

ENC 2012

EUROPEAN NUCLEAR CONFERENCE



MANCHESTER
9-12 December 2012

United Kingdom

Transactions Education & Training



ENS CONFERENCE

ENC 2012 Diamond Sponsor:



ENC 2012 Gold Sponsors:



ENC 2012 Silver Sponsor:



ENC 2012 Sponsor:



organised in collaboration with:



© 2012
European Nuclear Society
Rue Belliard 65
1040 Brussels, Belgium
Phone + 32 2 505 30 54
Fax +32 2 502 39 02
E-mail ens@euronuclear.org
Internet www.euronuclear.org

ISBN 978-92-95064-14-0

These transactions contain all contributions submitted by 7 December 2012.

The content of contributions published in this book reflects solely the opinions of the authors concerned. The European Nuclear Society is not responsible for details published and the accuracy of data presented.

ENC2012-A0012	PUTTING INTO PERSPECTIVE THE SUPPLY OF AND DEMAND FOR NUCLEAR EXPERTS: AN EHRO-N REPORT	Simonovska, V. (1); Von Estorff, U. (1) 1 - European Commission, Joint Research Centre, Institute for Energy and Transport, Netherlands
ENC2012-A0023	Lessons learnt from Building a Nuclear Training Accreditation model in the UK	Drury, D. (1) 1 - EDF Energy, United Kingdom
ENC2012-A0032	TOWARDS A NUCLEAR ECVET SYSTEM	Lacal Molina, M. A. (1); Von Estorff, U. (1) 1 - INSTITUTE FOR ENERGY AND TRANSPORT - JRC EC, Netherlands
ENC2012-A0052	INITIATIVES AND FACILITIES FOR E&T IN THE NUCLEAR SCIENCE AND TECHNOLOGY MASTER AT UPM	Ahnert, C. (1); Minguez, E. (1); Perlado, M. (1); Gallego, E. (1); Velarde, P. (1); Cabellos, O. (1); Garcia-Herranz, N. (1); Cuervo, D. (1); Jimenez, G. (1); Cotelo, M. (1); Lorente, A. (1); Gonzalez-Arrabal, R. (1); Rivera, A. (1); Del-Rio, E. (1) 1 - Universidad Politécnica de Madrid, Spain
ENC2012-A0065	Sustaining nuclear knowledge through SCK•CEN's Academy for Nuclear Science and Technology	Coeck, M. (1) 1 - Belgian Nuclear Research Centre SCK•CEN, Belgium
ENC2012-305	UNDERSTANDING BY SEEING THERMAL HYDRAULICS USING A GLASS MODEL OF A PRESSURIZED WATER REACTOR	Seewald, M. (1) 1- GFS GESELLSCHAFT FÜR SIMULATORFORSCHUNG MBH, Germany
ENC2012-A0090	Maintaining a high quality nuclear engineering programme: future challenges for the Belgian Nuclear higher Education Network	Berkvens, T. (1); Coeck, M. (1) 1 - SCK•CEN, Belgium
ENC2012-A0116	SIMULATION TECHNOLOGY FOR SEVERE ACCIDENTS TRAINING, ASSESSMENT AND MANAGEMENT	Rey, P. (1); Ortega, F. (1); Rivero, N. (1); Gil, E. (1) 1 - Tecnatom, Spain
ENC2012-A0132	Transferring Lessons Learned from Operating Experience, Increasing Knowledge	Garcia, A. B. (1); Bilbao, C. (1); Macia, C. (1); Gonzalez, F. (1) 1 - TECNATOM , Spain
ENC2012-A0158	NEW IAEA TRAINING INITIATIVES IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT	Ormai, P. (1); Kinker, J. (1) 1 - International Atomic Energy Agency, Austria
ENC2012-A0169	3D VISUALIZATION AND SIMULATION TO ENHANCE NUCLEAR LEARNING	Dimitri-Hakim, R. (1) 1 - L-3 MAPPS, Canada
ENC2012-A0186	The importance of knowledge management sustaining a full education & training system all over the career of nuclear engineers	Guet, C. (1); Debreuille, M.-F. (1); Barbalat, C. (1); Fiquet, J. (1) 1 - International Institute of Nuclear Energy, France
ENC2012-A0191	LINKING EMPOWERING LEADERSHIP TO SAFETY PARTICIPATION IN NUCLEAR POWER PLANTS: A STRUCTURAL EQUATION MODEL	Martínez-Córcoles, M. (1); Schöbel, M. (2); Gracia, F. (1); Tomás, I. (1); Peiró, J. M. (1) 1 - University of Valencia, Spain 2 - University of Basel, Switzerland
ENC2012-A0215	Advanced method for a realistic training dedicated to the radiation protection improvement	Kutschera, R. (1); Courageot, E. (1); Gaillard-Lecanu, E. (1); Jahan, S. (1); Therache, B. (2); Riedel, A. (3) 1 - EDF R&D STEP, France 2 - EDF DPN/CIV, France 3 - EDF DPN/UNIE, France

ENC2012-A0227	THE USE OF LEARNING AND TRAINING TOOLS FOR NUCLEAR EDUCATION AND TRAINING	Foulon, F. (1); Royer, E. (1); Compain, O. (1); Golfier, H. (1); Grard, H. (1); Lescop, B. (1); Moiron, M. (1) 1 - CEA/INSTN, France
ENC2012-A0096	TECNATOM, NUCLEAR TRAINING SERVICES IN A GLOBAL WORLD	Moreno, J. (1); Loizaga, I. (1) 1 - TECNATOM, Spain
ENC2012-A0244	Educating and training the next generation of nuclear security experts	Hall, H. (1); Sumner, J. (2); Icenhour, A. (2); Stainback, J. (3); Clark, C. (3); Robinson, C. (3); Garrison, A. (4); Abelquist, E. (4); Page, A. (4) 1 - University of Tennessee, United States 2 - Oak Ridge National Laboratory, United States 3 - Y-12 National Security Complex, United States 4 - Oak Ridge Associated Universities, United States
ENC2012-A0269	Experience of application of Behavioral Sciences methodologies to the obtaining Operating License process	Martinez-Soria, J. L. (1); Ruiz-Martinez, F. (1); Vazquez-Rodriguez, L. (1) 1 - Tecnatom, S.A., Spain
ENC2012-A0286	Advancing National and Joint Nuclear Research in the European Union: the NEWLANCER Project	Cizelj, L. (1); Diaconu, D. (2); Ghitescu, P. (3); Ivanov, I. (4); Tiselj, I. (5); Železnik, N. (6) 1 - Jožef Stefan Institute, Slovenia 2 - Institute for Nuclear Research Pitesti, Romania 3 - University "Politehnica" of Bucharest, Romania 4 - Technical University of Sofia, Bulgaria 5 - University of Ljubljana, Slovenia 6 - ARAO, Slovenia
ENC2012-A0018	Nuclear Power Training Programs in Southeast Texas (USA)	Henry, R. (1); Shawver, R. (2); Kieler, B. (1) 1 - Wharton County Junior College, United States 2 - Brazosport College, United States
ENC2012-A0050	EVALUATING THE LEVEL OF HUMAN RESOURCE MANAGEMENT	Pahkin, K. (1); Kuronen-Mattila, T. (2); Mäki, E. (2) 1 - Finnish Institute of Occupational Health, Finland 2 - Aalto University, Finland
ENC2012-A0060	SAFETY CASE ON A PAGE	Forbes, S. (1); Cartlidge, M. (1) 1 - Serco Energy, Building 150, Harwell Oxford, Didcot, Oxfordshire, OX11 and AWE, Aldermaston, Reading, Berkshire, RG7 4PR, United Kingdom
ENC2012-A0061	BELARUS CAPACITY TO CONTRIBUTE TO REGIONAL CO-OPERATION IN EDUCATION AND TRAINING ON NUCLEAR AND RADIATION SAFETY FOR EUROPE AND MIDDLE ASIA	Timoshchenko, A. (1) 1 - International Sakharov Environmental University, Belarus

ENC2012-A0098	INTERNATIONAL COLLABORATION FOR ENHANCED EXPERIENCES IN NUCLEAR EDUCATION	Harvel, G. D. (1); Nakayasu, F. (2) 1 - University of Ontario Institute of Technology, Canada 2 - Fukui University of Technology, Japan
ENC2012-A0154	ONTARIO EXPERIENCE IN EDUCATION AND TRAINING: A UTILITY-UNIVERSITY PARTNERSHIP	Bereznai, G. (1); Froats, J. (1); Harvel, G. (1) 1 - University of Ontario Institute of Technology, Canada
ENC2012-A0198	Lessons Learned from Fukushima Daichii - Development of Severe Accident Training Exercises for University Students	Hohorst, J. (1); Allison, C. (1); Allison, B. (1); Luettringhaus, U. (2); Torri, A. (2) 1 - Innovative Systems Software, United States 2 - Risk Management Associates, United States
ENC2012-A0200	Advances in the delivery of Nuclear Power Plant Simulation based learning	Smith, J. (1) 1 - Western Services Corporation, United States
ENC2012-A0248	The Safety Culture Questionnaire (SCQ): Its theoretical approach and empirical validation	López de Castro, B. (1); Gracia, F. J. (1); Tomás, I. (1); Peiró, J. M. (1) 1 - Universidad de Valencia, Spain
ENC2012-A0264	Effective Education and Training Technology, International Co-operations, Recruitment, and Attracting the Next Generation Safeguards Specialist	Eipeldauer, M. D. (1) 1 - ORNL UT-Battelle, United States
ENC2012-A0271	UNIVERSITY OF TEXAS STUDY ABROAD PROGRAM IN CONCEPTS IN NUCLEAR SCIENCE AND ENGINEERING AT THE TECHNICAL UNIVERSITY OF	Landsberger, S. (1); Graham, J. (1); Wilkins-Versalovic, H. (2); Bode, P. (3); Geurink, F. (3); Laan, A. (3); Steinebach, O. (3); De Vries, D. (3) 1 - University of Texas, Austin, Nuclear Engineering Teaching Lab, United States 2 - University of Texas at Austin, Cockrell School of Engineering, United States 3 - Reactor Institute of Delft, Netherlands
ENC2012-A0278	HUMAN RESOURCES CHALLENGE AND KNOWLEDGE MANAGEMENT IN SLOVAK NUCLEAR POWER ENGINEERING	Slugen, V. (1) 1 - Slovak University of Technology, UJFI, FEI STU, Slovakia

