the Publications Commission has the objective that that NUCLEAR ESPAÑA is delivered to the readers on time, requirement every day more demanded , but far from easy to obtain. For all this, the Publication Commission holds monthly meetings where the tasks are distributed. This includes the issues coordination, communications for the European and American Societies, search and selection of news about the nuclear companies and the Spanish institutions, etc.

The grant award is stimulating for members and collaborators, who see recognized their effort. Another task of the Commission is to choose the best article published during the year that is granted with the `Nuclear España Prize”. Also, there is an Honorary Mention to the issue distinguished by its technical quality.

Figure 3. Two special numbers for Nuclear España: number 300 and 36th Annual SNE Meeting at Santiago de Compostela

During 2010, the implantation of the Strategic Plan of the SNE, initiated the previous year has been continued. It is good to emphasize the inauguration of the new section "Nuclear people around the world" with four interviews to the Spanish nuclear professionals that work abroad: Luis Echávarri, Silvia Álamo, Santiago San Antonio and Carlos Alejaldre; as well as the consolidation of the press report section "nuclear in the media" and the writing of two editorials in each number, one of general character reflecting the position of the SNE Governing Board, and the other, technical, regarding the subject of the monographic issue, signed by the Committee of Publications.

Among others new features, it is remarkable the offering of including articles of special meaning at the present time on subjects different from the monographic one, with special indication on the cover page. In addition, the logo of the cover and the subtitles has been modified, adopting the legend: "The magazine of the professionals of the nuclear sector"; and the previous name of this Publication Commission has been changed by the one of "Writing Commission of the Magazine".

3. Conclusions

NUCLEAR ESPAÑA has maintained the beat of the nuclear activity in and outside Spain from its creation in July of 1982 to the present time. NUCLEAR ESPAÑA, next to the professional objectives, does a complementary mission that is not other that to spread the knowledge that allows its readers to think with scientifical criteria about the future of the nuclear power in our country.

During each one of these years it has help to transfer the knowledge from a mature generation of technical people, which have built and operate the plants to the young people that have entered in the nuclear field.

CINCH - Cooperation in education In Nuclear Chemistry

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ABSTRACT

The renaissance of nuclear power is already requiring a significant increase in the number of the respective specialists, amongst others are nuclear chemists. Because the current situation in nuclear chemistry education and training in Europe is quite diverse, a project for cooperation in education in nuclear chemistry (CINCH) was launched in February 2010.

The project aims to coordinate the education in Nuclear Chemistry, both at Ph.D. and undergraduate levels, within the EU, in collaboration with Russia. The system developed should

enable formation of a long-term Euratom Fission Training Scheme (EFTS) providing a common basis to the fragmented activities in this field and thus move the education and training in nuclear chemistry to a qualitatively new level. The main cornerstones of the project are: coordination of the education, training and e-learning/dissemination in Nuclear Chemistry. A careful supervision and evaluation is carried-out by an Advisory Board of end-users, academia and NGO (such as e.g. ENEN association).

Previous experience gained by ENEN association during the coordination of nuclear engineering education together with data collected by the Division of Nuclear and Radiochemistry of EuChemMS (DNRC) and IAEA serves to strengthen the base of CINCH. Also, the project serves as support and supplement to the training modules of EUROATOM "chemical" IPs and NOEs, namely that of ACTINET, ACSEPT, etc; thus providing synergy rather than competition in the field.

In the presentation, results of the review of teaching and training in nuclear chemistry in Europe and Russia were given. Detailed plans of the joint modular courses under development were introduced and the schedule of their demonstrations given. The new CINCH e-learning platform launched was presented together with the courses under development.

BASIC VS. APPLIED-ORIENTED DOCTORAL THESES IN NUCLEAR THERMAL HYDRAULICS AND SEVERE ACCIDENTS

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ABSTRACT

Doctoral theses in the fields of nuclear reactor thermal hydraulics and severe accidents, which were completed within graduate studies of nuclear engineering (Jozef Stefan Institute – JSI and University of Ljubljana), at the JSI Reactor Engineering Division, are reviewed from the point of view of “basic” vs. “applied-oriented”. The analysis shows a preponderance of basic theses over applied-oriented ones. The comparative merits of both kinds of theses for nuclear engineers intending to continue their careers in the nuclear industry are discussed. The survey of later positions of the considered holders of doctoral degrees in nuclear engineering shows that work on a basic thesis may still be an adequate basis for future careers in the nuclear or other industries.

1. Introduction

In the past few decades, the field of nuclear engineering developed from a purely “technical” field into a “scientific” field, within which advanced research is being performed. As a natural development, doctoral theses in this field also appeared and are nowadays an established part of nuclear engineering research. Doctoral theses may be broadly categorised into “basic” and “applied-oriented”. After obtaining doctoral degrees in nuclear engineering, students usually opt for one of the three main possibilities:

— to join a nuclear power plant, a nuclear utility company, a nuclear regulator, or a nuclear power plant vendor,

— to remain in the field of research, either by staying in the academic or research institution, where they have obtained their degree, or moving to another one,

— to move to some other field, where they eventually use some of the knowledge that they have acquired during their doctoral study of nuclear engineering.

Engineers with doctoral degrees that move to a nuclear power plant, to a nuclear utility company, or to a nuclear power plant vendor (in the remaining part of the paper, these will be referred collectively as “nuclear industry”), enjoy some advantages, be it either in the terms of position that are offered to them, in terms of starting salaries, or in terms of status. Whether such advantages are justified is open to debate. Namely, engineers who would spend their formative years after graduation at some nuclear power plant, where they would be in contact with the actual running of the plant and learn some additional basic skills, would perhaps be of more value to the nuclear industry than engineers, which have spent the same amount of time (a few years) in an academic institution, dealing with nuclear engineering through courses and research theses. However, this issue will not be addressed here. The assumption is that the nuclear industry has sensible reasons of its own to offer advantages to holders of doctoral degrees.

To obtain a doctoral degree, a student must perform a research, which represents a novel contribution to the field of nuclear engineering. To ensure an adequate level of the performed research, a usual requirement is that the results of the research be published in (at least) one paper in an international scientific journal. To achieve this, the thesis subjects often deal with basic research, which are connected to some field of nuclear engineering, but in which students that will move to the nuclear industry will in generally not be involved anymore (that is, with the basic research as such). Namely, results of “applied-oriented” theses, although not less intellectually demanding, usually do not provide the same novelty and originality, which are among the prerequisites for acceptance of papers in scientific journals. Thus, it appears at first glance that the education that students undergo while working on their doctoral theses might not be the most appropriate for the needs of the nuclear industry. The present paper addresses this issue on the example of theses in nuclear engineering, that have been completed within graduate studies of nuclear engineering at the Jozef Stefan Institute (JSI) and the University of Ljubljana, in the fields of nuclear reactor thermal hydraulics and severe accidents, at the JSI Reactor Engineering Division.