ENC2012-A0287	Perspectives of the smallest nuclear country for the research and education in nuclear safety	Cizelj, L. (1); Tiselj, I. (1) 1 - Jožef Stefan Institute, Slovenia
ENC2012-A0292	Supplementing nuclear education at universities by industry know-how and experience, delivered in specifically designed training programs	Glaubrecht, S. (1); Schönfelder, C. (1) 1 - AREVA NP GmbH, Germany
ENC2012-A0305	Learning by watching	Seewald, M. (1) 1 - Universität Gesamthochschule Essen, Germany

ENC
2012

EUROPEAN NUCLEAR CONFERENCE



United Kingdom

MANCHESTER
9-12 December 2012

EDUCATION & TRAINING

SUPPLY OF AND DEMAND FOR NUCLEAR EXPERTS IN THE EU BY 2020: EHRO-N REPORT (2012)

VERONIKA SIMONOVSKA, ULRİK VON ESTORFF
*European Commission, Joint Research Centre, Institute for Energy and Transport
P.O. Box 2, 1755 ZG Petten – The Netherlands*

ABSTRACT

A report from EHRO-N (European Human Resource Observatory of the Nuclear Energy Sector) published in 2012:

1. Determines that the supply of employees with specific educational background and competences, called nuclear experts, does not correspond to the demand for the same employees in the EU by 2020, and that

2. It is useful to put the data on the supply of and demand for nuclear experts in the EU in perspective, using available statistical data on supply of STEM (science, technology, engineering, mathematics) graduates in EU and data on the employed HRST (human resources in science and technology) in the EU labour market.

For more refined and accurate data that can determine policy directions, the most effective way would be to conduct regular nuclear human resource monitoring exercises in the EU in the future.

This paper is a summary of the first findings as well as of the lessons learnt.

1. Introduction

The introduction of EHRO-N in 2008 in the EU nuclear E&T landscape was prompted by the need for a central information source and an institution for monitoring the nuclear human resource for the nuclear energy sector in the EU. The idea was that EHRO-N would, on the basis of existing quantitative information, available either nationally or on EU level, conduct its own research, fill the gaps and provide a comprehensive quantitative and qualitative analysis of the supply of and demand for nuclear human resource within the EU for the years to come. Based on the above analysis EHRO-N would also be able to provide recommendations to remedy the deficiencies of the European nuclear E&T infrastructure as well as help develop the European scheme of nuclear qualifications and mutual recognition.

EHRO-N began its work in 2009 and was officially launched in December 2011. The first nuclear human resource supply/demand EHRO-N report was issued in May 2012.

The management of EHRO-N consists of mainly two bodies:

1. The Operating Agent which is the Institute for Energy and Transport of the Joint Research Centre of the European Commission, providing the necessary infrastructure, networking and long-term stability, and
2. The Senior Advisory Group (SAG), which is composed of highly-qualified experts active in the nuclear energy either in academia, industry or international regulatory setting who focus on providing general guidance on conceptual issues (e.g. type of data to be gathered, the analysis to be performed, the endorsement of major human resource-related reports and the preparation/execution of major communication campaigns).

2. EHRO-N Report of 2012: Methodological approach

Throughout 2010 and in the first half of 2011 EHRO-N team sent two sets of questionnaires to the:

1. Higher education institutions in EU-27 that offer nuclear-related degrees, and
2. Nuclear stakeholders, active on the EU-27 nuclear energy labour market (see Tab 1).

Name of organisation/country	Total number of nuclear experts employed in 2010	Approximate age span of nuclear experts employed in 2010 (can be expressed in %)				Need for new (to replace the retired experts + for new nuclear projects) nuclear experts within:		
		Below 35:	Between 35-45:	Between 45-55	Above 55	1 year	5 years	10 years

Tab 1: EHRO-N Questionnaire 2010 (for the demand side of the report)

The definition of nuclear experts provided alongside with the above table was that nuclear experts are nuclear engineers, nuclear physicists, nuclear chemists, etc. – all employed staff with *nuclear* education background (bachelor, master, PhD), and those with *non-nuclear* education background (bachelor, master, PhD) but with *competences/skills* in the nuclear field (for e.g. acquired through in-house/other training).

The quantitative data received from the higher education institutions was quality checked against a quality assurance procedure defined within the SAG of EHRO-N. It was also assessed against data available from other sources (e.g. IAEA data, national nuclear human resource reports, if available).

The relevant statistical information from these sources was used alongside with the quantitative data gathered via EHRO-N questionnaire:

- OECD reports (from 2000, 2004 and 2012),
- IAEA report on the status of the nuclear education and training (from 2010)
- National reports dealing specifically with the human resources needed for the nuclear energy sectors in France (from 2008), UK (from 2010), and Finland (from 2012), as well as publicly available data from the
- World Nuclear Association, and the
- Eurostat (especially on the numbers of science, engineering and technology (SET) graduates and HRST (Human Resource in Science and Technology) employees supplied and/or demanded in EU-27.

3. Analysis of the results

3.1. Supply side

Somewhat less than 190 higher education institutions received a questionnaire asking them about the:

1. Number of nuclear engineering students that graduated in year 2009;
2. Number of students following nuclear subjects that graduated in 2009;
3. Number of nuclear engineering students that started with their studies in the school year of 2009/2010; and
4. Number of students following nuclear subjects that started with their studies in the school year of 2009/2010.

The response rate of the higher education institutions contacted was above 90 %. The analysis showed that the total number of nuclear engineering students/students following nuclear energy – related subjects that graduated in the year 2009 on BSc, MSc, or PhD levels was somewhat above 2800 (see Fig 1).

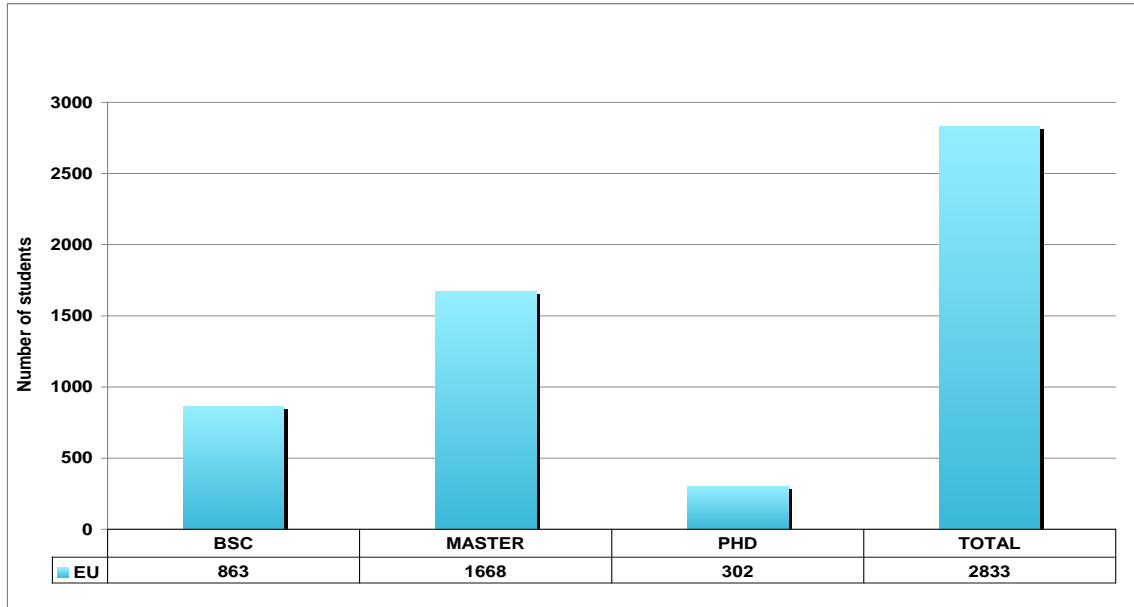


Fig 1: Number of nuclear engineering students/students following nuclear energy-related subjects that graduated in 2009 on BSc, MSc, PhD level in the EU-27 (Source: EHRO-N, 2012)

3.2. Demand side

Of the 358 nuclear stakeholders contacted, 242 or nearly 70% responded to the EHRO-N questionnaire. The information requested covered these data:

1. The total number of nuclear experts employed in 2010;
2. The division of the total number of nuclear experts employed in 2010 into 4 age groups:
 - below 35
 - between 35 and 45
 - between 45 and 55, and
 - above 55

3. The need for new nuclear experts within 1, 5, and 10 years (without making distinction whether these were needed in order to fill a position because of retirement or because of a creation of a completely new post).

Following an analysis of the responses received and estimations of the gap where companies did not respond to the questionnaire, showed that the total number of nuclear experts in the 358 nuclear organisations employed in the 358 nuclear organisations in the EU-27 in 2010 was 77 605 (62 958+14 647). The biggest share of experts fell into the age group “between 45 and 55”. (see Fig 2)

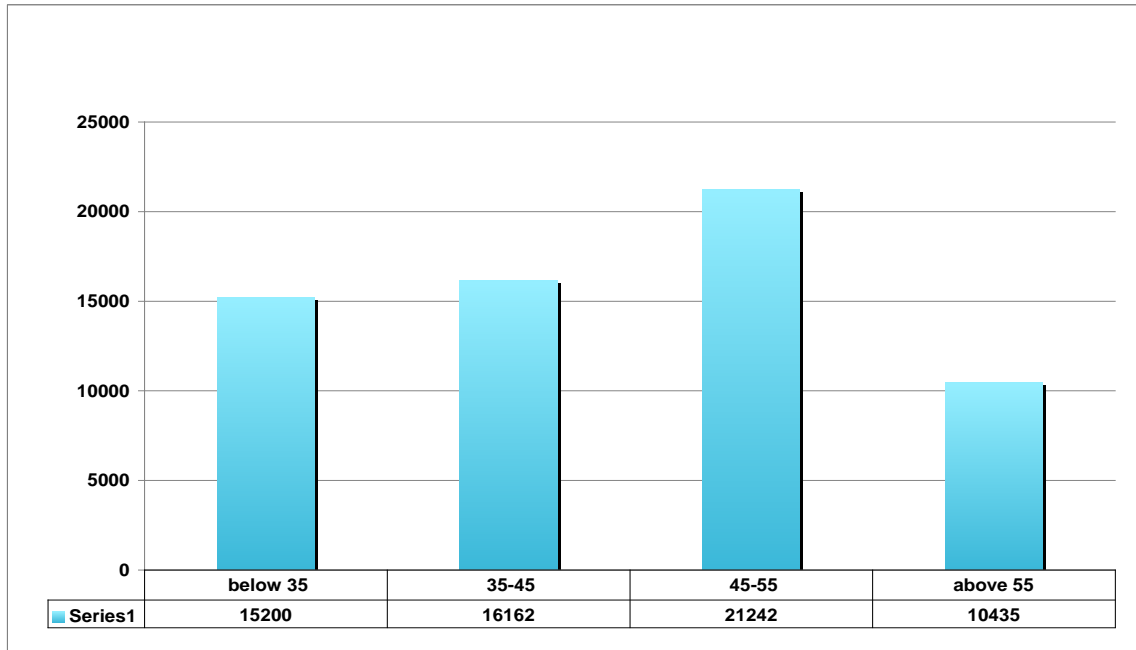


Fig 2: Total number of nuclear experts employed in the EU-27 in 2010 divided by age group
(Source: EHRO-N, 2012)

The total need for nuclear experts by 2020 of the 358 nuclear organisations active in the EU-27 in 2010 was 38 900 (30 664+8 236) (see Fig 3).

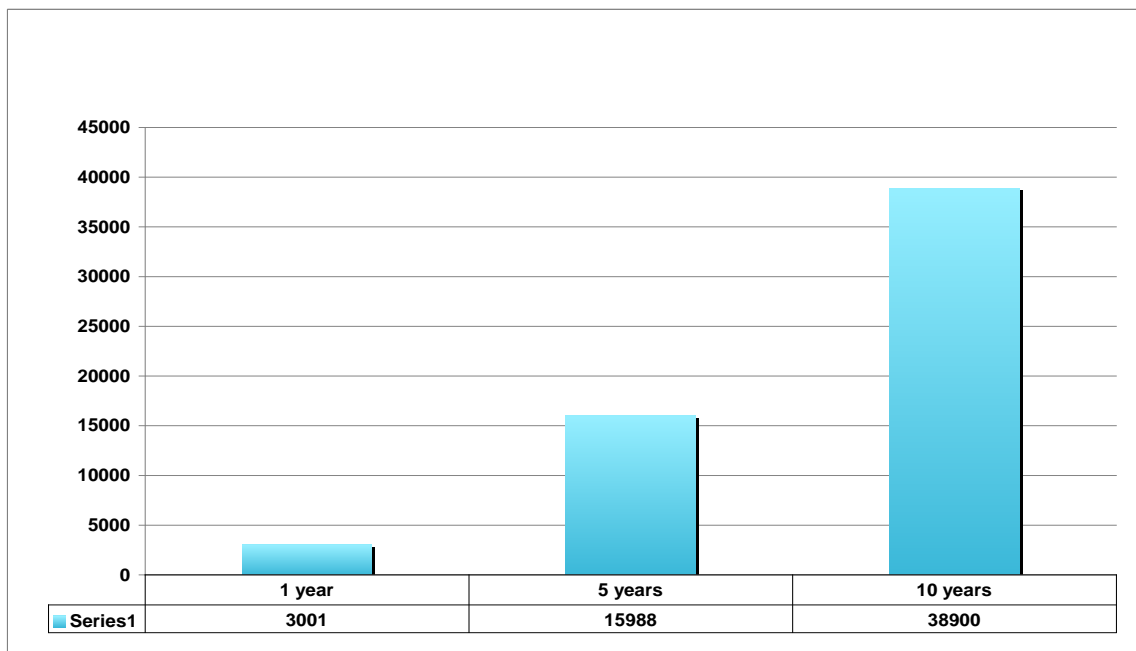


Fig 3: Total need for nuclear experts by the nuclear energy sector in EU-27 by 2020
(Source: EHRO-N, 2012)

3.3. European nuclear energy sector - current workforces' profiles/core occupations available in Europe

The estimate of 500 000 was taken as the number of the total workforce in the nuclear sector in EU-27. Essentially, a threefold categorisation of the competencies necessary to run a nuclear power station can be drawn, which includes:

1. **Nuclear experts:** employees with a specialised formal education in nuclear subjects (e.g. nuclear engineering, radiochemistry, radiation protection, etc.);
2. **“Nuclearised” staff:** people with formal education and training in a relevant (non-nuclear) area (e.g. mechanical, electrical, civil engineering, systems) but who need to acquire knowledge of the nuclear environment in which they have to apply their competencies;
3. **Nuclear-aware staff:** people requiring nuclear awareness to work in the industry (e.g. electricians, mechanics, and other crafts and support personnel).

Fig 4 shows the proportion of these three groups within a nuclear energy sector. The group of “Nuclearised” staff was further divided into 3 categories of profiles: non-nuclear engineers, technicians and other graduates. The basis for this analysis was a study done about the need for specific profiles of employees for the French nuclear energy sector. Thus, in the EU-27, the workforce in the nuclear energy sector, is hypothetically divided like this (see Fig 5):

- 1) 16% are nuclear experts: a result derived from the analysis of the EHRO-N questionnaire;
- 2) 74% are nuclearised engineers, other graduates, and technicians: this category is again in itself divided into some 38% technicians, 35% non-nuclear engineers and 27% other graduates; and
- 3) 10% are support and other employees (so called nuclear-aware employees).

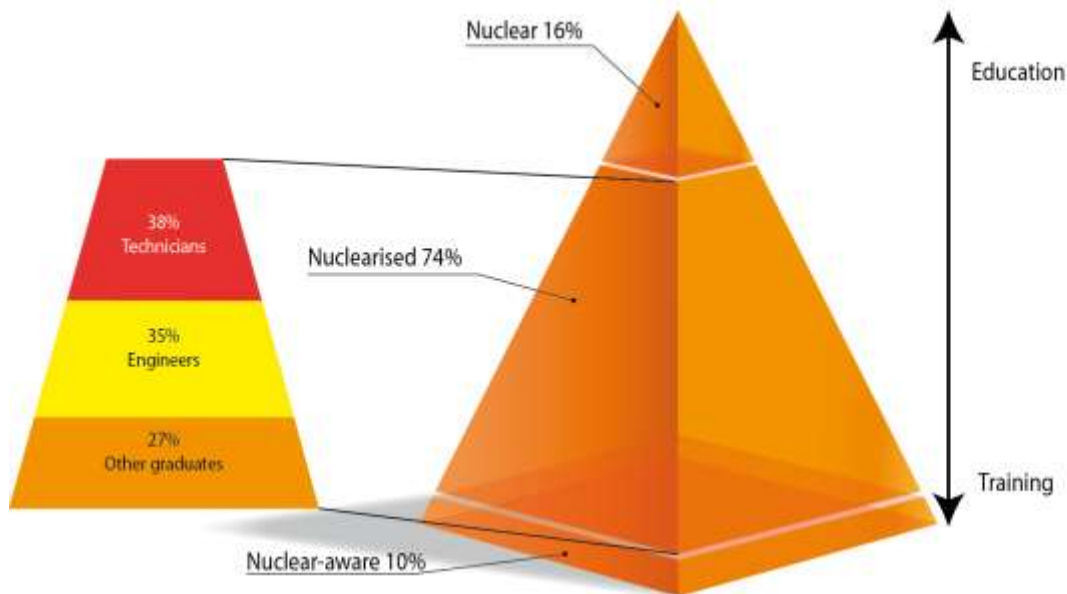


Fig 4: Hypothetical graphical representation of the nuclear energy sector in the EU-27 by type of employees (Source: EHRO-N, 2012)

3.4. Putting the supply and demand of nuclear experts by the European nuclear energy sector into perspective

On the supply side, the numerical data available from the above EHRO-N analysis was supplemented with the statistical data, mainly from Eurostat, on the numbers of graduates in science, technology, engineering and math, in the EU-27 (so called STEM students). The number of all graduates in all fields in the EU-27 in 2009 was 4 127 039. The share of STEM graduates within the above graduates in the EU-27 was 22% in 2009 or, in absolute terms, 907 949 students. The highest share of STEM graduates among the members of the EU-27 was in Austria, followed by Finland, Portugal, France, Spain, Germany, Czech Republic, Sweden and Italy, all of which had their shares above the EU-27 average.