2. Theses in nuclear thermal hydraulics and severe accidents at JSI

The graduate studies program in nuclear engineering was established in 1986, jointly by the JSI and the Faculty of Mathematics and Physics, University of Ljubljana. Since 1993, 21 doctoral theses have been completed (Table 1).

Topic	Number of theses
Reactor physics	3
Thermal hydraulics	8
Severe accidents	3
Structural mechanics	2
Probabilistic safety assessment	3
Other	2

Table 1. Doctoral theses in nuclear engineering in the period 1993-2010.

Although thermal-hydraulics and severe accidents are usually considered as separate topics (at technical conferences or in scientific journals), “basic” research in these fields involve, in most cases, fluid mechanics and heat and mass transfer. For this reason, they are considered together in the present paper. On the other hand, “applied-oriented” research at the JSI Reactor Engineering Division usually involves simulations of integral reactor systems using so-called system computer codes.

Table 2 shows in detail the topics and specific subjects of 11 doctoral theses in the fields of thermal hydraulics and severe accidents. References refer to the journal paper (or, if there was more than one, to the most important paper) in which the research was published (the paper was typically published in the same year or the following after the thesis was completed). Although 11 theses is a relatively small sample, it is sufficiently large to draw some general conclusions. Besides, by their very nature, doctoral theses are not, for the time being, meant to become massive, so much larger samples from single institutions will always be difficult to obtain.

One may see, that only two (refs. [2] and [4]) out of 11 theses could be categorized as “applied-oriented”: these theses dealt with simulations of transients in the PWR reactor primary system, using the well-known RELAP5 system code. For those not familiar with nuclear-reactor thermal-hydraulics, the US-developed RELAP5 code is among the most widely distributed and used codes for simulating transients in NPP primary systems. It allows the incorporation of own models of physical phenomena, making it also a possible research

Year	General topic	Research subject and work	Ref./ B or A
1997	Gas-liquid two-phase flow	Simulation of pressure transient in two-phase flow using own one-dimensional model and code	[1] / B
1999	Transients in PWR primary system	Simulation of transient in PWR primary system using RELAP5 system code, with emphasis on evaluation of uncertainty of peak cladding temperature during uncovering of the reactor core	[2] / A
2000	Steam explosions	Simulation of premixing phase of steam explosion (interaction between core melt and coolant) using own model and computer code	[3] / B
2001	Transients in PWR primary system	Simulation of transients in PWR primary system using RELAP5 system code, with emphasis on boiling in reactor core	[4] / A
2001	Gas-liquid two-phase flow	Simulation of stratified gas-liquid flow using own two-dimensional model and code	[5] / B
2001	Core melt in RPV lower plenum	Simulation of natural convection in fluid with internal heat generation using own Large-Eddy Simulation two-dimensional model and code	[6] / B
2003	Convective boiling	Simulation of convective nucleate boiling at low-pressure conditions using multi-purpose CFD code and own models for inter-phase momentum, heat and mass transfer	[7] / B
2006	Liquid turbulent flow	Simulation of passive scalar transport in turbulent flow using Direct Numerical Simulation	[8] / B
2008	Fluid-structure interaction	Coupled thermal-hydraulic simulation of one-dim. single or two-phase flow and structural simulation of two-dim. piping system modelled with beam approximation	[9] / B
2008	Droplet flow in atmosphere	Simulation of interaction between spray droplets and surrounding atmosphere, using multi-purpose CFD code and own models for heat, mass and momentum transfer between droplets and atmosphere	[10] / B
2009	Gas-liquid two-phase flow	Simulation of instabilities in stratified gas-liquid flow using own two-dimensional model and code	[11] / B

Table 2. Doctoral theses in the fields of thermal hydraulics and severe accidents in the period 1993-2010 (B: basic, A: applied-oriented).

tool for investigating different modelling. All other theses involved basic research in fluid mechanics and heat and mass transfer. Thus, the number of basic theses definitely dominates over the number of applied-oriented ones: the difference is not just a statistical uncertainty or a fluctuation, but a definitive trend, that seems likely to continue in the future.

Although the subjects of the theses had to comply with the general research policy of the JSI Reactor Engineering Division, there were no strict restrictions concerning their choice. In general, the subjects of the theses were chosen after considering the following:

1. Ongoing research programmes and projects.
2. Research interests of the thesis supervisor.

3. Research interests of the doctoral candidate.
4. Possibility to achieve results, which would deserve publication in a scientific journal within the time during which a thesis was expected to be completed.
5. Capabilities of the doctoral student, as estimated by the thesis supervisor.

The determining criterion, which influenced most the preponderance of basic theses, was the one listed under no.4. Namely, many applied theses could usually just as well fulfil the first 3 criteria. Also, a student having the capability to complete a basic thesis could also be expected to have sufficient capabilities to complete an applied-oriented one. However, as already stated, results from applied-oriented research work are usually difficult to publish in scientific journals. Given the declared aims of most journals, this is understandable: each journal is entitled to have its own policy, and it is not for fellows of academic and research institutions to question it. However, given that the publication of a paper has become almost a standard necessary condition for completing a doctoral thesis, this definitely causes a bias towards basic subjects.

From the above 11 students, 5 stayed at the Reactor Engineering Division as researchers (including those, that have completed applied-oriented theses) after completing their theses. Two of them moved to the utility company GEN energy, which owns the Slovenian part of the Krško nuclear power plant. Others moved to different industrial companies, where they are mainly involved in modelling of systems and physical phenomena. This shows, that work on a basic thesis, at least within the fields of nuclear thermal hydraulics and severe accidents, may still be an adequate basis for future careers in the nuclear or other industries.

3. Comparative merits of basic and applied-oriented doctoral theses

The discussion in the present section deals solely with the issue of holders of doctoral degrees, that move into the nuclear industry. Some of the arguments may also apply to doctors working in academic or research institutions or moving to different technical fields.

The main advantages of basic doctoral theses are the following:
— Students learn the details of a specific physical phenomenon. Apart from becoming knowledgeable in the studied phenomenon, they may use the acquired knowledge of basic physics to understand and start working on other related phenomena, which may have to be considered within safety analyses of nuclear power plants.
— Students learn to think about the methods, that are used in safety analyses of nuclear power plants (such as simulations within system codes), in terms of its physics. Thus, they will be able to understand the physical background of technical analyses, which will make them more likely to detect eventual physical errors and inconsistencies.

The main advantages of applied-oriented doctoral theses are the following:
— Students get used to think about the functioning of complex systems, including interactions and cause and effects between phenomena occurring in different components.
— Students acquire specific skills, necessary to perform technical analyses (including safety analyses) of nuclear power plants.
— Students learn about specific components of nuclear power plants.