In the EU-27 in 2009, the numbers of STEM students graduating from specific fields was as follows:

- 339 414 graduates in engineering or 37.4% of all STEM graduates.
- 96 422 graduates in physical science or 10.6% of all STEM graduates. and
- 45 712 graduates in mathematics and statistics or 5% of all STEM graduates.

On the demand side, the numerical data about nuclear experts needed in the EU-27 in the future available from EHRO-N analysis was supplemented with the statistical data available on the numbers of employees belonging to the group of science and technology human resource (HRST). 40% of the labour force in the EU-27 in 2009 belonged to the HRST group. The number of scientists and engineers within the HRST group was some 11 million in 2009. Most of them were employed in Germany, the United Kingdom, France, Spain, Poland and Italy. Of these the number of graduated engineers was somewhat less than 6.5 million based on the data available from 2007.

Based on the data on retirement of engineers in EU-27, it could be concluded that there will be a total need for at least some 1 200 000 engineers for the whole EU-27 labour market by 2020 just to replace the retired engineers by that same year. This means that around one third of all engineering graduates in the EU-27 (assuming that their numbers stay at the level of some 340 000 every year as in 2009) are needed every year by the employers just to replace the retired personnel.

The demand for nuclear experts by 2020 in the EU-27 by the nuclear energy sector will be somewhat less than 40 000 experts. In order to estimate the lowest future need for the nuclearised engineers, other graduates, and technicians by the nuclear energy sector in the EU-27, we assumed that the retirement rate is 25%:

Thus, the demand by 2020, in order to replace the retired nuclearised workforce, will be:

- 35 150 technicians or $(370\ 000 \cdot 38\%) \cdot 25\%$,
- 32 375 non-nuclear engineers or $(370\ 000 \cdot 35\%) \cdot 25\%$, which represents ca. 3% ($32\ 375 \cdot 100 / 1\ 204\ 088$) of all engineers needed to be employed because of retirement of engineers in the EU-27 labour force as a whole (see page 49 above), and
- 24 975 other graduates or $(370\ 000 \cdot 27\%) \cdot 25\%$.

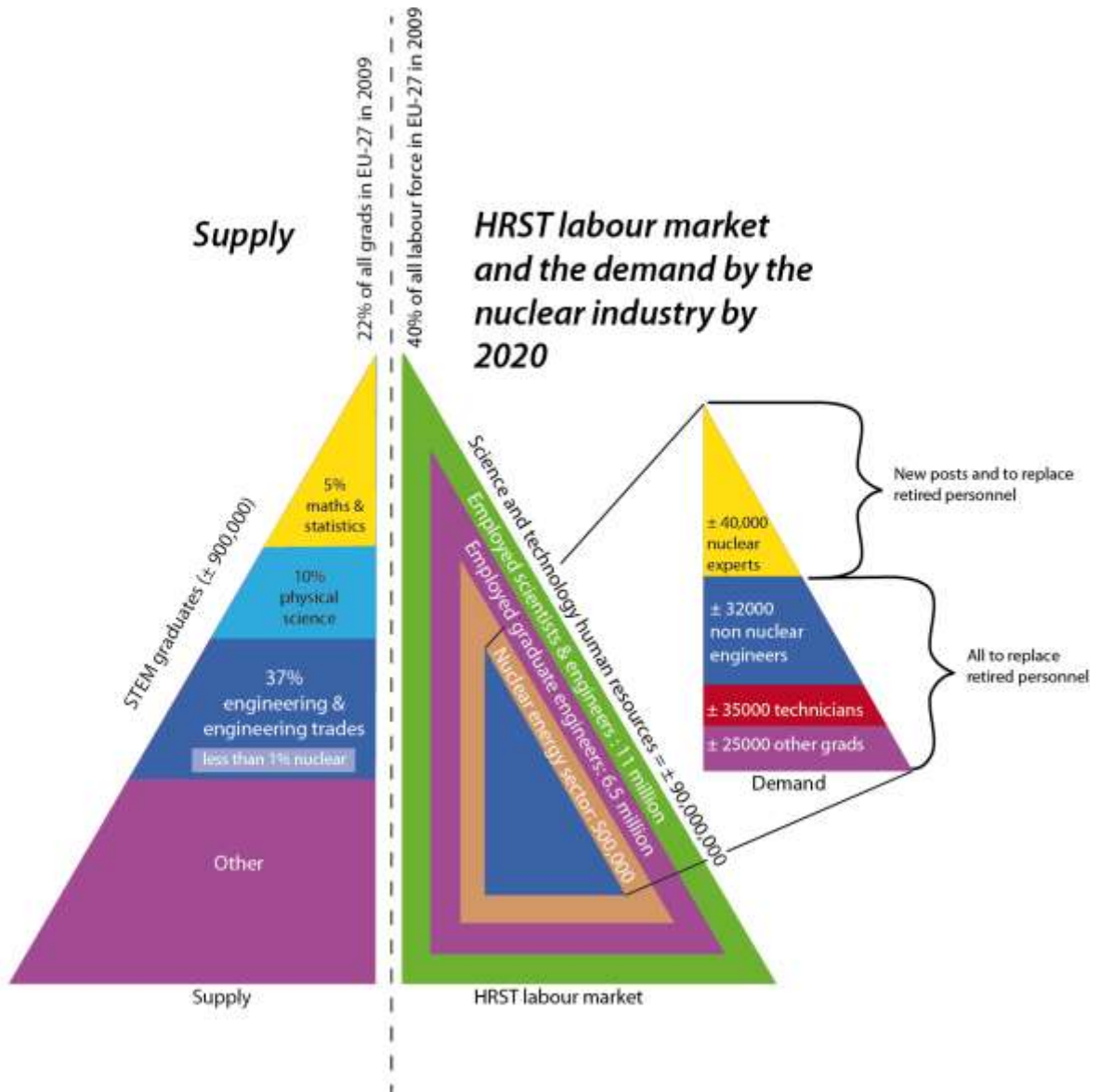


Fig 5: Graphical representation of the supply of STEM graduates in the EU-27 in 2009, the HRST workforce in the EU-27 in 2009, and the lowest hypothetical demand for nuclear experts, non - nuclear engineers, technicians and other graduates by the nuclear energy sector in the EU-27 by 2020 (Source: EHRO-N, 2012)

The supply of nuclear engineering students and students having had a nuclear energy-related subject in their studies (2800 in the EU-27 graduated in 2009) cover some 45%-70% of the demand for nuclear experts by the nuclear energy sector in the EU-27 (on average 4000 per year by 2020). This is true if one assumes that 100% of the relevant graduates mentioned are looking for an employment in the nuclear energy sector. A worrying observation is that by 2020 nearly 50% of nuclear experts employed today will retire while at the same time the retirement rate for other engineers is 25%.

The demand for nuclear experts which is not fulfilled by the supply from the higher university institutions in the EU-27 is directed towards the other STEM graduates (e.g. non-nuclear engineers, physical scientists, etc.), which are also needed by other (energy) industry sectors.

4. Conclusions

As there is a (growing) demand for STEM graduates from various sectors across the European economy, the nuclear energy stakeholders need to be aware of the wider context in which they operate. It becomes clear that only the joining of forces rather than competition could help to adequately respond to the human resource and skills challenges that the nuclear energy sector faces.

The future objective is clear: EHRO-N should be an authoritative and comprehensive platform for strong interaction between nuclear energy stakeholders in the EU as far as questions of nuclear human resource monitoring is concerned. For this become reality, it is important that EU Member States and nuclear stakeholders contribute actively to the EHRO-N surveys.

As for the future, EHRO-N's objective is to conduct another survey on the future supply and demand for nuclear experts in the EU-27 in 2013/2014. Furthermore, together with Atominstitut from Austria, EHRO-N is at the moment conducting an international survey that could offer a glimpse into the changes of (potential) students perception of the nuclear E&T after the accident in Fukushima.

Another of EHRO-N's important objective for the future would be the promotion of and the application of the European credit system for vocational education and training (ECVET) approach to the nuclear energy sector. The goal is to improve the quality of the nuclear workforce at professional, technical and craft level by facilitating borderless mobility and lifelong learning.

5. References

Simonovska V., von Estorff U., 2012. Putting into perspective the supply of and demand for nuclear experts by 2020 within the EU-27 nuclear energy sector. European Commission, Joint Research Centre. EUR 25291 EN.