The drawbacks of each type of theses are more or less just the advantages of the opposite type, so there is no need to discuss them by reversing the arguments.

The last two cited advantages of applied-oriented theses are often cited by the nuclear industry as arguments, that academic and research institutions do not provide adequate professionals for their needs. However, this is a misinterpretation of the role of academic and research institutions: as teaching institutions, their role is essentially to teach high-level knowledge, which will enable students to learn a wide variety of technical skills, as well as to understand the characteristics and modes of functioning of different technical systems. It is true, that students cannot start applying their knowledge right away after completing their doctoral theses, and that the nuclear industry must first invest in them before benefiting from them. It is also true, that students having worked on a basic subject might lack the broad vision, necessary to oversee the functioning of a complex industrial system. However, in the long term, students having completed a doctoral thesis on a basic subject are professionals, which could be expected to work on a much more wide range of topics.

4. Conclusions

A survey of doctoral theses in nuclear thermal hydraulics and severe accidents, performed at the JSI Reactor Engineering Division in the period 1993-2010, has shown a predominance of basic theses over applied-oriented ones. The main reasons for this state of affairs were analysed. Although the current situation is by no means perfect, the authors are of the opinion, that the merits of basic doctoral theses over applied-oriented ones overcome their drawbacks. Furthermore, a shift towards applied-oriented theses would be difficult due to the current criteria fot obtaining a doctoral degree.

5. Abbreviations

CFD Computational Fluid Dynamics
PWR Pressurized Water Reactor
RPV Reactor Pressure Vessel

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INTERNATIONAL TRAINING PROGRAM IN SUPPORT OF SAFETY ANALYSIS: 3D S.UN.COP - SCALING, UNCERTAINTY AND 3D THERMAL-HYDRAULICS/NEUTRON-KINETICS COUPLED CODES SEMINARS

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ABSTRACT

Thermal-hydraulic system computer codes are extensively used worldwide for analysis of nuclear facilities by utilities, regulatory bodies, nuclear power plant designers and vendors, nuclear fuel companies, research organizations, consulting companies, and technical support organizations. The computer code user represents a source of uncertainty that can influence the results of system code calculations. This influence is commonly known as the 'user effect' and stems from the limitations embedded in the codes as well as from the limited capability of the analysts to use the codes. Code user training and qualification is an effective means for reducing the variation of results caused by the application of the codes by different users. This paper describes a systematic approach to training code users who, upon completion of the training, should be able to perform calculations making the best possible use of the capabilities of best estimate codes. In other words, the program aims at contributing towards solving the problem of user effect. The 3D S.UN.COP (Scaling, Uncertainty and 3D COuPled code calculations) seminars have been organized as follow-up of the proposal to IAEA for the Permanent Training Course for System Code Users. Eleven seminars have been held at University of Pisa (two in 2004), at The Pennsylvania State University (2004), at the University of Zagreb (2005), at the School of Industrial Engineering of Barcelona (January-February 2006), in Buenos Aires, Argentina (October 2006), requested by Autoridad Regulatoria Nuclear (ARN), Nucleoelectrica Argentina S.A (NA-SA) and Comisión Nacional de Energía Atómica (CNEA), at the College Station, Texas A&M, (January-February 2007), in Hamilton and Niagara Falls, Ontario (October 2007) requested by Atomic Energy Canada Limited (AECL), Canadian Nuclear Society (CNS) and Canadian Nuclear Safety Commission (CNSC), in Petten, The Netherlands (October 2008) in cooperation with the Institute of Energy of the Joint Research Center of the European Commission (IE-JRC-EC), at the Royal Institute of Technology, Stockholm (October 2009) and in Petten, The Netherlands (October 2010) in cooperation with the Institute of Energy of the Joint Research Center of the European Commission (IE-JRC-EC). It was recognized that such courses represented both a source of continuing education for current code users and a mean for current code users to enter the formal training structure of a proposed 'permanent' stepwise approach to user training. The 3D S.UN.COP 2010 at IE-JRC was successfully held with the attendance of 23 participants coming from more than 10 countries and 20 different institutions (universities, vendors and national laboratories). More than 30 scientists (coming from more than 10 countries and 20 different institutions) were involved in the organization of the seminar, presenting theoretical aspects of the proposed methodologies and holding the training and the final examination. A certificate (LA Code User grade) was released to participants that successfully solved the assigned problems. The eleventh seminar has been held (March 2011) in Wilmington, North Carolina, involving more than 30 scientists between lecturers and code developers (http://www.nrgspg.ing.unipi.it/3dsuncop/).

1. Introduction

The best estimate thermal-hydraulic codes used in the area of nuclear reactor safety have reached a marked level of sophistication. Their capabilities to predict accidents and transients at existing plants have substantially improved over the past years as a result of large research efforts and can be considered satisfactory for practical needs provided that they are used by competent analysts.

Some recognized inadequacies in code calculation results are due to the limitations embedded in the codes. These range from some model deficiencies to approximation in the numeric solution. The transformation of the actual reference system geometry into an approximate noding scheme constitutes an additional limitation. Nodalization imperfections, insufficient knowledge of initial and boundary conditions, and 'user effects' add to the limitations of the code prediction. User effects [2] lie at the origin of most of the inaccuracies for the following reasons: Fully detailed, comprehensive code user guidelines do not exist. The actual (three dimensional) plant is modeled with several one dimensional approximations. Engineering knowledge has to be applied in the preparation of the input deck in order to deal with some of the code limitations. Certain problems are inherent in the approaches used in the modeling process such as: use of local pressure drop coefficients, critical flow rate multipliers, application to transient conditions of models qualified for steady state, application of the fully developed flow concept for different nuclear reactor conditions, etc.

The fact that an increasing number of users without adequate qualification have access to the system codes and nodalizations may produce diverging results and lead to the diffusion of erroneous evaluations. Experimental data, including the values of initial and boundary conditions that are used as a basis for comparisons are, in the large majority of cases, supplied without error bands.

Clear criteria for the acceptability of the results have not been agreed upon among experts in the area. A wide range of activities have recently been completed in the area of system thermal-hydraulics as a follow-up to considerable research efforts. Problems have been addressed, solutions to which have been at least partly agreed upon on international ground. These include: the need for best-estimate system codes [3] and [4], the general code qualification process [5] and [6], the proposal for nodalization qualification and attempts aiming at qualitative and quantitative accuracy evaluations [7]. Complex uncertainty methods have been proposed, following a pioneering study at USNRC [8]. This study attempted, among other things, to account for user effects on code results. An international study aiming at the comparison of assumptions and results of code uncertainty methodologies has been completed [9]. More recently, the IAEA developed a Safety Report on Accident Analysis of Nuclear Power Plants containing a set of practical suggestions based on best practice worldwide [10].