Available at: <http://ehron.jrc.ec.europa.eu/>

Title of Paper : Lessons Learnt from Building a Nuclear Accreditation model in the UK

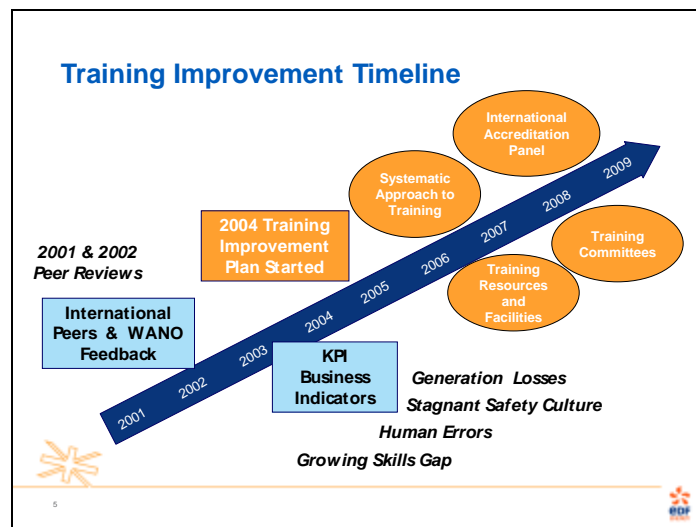
Introduction

EDF Energy (Existing Nuclear) operates a fleet of 15 reactors across the United Kingdom. The company has developed over the past 8 years a nuclear accreditation model based on the INPO guidance. This paper describes the development of the model and outlines some of the lessons learnt in the development and running of the model.

Description

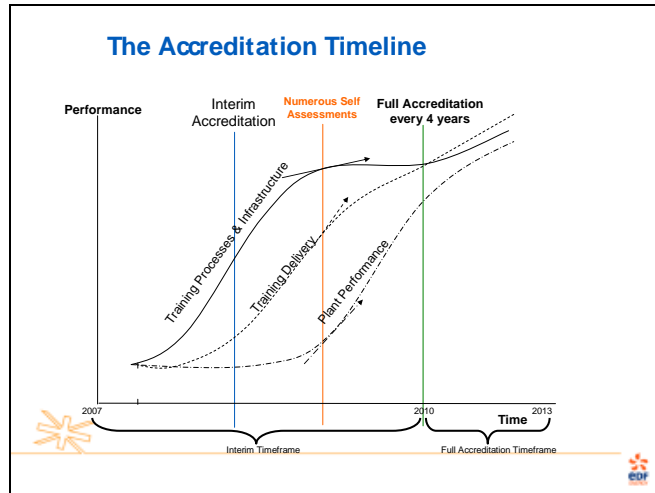
In 2003 British Energy was effectively bankrupt with debts in the region of £1.2 B. In 2009 the company had recovered from this position and was brought into EDF as part of the acquisition of British Energy by EDF in 2009. Based on feedback from international peers and plant performance indicators the company undertook an ambitious recovery programme focused on increased plant and people investment. The people investment was based around a step change improvement in the quality and capability of the training organisation in the company and included the introduction of a formalised Nuclear Training Accreditation programme based on the INPO model.

Figure 1: Training Improvement Timeline



The accreditation model is based on the principles outlined in ACAD 02-001. New training programmes were developed for 'role' specific training across Operations, Maintenance, Engineering and Technical staff positions. The methodology used by the model is based on the WANO & INPO Plant Evaluation processes. An international Training Standards Accreditation Board (TSAB) was established with senior nuclear industry figures from the US, UK, Spain, Germany & Switzerland. In order to enable the construction and development of new and improved training programmes across the fleet the concept of achieving 'Interim Accreditation' for a number of leading programmes was introduced. This allowed line engagement to be closely monitored and encouraged as individual NPPs worked towards Full Accreditation for all of their training programmes.

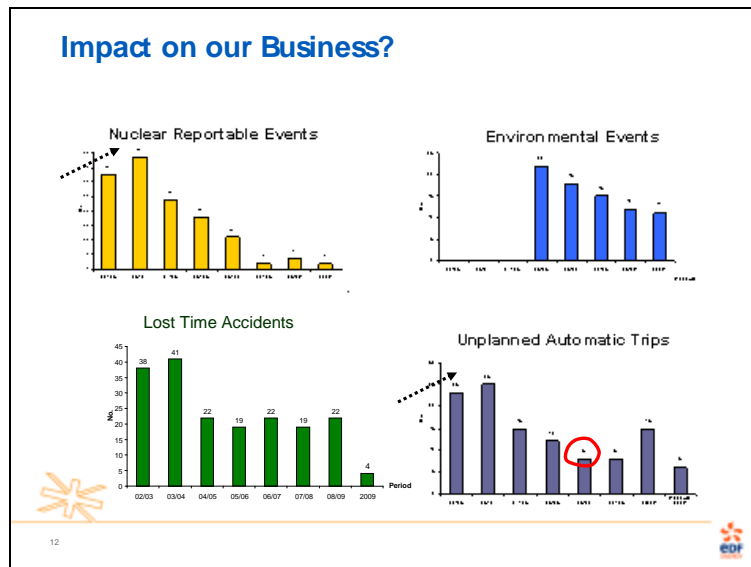
Figure 2: Interim Accreditation



Results

The company experienced significant improvements in both plant down times, reduced human performance and technical capability errors together with positive employee feedback regarding the nuclear safety culture. In 2006/7 cost savings in the region of £110M were achieved due to reductions in unforced losses. A number of challenges and lessons learnt have been identified during implementation of the training improvement plan. Senior leadership continuing support with the desire to change a working culture were essential features of the journey, together with positive stakeholder management from Trade Unions to regulators. Effective use of training performance indicators by the newly established training committees was a key lesson learnt.

Figure 3: Impact on the Business



Conclusion

The improved training programmes linked to the oversight of the EDF TSAB played a key part in helping to recover the British Energy position, supporting improvements both in nuclear safety and commercial viability across the fleet of NPPs.

TOWARDS A NUCLEAR ECVET SYSTEM

M.A. LACAL MOLINA, U. VON ESTORFF
*European Commission, Joint Research Centre, Institute for Energy and Transport
P.O. Box 2, 1755 ZG Petten – The Netherlands*

The Copenhagen Declaration agreed the cooperation for developing innovative policies and actions in the vocational education and training system. In this agreement the European Credit System for Vocational Training and Education was conceived in order to achieve that objective.

Since then, the different countries involved have worked together in order to encourage more individuals to make wider use of vocational learning opportunities.

In the nuclear field several actors have developed activities encouraging the implementation of the ECVET system. The main objective of this paper is to explain what activities have been developed by these actors and in which directions these activities were/are. Also to analyse the importance of all these activities taking into account all the information collected.

As a result, the document will give an overview of the ECVET activities within the nuclear field, making possible the reflection on the future of the ECVET system.

1. Introduction

In 2002, the Council Resolution agreed on 12th November [1] (Education, Youth and Culture) as well as the Copenhagen Declaration of 30th November [2] established as priority the developing of a credit transfer system for VET for the promotion of *transparency, comparability, transferability and recognition of competences and/or qualifications, between different countries and at different levels* [3].

Later in the Maastricht Communiqué of 14th December 2004 on the future priorities of enhanced European cooperation in Vocational Education and Training (VET) [4], the Ministers responsible for VET from 32 European countries, the European social partners and the Commission agreed to give priority to *the development and implementation of the European credit transfer system for VET (ECVET) in order to allow learners to build upon the achievements resulting from their learning pathways when moving between learning systems.*

Since then, the possibilities of an ECVET system has been studied at the same time that several pilot projects have been developed in a number of areas. But, taking into account the vast possibilities of ECVET, which aims to be a horizontal and vertical system for KSC recognition, still there are some unexplored fields.

2. ECVET Specifications

ECVET has as a main aim to face the challenges, opportunities and requirements of the new Europe, particularly the enlargement of the European Union, in the field of education and training. Taking into account that actually in Europe each country has its own system for vocational education and training, ECVET is the possibility of harmonization the current situation in order to facilitate:

- transfer of the learning outcomes (units and credit points obtained are transferable)
- progressive validation of the learning outcomes (in formal, non formal contexts).
- accumulation (capitalisation) of units and credit points.

Also ECVET answers the constantly demand of increasing the capacities of low-skilled workers in order to solve the gap produced by the ageing of the work population, as well as the need of

educate that target group in order to be competitive at international level. Besides, ECVET promotes a series of values as mutual trust, transparency and recognition of competences and qualifications across the 33 European countries involved in its implementation. These values are essential in order to create a system in which national systems are integrated for facilitating the mobility horizontally and vertically between sectors and systems. This mobility is essential for resolving the human resources need of several sectors, among them the nuclear one. For achieving its objectives, ECVET systems suggest several instruments which represent a substantial difference with other educational credits systems (e.g. Bologna system). These instruments are:

- Learning Outcomes (based on knowledge, skills and competencies): statements of what a learner knows, understands and is able to do on completion of a learning process.
- Memorandum of Understanding (MoU): agreement between the different actors.
- Learning Agreement: official document in which the different actors involved in the learning process are supporting the transfer of the learner.

In addition of these tools, ECVET integrates existing instruments into a single framework that should be implemented by all EU Member States by 2012 (e.g. Europass, EQF,...).

3. Towards a nuclear ECVET system

During the past ten years, ECVET has been studied at the same time that several pilot projects have been developed in a number of areas. Among them are very successful projects like ASSET [5], EOSE's pilot projects [6] or EWS' ECVET activities [7].

Despite the quantity of ECVET Pilot Projects initiated in the past decade, until the moment no ECVET Pilot Project has developed in the nuclear field.