2. IAEA Safety Report On Accident Analysis

During the period 1997-1999, the IAEA developed a document consistent with its revised Nuclear Safety Standards Series [10] that provides guidance on accident analysis of nuclear power plants (NPPs). The report includes a number of practical suggestions on the manner in which to perform accident analysis of NPPs. These cover the selection of initiating events, acceptance criteria, computer codes, modeling assumptions, the preparation of input, qualification of users, presentation of results, and quality assurance (QA). The suggestions are both conceptual as well as formal and are based on present practice worldwide for performing accident analysis. The report covers all major steps in performing analyses and is intended primarily for code users.

Within the framework of the IAEA guidance the important role of the user effects on the analysis is addressed. The need for user qualification and training is clearly recognized. The systematic training of analysts is emphasized as being crucial for the quality of the analysis results. Three areas of training, in particular, are specified: practical training on the design and operation of the plant; software specific training; and application specific training.

Training on the phenomena and methodologies is typically provided at the university level, but cannot always be considered as sufficient. Furthermore, training on the specific application of system codes is not usually provided at this level. Practical training on the design and operation of the plant is, however, essential for the development of the plant models. Software specific training is important for the effective use of the individual code. Application specific training requires the involvement of a strong support group that shares its experience with the trainees and provides careful supervision and review.

Training at all three levels ending with examination is encouraged for a better effectiveness of the training. Such a procedure is considered as a step in the direction of establishing a standard approach that could be applicable on an international basis.

A significant number of the suggestions made by the IAEA relate to the preparation of input decks and to the collection of the relevant plant data as well as to the presentation and evaluation of the results and to QA. In addition, the report specifies a procedure for performing accident analysis that covers all important steps needed for this task.

3. Code Users

Best estimate codes are used by designer/vendors of NPPs, by utilities, licensing authorities, research organizations including universities, nuclear fuel companies, and by technical support organizations. The objectives of using the codes may be quite different, ranging from design or safety assessment to simply understanding the transient behavior of a simple system. In view of the current computing capabilities, a system code (e.g. RELAP, TRAC, CATHARE, or ATHLET) can be put into operation in a few days. In the same time span, results can be obtained for a complex system provided that there is a nodalization available. An unqualified input deck related to a complex system such as an NPP can be set up in time periods of a few weeks using the available code manuals. However, these periods can be shortened if the analyst is a ‘qualified’ code user. Qualified code user groups already exist; scientists who have been working with system codes for more than thirty years belong to such groups.

The most sensitive use of the code deals with situations in which the results obtained have an effect on the design or safety assessment of the NPP. In this context, the code validation process, nodalization qualification, qualitative or quantitative accuracy evaluation, and the use of the code by a qualified code user have been recognized as necessary steps to reduce the possibility of producing poor code predictions [11].

4. Permanent User Training Course For System Code: The Proposal

As a follow-up to the Specialists Meeting held at the IAEA in September 1998, the Universities of Pisa and Zagreb and the Jožef Stefan Institute, Ljubljana, jointly presented a Proposal to IAEA for the Permanent Training Course for System Code Users [1]. It was recognized that such a course would represent both a source of continuing education for current code users and a means for current code users to enter the formal training structure of a proposed ‘permanent’ stepwise approach to user training.

Before finalizing the main outcomes in relation to the proposed user training, the following can be emphasized:

- the user gives a contribution to the overall uncertainty that unavoidably characterizes system code calculation results;
- in the majority of cases, it is impossible to distinguish among uncertainty sources like 'user effect', 'nodalization inadequacy', 'physical model deficiencies', 'uncertainty in boundary or initial conditions', 'computer/compiler effect';
- 'reducing the user effect' or 'finding the optimum nodalization' should not be regarded as a process that removes the need to assess the uncertainty;
- in general, it is misleading to prepare guidelines that focus codes predictions into a narrow part of the uncertainty. As a follow up of the massive work conducted in different organizations, the need was felt to fix criteria for training the code user. As a first step, the kind of code user and the level of responsibility of a calculation result should be discussed.

4.1 Levels of User Qualification

Two main levels for code user qualification are distinguished in the following:

- Code user, level "A" (LA);
- Responsible of the calculation results, level "B" (LB).

A Senior grade level should be considered for the LB code user (LBS). Requisites are detailed hereafter for the LA grade only; these must be intended as a necessary step (in the future) to achieve the LB and the LBS grades. The main difference between LA and LB lies in the documented experience with the use of a system code; for the LB and the LBS grades, this can be fixed in 5 and 10 years, respectively, after achieving the LA grade. In such a context, any calculation having an impact in the sense previously defined must be approved by a LB (or LBS) code user and performed by a different LA or LB (or LBS) code user.

4.2 Requisites for Code User Qualification

4.2.1 LA Code User Grade

The identification of the requisites for a qualified code user derives from the areas and the steps concerned with a qualified system code calculation: a system code is one of the (four) codes previously defined and a qualified calculation in principle includes the uncertainty analysis. The starting condition for LA code user is a scientist with generic knowledge of nuclear power plants and reactor thermalhydraulics (e.g. in possession of the master degree in US, of the 'Laurea' in Italy, etc.).

*Areas for code user qualification**:*** The requisites for the LA grade code user are in the following areas:

A) Generic code development and assessment processes;
B) Specific code structure;
C) Code use -Fundamental Problems (FP);
D) Code use -Basic Experiments (BETF);
E) Code use -Separate Effect Test Facilities (SETF);
F) Code use -Integral Test Facilities (ITF);
G) Code use -Nuclear Power Plant transient Data
H) Uncertainty Methods including concepts like
nodalization, accuracy quantification, user effects.

Area A)

Sub-area Al): Conservation (or balance) equations in thermalhydraulics including definitions like HEM/EVET, UVUT(UP), Drift Flux, lD, 3-D, 1-field, Multi-field, [4]. Conduction and radiation heat transfer. Neutron Transport Theory and Neutron Kinetics approximation. Constitutive (closure) equations including convection heat transfer. Special Components (e.g. pump, separator). Material properties. Simulation of nuclear plant and BoP related control systems. Numerical methods. General structure of a system code. *Sub-area A2)*: Developmental Assessment. Independent Assessment including SET Code Validation Matrix, [5], and Integral Test Code Validation Matrix, [6]. Examples of specific Code validation Matrices.

Area B)

Sub-area Bl): Structure of the system code selected by the LA code user: thermalhydraulics, neutronics, control system, special components, material properties, numerical solution.

Sub-area B2): Structure of the input deck; examples of user choices.

Area C)

Sub-area Cl): Definition of Fundamental Problem (FP): simple problems for which analytical solution may be available or less. Examples of code results from applications to FP; different areas of the code must be concerned (e.g. neutronics, thermalhydraulics, and numerics).

Sub-area C2): The LA code user must deeply analyze[1] at least three specified FPs, searching for and characterizing the effects of nodalization details, time step selection and other code-specific features.