But different actors have developed activities within the nuclear area related to ECVET system. Among these actors:

- DG Research and Innovation of the European Commission (DG RTD)
- The European Fission Training Scheme (EFTS) Project Partnerships within the Seventh Framework Programme of the European Atomic Energy Community (Euratom)
- Other international organizations like ENS and FORATOM.
- The Institute for Energy and Transport (JRC-EC)

It is important to remark that all these actors have taken into account a number of particularities for the implementation of ECVET in the nuclear field. One of these particularities is the whole of responsible institutions – schools, universities, businesses, utilities, authorities, etc. – which differ between and within countries. But also special conditions of the nuclear sector as safety culture and national requirements, conditions that are very specific of this sector.

for building a nuclear ECVET framework. Several actions have been developed and others are in prospective.

3.1 DG Research and Innovation of the European Commission (DG RTD)

This Direction General of the European Commission, particularly

This Directorate General of the European Commission has been without doubt one of the most important players since ECVET was introduced in the nuclear field.

In 2010 the Directorate General for Education and Culture (DG EAC) contacted with this Directorate and decided to collaborate for implementing ECVET in the sector.

Since then, Georges Van Goethem, responsible of this important task, has done a great job of communication, information and dissemination of ECVET in the nuclear field. His work has been crucial to involve other actors.

In fact it was this work that led to other actors. Euratom projects, ENS, Foratom and IET-JRC EC have become involved in the arduous task of disseminating the principles and tools of ECVET and its benefits.

Moreover, because ECVET evolves as its actors evolve, the task of this direction is becoming more intense and extended its horizons beyond communication, information and dissemination, it is positioned as a leading and experienced actor advises other actors on the most constructive way of creating a nuclear ECVET.

Certainly, the work of this actor is one of the most important since due to its institutional character,

the experience of the person in charge and contact with other DG Education and Culture (responsible for ECVET) make key to implement ECVET nuclear industry in the best possible response to their particularities.

3.2- The European Fission Training Scheme (EFTS) Project Partnerships within the Seventh Framework Programme of the European Atomic Energy Community (Euratom)

Actually these Projects are:

- CINCH [8]: Cooperation in Education in Nuclear Chemistry
- CORONA [9]: Establishment of a Regional Center of Competence for VVER Technology and Nuclear Applications .
- ENEN III[10]: European Nuclear Engineering Network Training Schemes.
- ENETRAP II [11]: European Network on Education and Training in Radiological Protection.
- EURECA! : European cooperation with Canada
- GENTLE: Graduate and Executive Nuclear Training and Lifelong Education
- PETRUS II [12] Education and Training on Geological disposal of radioactive wastes.
- TRASNUSAFE [13]: Training Schemes on Nuclear Safety Culture.

The importance of these projects is that they are implementing the principles of ECVET. The ECVET introduction of these projects (initially five) occurred through the work of DG RTD.

When DG RTD and DG EAC decided to collaborate in the implementation of ECVET in the nuclear field, DG RTD immediately got in touch with these projects to take into account in their Work Packages the benefits of the new system. Also to look for ways for implementing its principles and tools as well as for using its instruments.

The partners of these projects who received this assignment were faced with a challenge as far ECVET was unknown in the nuclear field.

However, all these projects (including the newest) have sought to remain faithful to the principles ECVET and its activity has been precisely in this area that has allowed us to reach several conclusions about ECVET:

- Is possible in the nuclear field
- Is necessary and can benefit an industry whose needs go through using human resources from other sectors in the absence of equity
- Facilitate mobility between countries and allows those new countries can take advantage of the experience of those who for various reasons have ceased to be
- Its implementation can result more difficult than in other sectors because of the particularity of nuclear

The work of these projects has been certainly a great help because it allowed small scale analyse what could be in the nuclear field ECVET both positive and negative aspects.

So, considering its positive aspects, one could say that ECVET could help resolve difficulties in terms of human resources facing the nuclear industry. Meanwhile, in relation to its negative aspects, ECVET needs to be defined taking into account the specificities of the sector without losing its essence. The latter has been promoted by these projects the appearance of different answers that could be very useful in the future.

3.3. European Nuclear Society and Foratom.

The European Nuclear Society (ENS) and Foratom are the most important associations in the nuclear field. Both of them are present in almost all of Europe and have members belonging to different sectors of the nuclear sector: industry, research centres, universities, consultants, etc. Therefore, they can be considered as two associations representing the nuclear field widely. And between their activities they have the task of ensuring the welfare of its members constantly seeking new horizons for them.

Regarding vocational education and training, the ENS as well as Foratom have had a recognized outreach and communication to be an important support for ECVET activities carried out by other actors (e.g. IET-JRC or DG RTD).

To this we must add that to understand and to analyse the benefits and the structure of ECVET, both associations have formed their respective staff in acquiring the knowledge that can help the nuclear community to carry out the implementation of ECVET.

Also they are a very good fora of discussion and debate about ECVET issues in the nuclear sector and several of their member are highly involved in several ECVET activities. During the past years, as well as actually, their task has been essential to disseminate the ECVET system within the nuclear community. In the future, their task will be essential not only to disseminate and communicate even in assist and involve other actors.

3.4. The Institute for Energy and Transport (JRC-EC)

In October of 2009 was set up the European Human Resources Observatory for the Nuclear Energy Sector (EHRO-N) [14]. The Institute for Energy and Transport (IET) of the European Commission's Directorate General Joint Research Centre (DG JRC) was charged with its implementation as was as its management.

In this context in December 2010, the DG RTD and DG EAC considered adequate that a part of the EHRO-N team take charge of promoting ECVET in the nuclear sector.

Since then they have carried out various activities, which include:

- Questionnaire. The questionnaire was based on the potential benefits of ECVET for the nuclear industry. The results of this questionnaire allowed to determine the need for ECVET be adapted to certain specifics of the nuclear field. Likewise the questionnaire was the starting point for the nuclear community would know ECVET and the need for its implementation in the nuclear field.

- Workshops. Undoubtedly, one of the key activities of the EIT-JRC. It is a series of three workshops held in October 2011 in Bergen (Netherlands), in February 2012 in Petten (Netherlands) and in October 2012 in Thessaloniki (Greece). These workshops had as a main objective to achieve one of the main goals of the ECVET activities within the nuclear sector: to complete (or almost complete due to the huge amount of job profiles) a job taxonomy. A job taxonomy it is a very important key for the development of a common language, the basis of the harmonization.

Also a job taxonomy allows the VET providers to develop training courses and vocational education taking into account the ECVET principles. Courses and education created under these principles will be the basis of mobility. Harmonization and mobility two of the main benefits of the ECVET system that can resolve the human resources needs of nuclear sector.

In these three workshops a group of experts from different European countries and different fields within the nuclear sector developed a series of job descriptions based in the common jobs of a Nuclear Power Plant.

Once the taxonomy is completed (in 2013) the results will be submitted for the approval of the European nuclear community (European nuclear platforms, utilities, stakeholders,..). This action will do in order to get the nuclear community consensus.

- Seminar. In September 2012, the IET-JRC in collaboration with the ECVET Team [16] (supported by DG EAC) organised the first ECVET Seminar for the Nuclear Energy Sector. The main objective of the seminar was to disseminate the ECVET principles, benefits and tools in order to offer to the nuclear VET providers the opportunity to acquire the knowledge needed for implementing the ECVET system.

Regarding the implementation of ECVET, it is important the dissemination but also the education of these people who will implement it. This customised seminar was very important in terms of providing the right knowledge for the ECVET implementation within the nuclear community.

Also this seminar was the possibility to create the starting point of a future ECVET nuclear network. As well as to established a contact with the ECVET Team and visibility in the ECVET community.

- Documentation. ECVET is based in the mutual trust reflected in its documentation. For the implementation of ECVET within the nuclear sector this documentation has been created exclusively by the IET-JRC ECVET team and it is in relation with ECVET structure. It is been created with the of reference other ECVET pilot projects as well as CEDEFOP documentation. This documentation consist of templates that are intended be helpful for partners undertaking an ECVET collaboration, while promoting a standardization of the ECVET tools. They are the following:

a) *Learning Agreement (L.A.)*: official document in which the different actors involved in the learning process are supporting the transfer of the learner. By means of the L.A. Home and Host Institutions establish the terms applicable to the mobility of an individual learner during a certain period, stating eventually the achieved learning outcomes which can be transferred to other European documents..

b) *Memorandum of Understanding (MoU)*: agreement between the different actors (Competent Institutions and ECVET providers) aiming at qualification of specific competencies and at arrangements for credit transfer for learners based on ECVET and learning outcomes.

c) *KSC Catalog*: despite is not a document basic of the ECVET system, this document will be helpful in in having a common language for the learning outcomes. It is a recompilation of Knowledge, Skills and Competences, organized by discipline.

4. Conclusions

Undoubtedly ECVET is a system that could produce many benefits such as mobility within the EU-27 and all the country clubs joined (33 in total), mutual recognition of vocational education and training systems, long-life learning Possibility and recognition of different learning outcomes Given for different type of ECVET providers.

But the greatest benefit will be to resolve the human resources gap of the recent years in the nuclear industry. This is because ECVET is clue regarding the creation of a highly qualified workforce (based on formal and non-formal training) as well as the dissemination of best practices exchange between Institutions and countries.

The various actors mentioned, like many individual actors (universities, VET providers, companies,), are working hard to make this a reality. In fact in the last two years the presence of ECVET has multiplied within the nuclear community.

However every effort is enough, we need greater awareness of the benefits of ECVET and to activate pro-nuclear feeling ECVET within the nuclear community. This can be achieved from the experience and the practice and especially from the dissemination of the best achievements of the various actors involved.

So, for doing feasible the benefits of the implementation of ECVET, in the nuclear community need to involved actively itself. And all the actors (mentioned above and individuals) need to intensify and share their activities especially those most successful.