Area D)

Sub-area Dl): Definition of Basic test facilities and related experiments (BETF): researches aiming at the characterization of an individual phenomenon or of an individual quantity appearing in the code implemented equations, not necessarily connected with the NPP. Examples of code results from applications to BETF.

[1] - to develop a nodalization starting from a supplied data base or problem specifications;
- to run a reference test case;
- to compare the results of the reference test case with data (experimental data, results of other codes, analytical solution), if available;
- to run sensitivity calculations;
- to produce a comprehensive calculation report (having an assigned format).

Sub-area D2): The LA code user must deeply analyze[1] at least two selected BETF, searching for and characterizing the effects of nodalization details, time step selection, error in boundary and initial conditions, and other code-specific features.

Area E)

Sub-area El): Definition of Separate Effect Test Facility (SETF): test facility where a component (or an ensemble of components) or a phenomenon (or an ensemble of phenomena) of the reference NPP is simulated. Details about scaling laws and design criteria. Examples of code results from applications to SETF.

Sub-area E2): The LA code user must deeply analyze[1] at least one specified SETF experiment, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions and other code-specific features.

Area F)

Sub-area Fl): Definition of Integral Test Facility (ITF): test facility where the transient behavior of the entire NPP is addressed. Details about scaling laws and design criteria. Details about existing (or dismantled) ITF and related experimental programs. ISPs activity. Examples of code results from applications to ITF.

Sub-area F2): The LA code user must deeply analyze[1] at least two specified ITF experiments, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions and other code-specific features.

Area G)

Sub-area Gl): Description of the concerned NPP and of the relevant (to the concerned NPPD and calculation) BoP and ECC systems. Examples of code results from applications to NPPD.

Sub-area G2): The LA code user must deeply analyze[1] at least two specified NPP transients, searching for and characterizing the effects of nodalization details, time step selection, errors in boundary and initial conditions and other code-specific features.

Area H)

Description of the available uncertainty methodologies. The LA code user must be aware of the state of the art in this field.

4.2.2LB Code User Grade

A qualified user at the LB grade must be in possession of the same expertise as the LA grade and:

I) he must have a documented experience in the use of system codes of at least 5 additional years;

J) he must know the fundamentals of Reactor Safety and Operation- and Design having generic expertise in the area of application of the concerned calculation;

K) he must be aware of the use and of the consequences of the calculation results; this may imply the knowledge of the licensing process.

4.2.3LBS Code User Grade

A qualified user at the LBS grade must be in possession of the same expertise as the LB grade and:

L) he must have an additional documented experience in the use of system codes of at least 5 additional years.

4.3 Modalities for the achievements of the LA, LB and LBS Code User grades

LA grade: Two years training and "Home Work" with modalities defined in Table 1, are necessary to achieve the LA grade, following an examination.

LB grade: The steps and the time schedule needed to achieve the LB code user grade are summarized in Tab. 1. An examination is needed (5 years after the LA grade).

LBS grade: The steps and the time schedule needed to achieve the LBS code user grade are summarized in Tab. 1. The LBS code use grade can be obtained (5 years after achieving the LB grade) following the demonstration of performed activity in the 5 years period.

4.4 Course Conduct

The training of the code user requires the conduct of lectures, practical on-site exercises, homework, and examination while, for the senior code user, only a review of documented experience and on-site examination is foreseen.

The code user training, including practical exercises, which represent an essential part of the course, lasts two years and covers the following areas:

A) Generic code development and assessment processes:

general structure of a system code; conservation (or balance) equations in thermal-hydraulics; conduction and radiation heat transfer; neutron transport theory and neutron kinetics approximation; constitutive (closure) equations including convection heat transfer; special components (e.g. pump, separator); material properties; constitutive (closure) equations including convection heat transfer; special components (e.g. pump, separator); material properties; simulation of NPP and balance of plant (BoP) related control systems; numerical methods; developmental assessment; independent assessment including the separate effect test code validation matrix [5], and integral test code validation matrix [6]; and examples of specific code validation matrices.

B) Specific code structure: structure of a system code selected by the code user: thermal-hydraulics, neutronics, control system, special components, material properties, and numerical solution; and structure of the input deck, examples of user options.

C) Fundamental problems or simple problems for which analytical solution may be available:

D) definition of fundamental problems; and examples of code results from applications involving different areas of the code concerned (e.g. neutronics, thermal-hydraulics, numerics). Basic test facilities and related experiments for the characterization of an individual phenomenon or of an individual quantity appearing in the code equations.

E) SETFs where a component (or an ensemble of components) or a phenomenon (or an ensemble of phenomena) of the reference NPP is simulated: details of scaling laws and design criteria; and examples of code results from applications.

F) ITFs where the transient behavior of the entire NPP is addressed: details of scaling laws and design criteria; and details of ITFs and related experimental programs; International Standard Problem activity; and an example of code results from applications to ITFs.

G) Applications to nuclear power plants: description of the NPP concerned and of the relevant BoP system and emergency core cooling system; an example of code results from applications to an NPP; practical exercises in the use of the code for NPP accident analysis highlighting the detection of errors in boundary and initial conditions and other code specific features; use of NPP simulators/analyzers.

H) Uncertainty methods including accuracy quantification: description of the available uncertainty methodologies; and state of the art and future prospects in this field. In addition to the aforementioned areas, senior code user training also covers:

I) The use of accident analysis in reactor design and safety assessment.

J) Effects of analysis results on the licensing process.

4.5 Training Exercises

Practical exercises foreseen during the training include development of the nodalization from the pre-prepared database with problem specifications. To this end, didactic material and presentations/lectures on the exercise will be provided with a detailed explanation of the objectives of the work that the trainee must perform. Extensive application of the code by the trainee at his own institution following detailed recommendations and under the supervision of the course lecturers is foreseen as 'homework'. The use of the code at the course venue is foreseen for the following applications: fundamental problems including nodalization development; basic test facilities and related experiments including nodalization development; SETFs and related experiments including nodalization development; ITF experiments with nodalization modifications; and NPP transients including nodalization modifications.

For each of the above cases, the trainee will be required to:

1. develop (or modify) a nodalization starting from the database or problem specifications provided;
2. run the reference test case;
3. compare the results of the reference test case with data (experimental data, results of other codes, analytical solution);
4. run sensitivity calculations;
5. produce a comprehensive calculation report following a prescribed format whereby the report should include, for example:
   - the description of a particular facility;

- the description of an experiment (including relevance to scaling and relevance to safety);
- modalities for developing (or modifying) the nodalization;
- the description and use of nodalization qualification criteria for steady state and transient calculations;
- qualitative and quantitative accuracy evaluation;
- use of thresholds for the acceptability of results for the reference case;
- planning and analysis of the sensitivity runs; and
- an overall evaluation of the activity (code capabilities, nodalization adequacy, scaling, impact of the results on the safety and the design of NPP, etc.).