5. References

[1] Council Resolution of 19 December 2002 on the promotion of enhanced European cooperation in vocational education and training; JO C13.2003. [http://eur-](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF)

[lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF)

[2] Copenhagen Declaration by the Ministers of Vocational Education and Training of the EU Member States, the EFTA/EEA and candidate countries, the Commission and the European Social Partners. http://ec.europa.eu/education/pdf/doc125_en.pdf

[3] Council Resolution of 19 December 2002 on the promotion of enhanced European cooperation in vocational education and training. [http://eur-](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF)

[lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2003:013:0002:0004:EN:PDF)

[4] Maastricht Communiqué of 14th December 2004 on the future priorities of enhanced European cooperation in Vocational Education and Training (VET) http://ec.europa.eu/education/lifelong-learning-policy/doc/vocational/maastricht_en.pdf

- [5] ASSET <http://www.assetecvet.eu/>
- [6] European Observatoire of Sport and Employment (EOS) <http://www.eose.org/index.php>
- [7] European Federation for Welding, Joining and Cutting (EWF) <http://www.ewf.be/>
- [8] CINCH
http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11351751&pid=0&q=8588EB350807D6C12A69BEF285F491D5&type=sim
- [9] CORONA <http://projectcorona.eu/>
- [10] ENEN III <http://www.enen-assoc.org/en/training/for-nuclear-community/efts-fp7/enen-iii.html>
- [11] ENETRAP <http://enetrapp2.sckcen.be/>
- [12] PETRUS II <http://www.enen-assoc.org/en/training/for-nuclear-community/efts-fp7/petrus.html>
- [13] TRASNUSAFE
http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_LANG=EN&PJ_RCN=11614445&pid=10&q=B6598FCEE1FA858EBE23B12DDA3704AF&type=sim
- [14] European Human Resources Observatory for the Nuclear Energy Sector
<http://ehron.jrc.ec.europa.eu/>
- [15] Institute for Energy and Transport (IET) of the European Commission's Directorate General Joint Research Centre (DG JRC) <http://iet.jrc.ec.europa.eu/>
- [16] ECVET Team <http://www.ecvet-team.eu/>
- [17] ECVET Magazine, October 2012 <http://www.ecvet-team.eu/en/content/magazines-ecvet>

INITIATIVES AND FACILITIES FOR E&T IN THE NUCLEAR SCIENCE AND TECHNOLOGY MASTER AT UPM

C.AHNERT, E.MINGUEZ, M.PERLADO, E.GALLEGO, P.VELARDE, O.CABELLOS,
N.GARCÍA-HERRANZ, D.CUERVO, G.JIMENEZ, M.COTELO, A.LORENTE,
R.GONZALEZ-ARRABAL, A.RIVERA, E.DEL RIO

*Departamento de Ingeniería Nuclear, Universidad Politécnica de Madrid
José Gutiérrez Abascal, 2, 28006 Madrid, Spain
www.din.upm.es
E-mail: carol@din.upm.es*

1. Introduction

The present Master/Doctorate in Nuclear Science and Technology programme implemented in the Department of Nuclear Engineering of the Universidad Politécnica de Madrid (NED-UPM) has the excellence qualification by the Spanish Ministry of Education. One of the main objectives of this programme is the training for the development of methodologies of simulation, design and advanced analysis, including experimental tools, necessary in research and in professional work in the nuclear field. This is, Fission and Fusion Reactors, including fuel cycle, waste management and safety aspects, and also non-energy uses of nuclear physics and technologies. The programme includes other basic disciplinary contents such as Quantum Mechanics and Atomic & Nuclear Physics, Non-Energy uses of Radiation Sources (such as Lasers and Accelerators) as well as, Nanotechnology.

In this context, based on the experience gained through research, significant efforts have been done to improve the following subjects in the curricula: Nuclear Power Plants (NPP), Nuclear Technology, Nuclear Safety, Nuclear Reactor Design, Radiation Sources for Diagnosis, Medical, Industrial Application, and Quantum Mechanics Applications such as nanoscience and Nanotechnology.

But more realistic studies are also required to complete the education & training objectives in the “Nuclear Safety” and “Nuclear Power Plants” programmes. For this purpose, we use a full scope Interactive Graphical Simulator (IGS) running in real-time, which was donated by the Spanish José Cabrera NPP, after its operation ceased in 2006. The simulator was used during the commercial exploitation of the plant for training of the main control room personnel, technical support engineers, and for operations management. It was commissioned in NED-UPM in 2008.

On the experimental side, NED-UPM has a neutron measurements laboratory with a calibration bench, and presently a new facility based on sputtering techniques is being commissioned in order to support training and research on development and testing of new high radiation-resistant materials.

2. Codes and experiments for design and advanced analysis in Nuclear Engineering.

The experience gained in the last years by NED-UPM in the development of Codes for design and advanced analysis in Reactor Physics has been included in the Master Programme, with the understanding of the current computational methodologies/codes from the nuclear data processing, the lattice and core calculations codes, the 3D Core Physics simulations at static and dynamic conditions, and finally the power plant simulators.

A large experience in Plasma Physics and Advanced Materials development, characterization and testing under irradiation, together with Reactor Systems for Nuclear

Fusion, is also incorporated in the Programme. This includes the development of codes for High Energy Density Matter studies, which is key for inertial fusion energy (both Radiation Hydrodynamics and Atomic Physics), but also original codes in atomic quantum and classical dynamics and defects diffusion for Materials Research in a scheme of multiscale simulation, with new developments in Fluid dynamics and Basic Physics for Liquid Metals behaviour, important in new generation of Fission and Fusion Reactors, and accessibility to experimental facilities for the students.

The “Nuclear Reactor Design” programme has been focused on the understanding of the computational codes for nuclear reactor design, starting with the nuclear data processing codes, the core calculations codes, and finally the plant simulators codes (JANIS, NJOY, WIMSD, ORIGEN/ACAB, MCNP, COBAYA/SIMULA, COBRA, SIMTRAN, RELAP).

Some of these codes have been developed in our NED-UPM for many years including the generation of the necessary cross-section libraries for accurate use of the codes. First, visualizing with JANIS code, and checking nuclear data from Evaluated Nuclear Data Files (ENDF), with ENDF Utility Codes. Different lattice codes have been developed to solve the neutron transport equation to model pin-cells and clusters taking part of the SEANAP system developed by NED-UPM for NPP design. Deterministic computational methods are complemented with Monte Carlo calculations. Students are introduced in this methodology and several examples for shielding and criticality systems are simulated with MCNP4.

For activation and burn-up calculations ACAB and ORIGEN2.2 codes are used. ACAB code (partially developed by NED-UPM) is designed to perform activation and transmutation calculations for nuclear applications. ACAB is used to simulate realistic operational scenarios of very different nuclear systems: inertial fusion, magnetic fusion, accelerator driven systems, and fission reactors.

Neutronic calculations for core design in 2D and 3D are introduced with COBAYA and SIMULA codes, respectively. These codes also are part of SEANAP system. For core design and operational monitoring we use our SIMTRAN code, SIMTRAN is a 3D-PWR core dynamics code, under development and validation for 20 years. It was developed as a single code merge, with data sharing through the 3D neutron-kinetics nodal code (SIMULA) and the multichannel, with cross flows, thermal-hydraulics code COBRA IIIC/MIT2. COBAYA3 is also now integrated in the NURESIM European platform for best-estimate reactors simulation.

For Multiscale Simulation of Materials, a significant number of developments have been performed with original development or co-development of Molecular Dynamics codes such as MDCASK, and Kinetic MonteCarlo (modified BIGMAC). In general, the full scale is covered from First Principles (SIESTA, VASP), Molecular Dynamics (MDCASK and LAMMPS), Defects Diffusion by MonteCarlo, Dislocation Dynamics, and Structural Codes such as ANSYS, but also with a large modification and adaptation to our problems of free codes such as CODEASTER.

Fluid dynamics problems in nuclear facilities (both reactors or research in New Sources) is covered by implementing and using popular CFD codes such as ANSYS-FLUENT or STAR-CD, extensively modified in some cases for specific problems. In particular, a large modification includes new data generated by using Quantum and Classical Molecular Dynamics, to study liquid metals such as LiPb or others, and get responses to problems of heat transport, corrosion or phase transition. Safety aspects for new Nuclear Systems are considered by using a special version of the MELCOR code for liquid metals, which is being implemented. Also in the safety area, and for fusion reactors, the diffusion and transport of tritium inventory has been originally implemented with new data in codes such as TMAP in order to estimate the final T inventory.

A key aspect developed is the computational coupling of those codes; from the 3D CAD/CAM description of the system to be studied, the particle transport, the heat deposition and particle irradiation, the generation of the basic numbers of material damage and activation, the fluid dynamics of the heat extraction (coolant), the tritium breeding in case of fusion, and the thermo-mechanical effects up to the Power Plant Thermodynamics cycle.

Atmospheric dispersion of radioactive elements in case of accidents are modelled with available codes but also with some new including new chemistry and physics such as Tritium analysis. A new battery of data has been included for components different of HTO, HT and organic bound tritium (OBT), with new models in NORMTRI, UFOTRI and the weather ECMWF/FLEXPART dispersion model, to incorporate the sequential chain of elements after deposition and through the organic systems with evaluation to the environment.