4.6 Examination

On-site examination at different stages during the course is considered a condition for the successful completion of the code user training. The homework that the candidate must complete before attempting the on-site examination includes:

A) Studying the material/documents supplied by the course organizers.
B) Solving the problems assigned by the course organizers. This also involves the preparation of suitable reports that must be approved by the course organizers.

The on-site tests consist of four main steps that include the evaluation of the reports prepared by the candidate, answering questions on the reports and course subjects and demonstrating the capability to work with the selected code. Each step must be accomplished before proceeding to the subsequent one. The completion of all the steps of the examination requires that the candidate spend one full week at the course venue

Table 1: Subjects and time schedule necessary for the LA Code user grade.

Code User Grade	WEEKS	LECTURES	SPECIF FOR HOME-WORK	HOME-WORK	ON-SITE TEST
LA	1-2	A1, A2^, B1, B2^, C1, D1			
	3		C2, D2		
	4-25			A, B, C2*, D2*	
	26				A1, B1, C, D, C2°, D2°
	27	A2, E1	E2		
	28-50			E2*	
	51				A2, E, E2°
	52	B2, F1	F2		
	53 - 76			F2*	
	77				B2, F, F2°
	78	H, G1	G2*		
	79-102			G2*	
	103				G, H, G2*
LB (5 yrs after LA)	1				I*, J, K, K°
LBS (5 yrs after LB)	1				L*
^ Fundamental, * Report necessary, ° Solution of submitted problems and discussion					

5. 3D S.UN.COP SEMINARS: FOLLOW-UP OF THE PROPOSAL

5.1 Background Information about 3D SUNCOP Trainings

The 3D S.UN.COP (*Scaling, Uncertainty and 3D COuPled code calculations*) training aims to transfer competence, knowledge and experience from recognized international experts in the area of scaling, uncertainty and 3D coupled code calculations in nuclear reactor safety technology to analysts with a suitable background in nuclear technology.

The training is open to research organizations, companies, vendors, industry, academic institutions, regulatory authorities, national laboratories, etc. The seminar is in general subdivided into three parts and participants may choose to attend a one-, two- or three-week course. The first week is dedicated to the background information including the theoretical bases for the proposed methodologies; the second week is devoted to the practical application of the methodologies and to the hands-on training on numerical codes; the third week is dedicated to the user qualification problem through the hands-on training for advanced user and include a final exam. From the point of view of the conduct of the training, the weeks are characterized by lectures, code-expert teaching and by hands-on-application,. More than thirty scientists (including the organizers and the external lecturers) are in general involved in the organization of the seminars, presenting theoretical aspects of the proposed methodologies and holding the training and the final examination. A certificate of qualified code user is released to participants that successfully solve the assigned problems during the exams.

The framework in which the 3D S.UN.COP seminars have been designed may be derived from Figure 1, where the roles of two main international institutions (OECD and IAEA) and of the US NRC (and the regulatory bodies of other countries) in order to address the problem of user effect are outlined together with the proposed programs and produced documents. Figure 2 depicts how the 3D S.UN.COP ensures the nuclear technology maintenance and advancements through the qualification of personnel in regulatory bodies, research activities and industries by mean of teaching of very well known scientists belonging to the same type of institutions.

At present, three institutions are planning and managing the 3D SUNCOP: 1- the Department of Mechanical, Nuclear and Production Engineering (DIMNP) of the University of Pisa, Italy (UNIPI, *the group was the pioneer in the organization of the initial 3D SUNCOP trainings*), 2-the group of Dynamic Analysis of Energy Systems of the Department of Physics and Nuclear Engineering, Technical University of Catalonia (UPC), at the premises of the School of Industrial Engineering of Barcelona, Spain (ETSEIB), and 3- the Department of Power Systems (ZVNE) of the Faculty of Electrical Engineering and Computing of Zagreb, Croatia (FER), University of Zagreb (UNIZG).

Eleven Training Courses have been organized up to now and were successfully held at:

- The University of Pisa (Pisa, Italy), 5 – 9 January 2004 (6 participants)
- The Pennsylvania State University (University Park, PA, USA), 24 – 28 May 2004 (15 participants)
- The University of Pisa (Pisa, Italy), 14 – 18 June 2004 (11 participants)
- The University of Zagreb (Zagreb, Croatia), 20 June – 8 July 2005 (19 participants)
- The Polytechnic University of Catalonia (Barcelona, Spain), 23 January – 10 February 2006 (33 participants)
- The Autoridad Regulatoria Nuclear (ARN), the Comisión Nacional de Energía Atómica (CNEA), the Nucleoelectrica Argentina S.A (NA-SA) and the Universidad Argentina De la Empresa (Buenos Aires, Argentina), 2 October – 14 October 2006 (37 participants)
- The Texas A&M University (College Station, Texas, USA), 22 January – 9 February 2007 (26 participants)
- The Hamilton & Niagara Falls, Ontario, Canada (2007), 8 October – 26 October (33 participants)
- The IE-FRC Petten & Alkmaar, (Amsterdam, Netherlands) 13 October – 31 October 2008 (35 participants)
- The Royals Institute of Technology (Stockholm, Sweden) 12 October – 30 October 2009 (38 participants)
- The IE-JRC Petten (Netherlands) 18 October – 5 November 2010 (23 participants)

5.2 OBJECTIVES AND FEATURES OF THE 3D S.UN.COP SEMINAR TRAININGS

The main objective of the seminar activity was the training in safety analysis of analysts with a suitable background in nuclear technology. The training was devoted to the promotion and use of international guidance and to homogenize the approach to the use of computer codes for accident analysis. Between the main objectives are:

- To transfer knowledge and expertise in Uncertainty Methodologies, Thermal-Hydraulics System Code and 3D Coupled Code Applications;
- To diffuse the use of international guidance;
- To homogenize the approach in the use of computer codes (like RELAP, TRACE, CATHARE, ATHLET, CATHENA, PARC, RELAP/SCDAP, MELCOR, IMPACT) for accident analysis;
- To disseminate the use of standard procedures for qualifying thermal-hydraulic system code calculation (e.g. through the application of the UMAE <Uncertainty Methodology based on Accuracy Extrapolation> [12]);
- To promote Best Estimate Plus Uncertainty (BEPU) methodologies in thermal-hydraulic accident analysis through the presentation of the current industrial applications and the description of the theoretical aspects of the deterministic and statistical uncertainty methods as well as the method based upon the propagation of output errors (called CIAU <Code with the capability of Internal Assessment of Uncertainty> [13, 14]);
- To spread available-robust approaches based on BEPU methodology in Licensing Process;
- To address and reduce User Effects;
- To realize a meeting point for exchanges of ideas among the worlds of Academy, Research Laboratories, Industry, Regulatory Authorities and International Institutions.

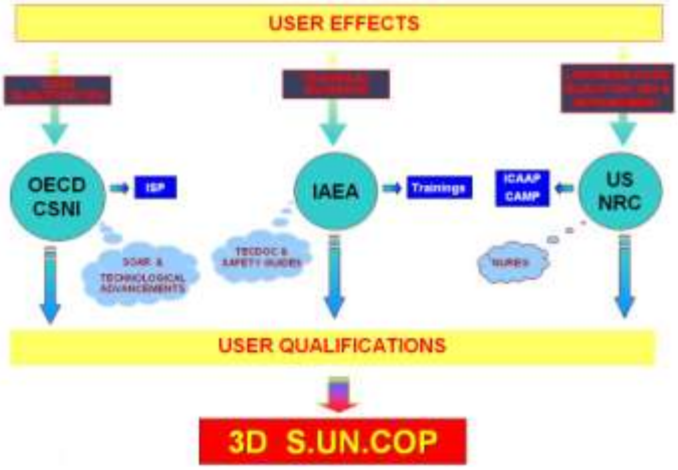

Figure 1. 3D S.UN.COP Framework to address the user effect problem.

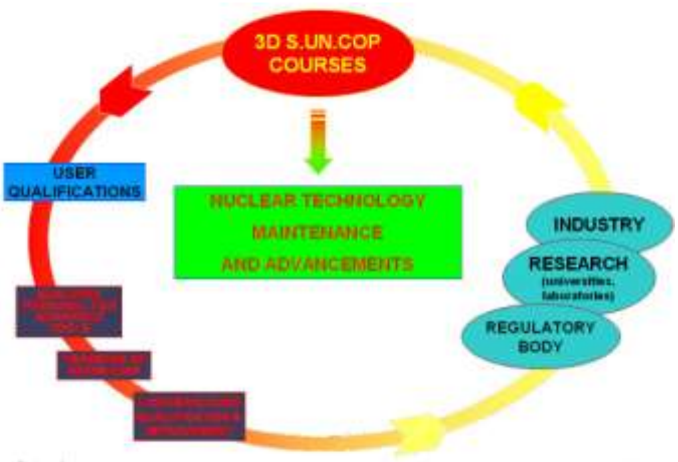

Figure 2. 3D S.UN.COP Loop of benefits.

Other two fundamental goals to achieve are:

- *<u>To ensure of a suitable Quality Assurance (QA) for the training</u>*. Higher Education in Europe is nowadays involved in a process of change as focus has to be set on the student's workload and on his significant learning. This is a wide subject with many implications that are leading to important changes. Different initiatives have been already carried out in many European universities looking for this new approach in teaching organization and in the methodology used. Some essential aspects to be taken into account are the definition of the learning objectives and results, the planning of activities necessary to reach these objectives, the use of active learning methodologies (cooperative learning, problem-based learning) and the use of continuous learning measurement. To fulfil this main goal, some other objectives have been established:

- To ensure the teaching quality at the following levels
- To ensure an adequate learning measurement
- To establish a procedure for admission of participants
- To ensure adequacy of teachers
- To consider the tools for preserving the knowledge
- To follow the international developments

➢ *The connection with EC objectives and framework*. To connect the 3D SUNCOP training with EC objectives and framework. This includes:

- Experience and dissemination from past and present EC projects which have links with the 3D SUNCOP training subjects (CRISSUE-S, VALCO, CERTA…)
- Consideration of key results of EC Framework Programs.
- Consideration of transfer of knowledge inside EC TACIS and Phare projects.
- Consideration of any individual EC program that may have any connection with the 3D SUNCOP subjects.
- Consideration of ENEN network initiatives.
- Consideration of (new) relevant political areas for the EC.
- To establish a permanent contact with EC offices (Bruxelles, JRC, etc...)

The following main features of the seminar-course may be identified and outlined:

❖ *The idea of practical use of the code*: a course without practical code application has (much) lower validity.
❖ *The idea to mix different codes*: the use of different code is worthwhile also to establish a common basis for code assessment and for the acceptability of code results.
❖ *The need of exam*: exams were in the past courses (very) well accepted by code users. The exam gave them the possibility to show their expertise and to demonstrate the effort done during the course.
❖ *The practical use of procedures for nodalisation qualification* that can be directly applied in the participants institutions.
❖ *The practical use of procedures for accuracy quantification* that are demonstrated at the qualitative and the quantitative level.
❖ *The "joining" between BE codes and uncertainty evaluation* that shows the full application of uncertainty methodologies and the worth of these within a licensing process.
❖ The establishment, promotion and use of international guidance through *large participation of very well known international experts*

5.3 3D S.UN.COP Training Structure

The seminar is subdivided into three main parts, each of one with a program to be developed in one week. The changes between lectures, computer work and model discussion showed up useful to maintain a steady high level of participant's attendance. The duration of the individual sessions varied substantially according to the complexity of the subjects and the training needs of the participants:

- The first week (titled "Fundamental Theoretical Aspects") is fully dedicated to lectures describing the concepts of the proposed methodologies. The following 8 technical sessions (with more than 30 lectures) are presented covering the main topics hereafter listed:
  - *Session I: system codes: evaluation, application, modelling & scaling*
    - models and capabilities of system code models
    - development process of generic codes and developmental assessment
    - scaling of thermal-hydraulic phenomena
    - separate and integral test facility matrices
  - *Session II : International Standard Problems*

- lesson learnd from OECD/CSNI ISP
- characterization and Results from some ISP

- *Session III: best estimate in system code applications and uncertainty evaluation*
  - IAEA safety standards
  - origins of uncertainty
  - approaches to calculate uncertainty
  - user effect
  - evaluation of safety margins using BEPU methodologies
  - international programs on uncertainty (UMS [11] and BEMUSE [12])
- *Session IV: qualification procedures*
  - qualifying, validating and documenting input deck
  - the feature of UMAE methodology
  - description and use of nodalization qualification criteria for steady state and transient calculation
  - use of thresholds for the acceptability of results for the reference case;
  - qualitative accuracy evaluation
  - quantitative accuracy evaluation by Fast Fourier Transform Based Method
- *Session V: methods for sensitivity and uncertainty analysis*
  - GRS statistical uncertainty methodology
  - CIAU Method for Uncertainty Evaluation
  - ASAP and GASAP procedures for Sensitivity Analysis
  - Comparison of Uncertainty Methods with CSAU Methodology

Session VI: relevant topics in best estimate licensing approach
- best estimate approach and rules in licensing

Session VII: 3D Neutron-Kinetics/Thermal-Hydraulic Coupling
- Cross section generation: models and applications
- coupling 3D neutron-kinetics/thermal-hydraulic codes (3D NK-TH)
- uncertainties in basic cross-section
- CIAU extension to 3D NK-TH

- The second week (titled "Industrial Application, Coupling Methodologies and Hands-on Training") is devoted to lectures on the practical aspects of the proposed methodologies and to the hands-on training on numerical codes like ATHLET, CATHARE, CATHENA, RELAP5 USNRC, RELAP5-3D ©, TRACE, PARCS, RELAP/SCDAP and IMPACT.. The following 4 technical sessions are presented covering the main topics hereafter listed:
  - *Session I: industrial application of the best estimate plus uncertainty methodology: general Aspects and Procedures*

- Historical Evolution of LOCA Regulatory Requirements
- CSAU and EMDAP (RG 1.157 and RG 1.203) methodologies with particular emphasis to the PIRT process
- Computer Code, Evaluation Model Assessment of Biases and Uncertainties
- Industry Best Practices in Evaluation Model Development and Assessment

- *Session II: industrial application of the best estimate plus uncertainty methodology: Vendors' Application and Sample Results*
  - Westinghouse realistic large break LOCA methodology
  - AREVA realistic accident analysis methodology
  - GE Technology for Establishing and Confirming Uncertainties
  - BEAU for CANDU reactors
  - UMAE/CIAU application to Angra-2 DEGB licensing calculation

Session III: Interactions of Thermal-Hydraulics with Fuel behaviour, Structural Mechanics and Computational Fluid Dynamics
- Modelling Fuel Behaviour and its Interaction with Thermal-hydraulics
- Safety Limits, with Particular Reference to High Burn-Up
- Mox Fuel and related Safety Issues
- Pressurised Thermal Shock
- Role of CFD Codes and Bases for their Use in Nuclear Reactor Technology

Each of the parallel hands-on trainings on numerical codes consists of about 20 hours and covers the following main topics:
- Structure of specific codes
- Numerical methods

- Description of input decks
- Example of code results from applications to ITFs (LOFT, LOBI, BETHSY)

- The third week (titled “Code Hands-on Training for Transient Analysis in ITF”) is designed for advanced-users addressing the user effect problem. The participants are divided in group of three and each group receive the training from one teacher. The applications of the proposed methodologies (UMAE, CIAU etc.) are illustrated through the BETHSY ISP 27 (SBLOCA) and LOFT L2-5 (LBLOCA) tests. Applications and exercises using several tools (RELAP5, WinGraf, FFTBM, UBEP, CIAU, etc…) are considered. The following main topics are covered:
  - Modalities for developing (or modifying) the nodalization
  - Plant accident and transient analyses
  - Examples of code results from application to a NPP
  - Code hands-on training through the application of system codes to ITFs

A final examination on the lessons learned during the seminar is designed and consists of three parts:

I) Written Part: Questions about the topics discussed during the seminar are proposed and 20 questions are assigned both to each participant and to each group. At least 14 questions must be correctly answered by the group and 14 by each participant.

II) Application Part: Two types of problems are proposed to the single participant and to the group:

Detection of Simple Input Error : each participant receives the experimental data of the selected transient, the correct RELAP5 nodalization input deck and the restart file of the wrong input deck containing one simple input error. Each participant shall identify the error.

Detection of Complex Input Error: Each group receives the experimental data of the selected transient, the correct RELAP5 nodalization input deck and the restart file of the wrong input deck containing one complex input error. Each group shall identify the error, evaluation reports are submitted in a written form containing short notes about the reasons for the differences between results of the reference calculation and results from the ‘modified’ nodalization. At least one problem over two shall be correctly solved to obtain the certificate

III) Final Discussion: Each participant takes an oral examination of about 15-20 minutes, discussing own results (or results obtained by own group) with the examiners. General questions related to lectures presented during the three-weeks seminar are asked to the participants. A certificate of type “LA Code User Grade” (see Table 1) like the one depicted in Figure 3 is released to participants that successfully solved the assigned problems.

5.4 3D S.UN.COP 2010 in IE-JRC-EC Petten (Netherlands)

The 3D S.UN.COP 2010 was successfully held in Petten (Netherlands) from October 18th to November 5th with the attendance of 23 participants coming from 8 countries and 16 different institutions (universities, vendors and national laboratories). 32 scientists (13 countries and 23 different institutions) were involved in the organization of the seminar, presenting theoretical aspects of the proposed methodologies and holding the training and the final examination.

All the participants achieved a basic capability to set up, run and evaluate the results of a thermal-hydraulic system code (e.g. RELAP5) through the application of the proposed qualitative and quantitative accuracy evaluation procedures.

At the end of the seminar a questionnaire for the evaluation of the course was distributed to the participants. All of them very positively evaluated the conduct of the training as can be derived from the charts in Figure 4.

Figure 3. 3D S.UN.COP “LA Code User Grade” Certificate.

6. Conclusions

An effort is being made to develop a proposal for a systematic approach to user training. The estimated duration of training at the course venue, including a set of training seminars, workshops, and practical exercises, is approximately two years. In addition, the specification and assignment of tasks to be performed by the participants at their home institutions, with continuous supervision from the training center, has been foreseen.

The 3D S.UN.COP seminars constitute the follow-up of the presented proposal. The responses of the participants during the training demonstrated an increase in the capabilities to develop and/or modify the nodalizations and to perform a qualitative and quantitative accuracy evaluation. It is expected that the participants will be able to set up more accurate, reliable and efficient simulation models, applying the procedures for qualifying the thermal-hydraulic system code calculations, and for the evaluation of the uncertainty. The eleventh seminar has been held (March 2011) at the Royal at Wilmington, North Carolina (USA), involving more than 30 scientists between lecturers and code developers (www.grnspg.ing.unipi.it/3dsuncop/).

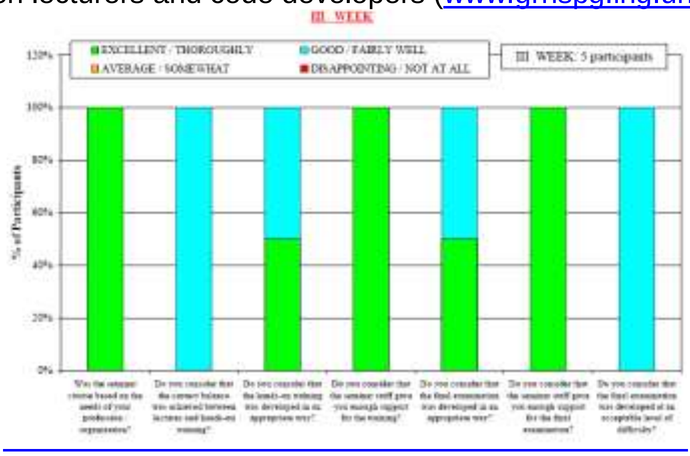

Figure 4: Design & conduct of the seminar-training.

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