3. Facilities

3.1 Interactive Graphical Simulator

NED-UPM was provided in 2008 with the *Interactive Graphical Simulator* of the PWR nuclear power plant “José Cabrera”, whose operation ceased definitively in 2006. The simulator is a state-of-the-art full-scope real-time simulator, which was used for training and qualification of the plant operators. The Simulator plays an important role for education and training of our students, providing an attractive virtual space that allows to improve the understanding of the whole plant components and its safety systems. The *Consejo de Seguridad Nuclear* grants each course several fellowships for training of students in this installation.

The Interactive Graphical Simulator is a full scope PWR nuclear Power plant engineering simulator that is especially useful for didactic purposes, as it is an interactive tool that allows the student to complete the teaching-learning methodology in nuclear science and technology as is recommended in the new engineering studies adapted to the Bologna rules. This simulator attracts, motivates and retains students within the nuclear science, and improves the quality of training, making students more active in their own learning and replacing simple memorization of the complex processes involved in the operation of a nuclear power plant by a more meaningful learning, involving interactive and team working experience.

The simulator provides the plant responses using TRAC as the software package. Very illustrative screens display all the plant systems, and allow to act directly on the system components. Alarm control panels, similar to the ones existing in the control room of a nuclear power plant, are also available to alert users to potential equipment problems or unusual conditions. The components and systems of the whole power plant are simulated, this includes the nuclear reactor, the pressurized vessel, the primary and secondary loops, the turbine, the condenser, the fluids systems, the instrumentation and control components, and the electrical systems, as well as the emergency systems that are automatic started when needed.

The simulator provides the real plant responses during normal operation, and simulates several maneuvers, a series of malfunctions, and operational transients, and it also allows the training in emergency operation procedures. With the simulation of these situations the student is trained in the plant behavior, and in the nuclear and thermohydraulics phenomenology in the nuclear reactor and in the components of the whole plant.

Standard operational situations to run by the students are: Normal operation in nominal power; Nuclear power variations and turbine demand follow; Plant start-up from Cold-Zero-Power to Full-Power; and Plant down from Full-Power to Cold-Zero-Power, and evolution during the Zero-Power period.

For the simulation of hypothetical accidents, best-estimate and realistic codes are used. The evolution is run in real time, and the students take conscience of the time and the risk of these potential situations, and the high reliability needed in order to limit the global risk. The accidental and complex situations run by the students are: Loss of coolant accident (LOCA), Steam generator tubes leakage or rupture, stop of the main pump rotor, transients with failure of the protection system and the reactor scram, Pressurizer fault, Main steam line break (MSLB) in/out the Containment building, Anticipated Transients without Scram (ATWS), etc.

3.2 Neutron dosimetry laboratory

The neutron measurements laboratory of NED-UPM has two neutron sources ($^{241}\text{Am-Be}$ with 77 and 111 GBq), a cylindrical water cask (0,9m diameter) for irradiation with thermalized neutron, and a precision bench for irradiations in air by means of a fully automated pneumatic device for storage, transport and positioning of the source and measuring instruments. The installation has a Bonner spheres spectrometer with a small $^6\text{LiI(Eu)}$ scintillation detector, four shadow cones (made of iron and polyethylene) and a Berthold LB6411 ambient dosimeter.

By using detailed Monte Carlo methods with MCNP code, several studies have been carried out to characterize the neutron fields in the laboratory in a set of reference points when the $^{241}\text{Am-Be}$ source is situated in irradiation position 3 m over the floor and 4.5 m far from the nearest walls. The ambient dose equivalent obtained by calculations has been also compared with that obtained from the spectrometric measurements and directly with the dosimeter measurements.

3.3 Experimental sputtering set-up for coating deposition.

The research company Nano4Energy is specialized on development, design and commissioning setups for sputtering deposition. In particular, this company develops coating solutions by using High Impulse Magnetron Sputtering (HIPIMS), DC and RF sputtering techniques. The company is commissioning a pre-industrial process at NED-UPM for the development of sputtering deposition of thin film for different purpose (photovoltaic cells, optical coatings, plasma facing components...).

That installation will be used with adequate modifications for diagnosis and irradiation of advanced materials in the same conditions that those at the first wall of the chamber of Laser Fusion Reactors. A similar facility already used at the Spanish Research Council CSIC will be now upgraded for higher voltage and stronger conditions. The installation will also be used for research activities for the Programme students. Moreover, because of the versatility of the facility and the experience in coating deposition of NED-UPM members, this setup is also intended to be used for the deposition of nanostructured-based materials (high radiation resistant).

4. International Masters Programs

NED-UPM is involved in several international programs:

- European Master of Science in Nuclear Engineering
- Erasmus-Mundus Nuclear Fusion Science and Technology
- Erasmus Curricula in Plasma Physics and Fusion Technology (PLAPA, New program)

Our University is involved and participates in several Education and Training Platforms, at national level is part of the CEIDEN technological Platform, at European level in the Sustainable Nuclear Energy Technology Platform (SNE-TP), and the European Nuclear

Education Network (ENEN) association, both promoted by the European Commission. We also participate in the National Platform for Fusion Technology, and in the recently started National Ministerial Programme INDUCIENCIA that aims to join industry with universities and research institutions; in both cases the participation is not only for research and development, but also with intensive subprograms for education and training. Also the University has participated in programs of the World Nuclear University (WNU), and the Frederic Joliot & Otto Hahn Summer School (UE).

5. Research Programs

NED-UPM has agreements with several foreign universities and companies in the nuclear field, being some of them cooperative partners in European research projects. Our Doctoral students may take advantage of that, doing the PhD research work in the projects, also NED-UPM supports the invitation of relevant foreign professors to teach advanced seminars to our students. New Programmes are also established with Institutions in Chile, Argentina, Japan and China.

The different research areas carried out in NED-UPM cover the main topics in Nuclear Engineering field, supported by the National Research Programs, the Nuclear Safety Council, the National Radioactive Waste Management Company ENRESA, the nuclear power plants, or international organizations as EURATOM, STFC RAL in the UK, CEA in France, CERN, LLNL and LANL in USA, Japanese Science and Technology through Bilateral Agreement (ILE Osaka and Graduate Photonic Institute).

- Fission Reactor Physics
 - SEANAP System for PWR reactor cores design and analysis with original methodology.
 - PWR operation surveillance.
 - Nuclear data needs, processing and development of tools
 - Burnup credit criticality safety
 - Sensitivity and uncertainty analysis for nuclear criticality safety and burnup calculations
- Nuclear Safety
 -
 - Analysis of Severe Accidents in LWR
 - Integrated Safety Assessment and Probabilistic Safety Assessment for NPP
- Radiological protection
 - Dosimetry and neutron metrology
 - Environmental, radiological and economic impact of nuclear energy
 - Decision support systems for Nuclear Emergencies and post-accident management
- Nuclear Fusion
 - Development of computational models for target physics in Inertial Confinement Fusion
 - Design and analysis of experiments under the EU support, for X-ray lasers and for ICF.
 - Fusion reactors study and design (both engineering/experimental and Power Plants)
 - Development of computational models for the analysis of activation and material damage by irradiation.
 - Experiments in the area of Materials Irradiation and NanoMaterials development in collaboration with other research centers
- Fluid Dynamics
 - Development of a 2D fluid dynamic model with radiation transport using advanced techniques.
 - Development of new algorithms for considering in the state-of-art codes for engineering design new data bank and modifications to incorporate new fluids, key in new reactors.

- Materials
 - Development of New Advanced Materials with new nanostructures to support very high irradiation of Ions, X-rays, Gammas and Neutrons. Structural and Functional materials such as optical lenses using both Multiscale Modeling and Experiments.
 - Damage in nuclear reactors vessels
 - Separation and Transmutation of radioactive waste.
- New Sources of Radiation (by Lasers and Accelerators)
 - Design of New Facilities for very advanced Irradiation in extreme high fluxes of Particles and Radiation and potentially new methods for Medical and Industrial Applications, and Material and Biological Diagnosis.
 - Laser Generated Ions, Positron and Neutrons
 - Spallation Sources

6. Conclusions

The introduction of the current computational methodologies/codes for nuclear engineering in our programme covers a difficult gap between nuclear reactor theory and simulations. For students, the understanding in a comprehensive way of these codes is an important value in simulation, design and advanced analysis both in the research activities and in the professional work.

The Interactive Graphical Simulator has been proven to be an optimal tool to transfer the knowledge of the physical phenomena that are involved in the nuclear power plants, from the nuclear reactor to the whole set of systems and equipment on a nuclear power plant. The experimental set-ups for neutron research and for coating fabrication offer new opportunities for training and research activities. All of them are relevant tools for motivation of the students, and to complete the theoretical lessons. They also follow the tendency recommended for the European Space for higher Education (Bologna) adapted studies, help to increase the hands-on work of the student, and allows them to experience the work inside a team, in practical and real installations.

SUSTAINING NUCLEAR KNOWLEDGE THROUGH SCK•CEN'S ACADEMY FOR NUCLEAR SCIENCE AND TECHNOLOGY

M. COECK

*Belgian Nuclear Research Centre SCK•CEN
Boeretang 200, BE 2400 Mol - Belgium*

ABSTRACT

The perceived growth of the use of radioactivity in different application fields such as industrial, research, medical and other sectors, requires an advanced understanding of nuclear sciences and technologies in order to guarantee safe working conditions, and thus to assure the protection of man and environment.

Within this perspective, maintaining a high level of competence in nuclear, assuring suitable well-trained personnel and adequate knowledge management is crucial to ensure future careful use of ionising radiation and the development of new technologies in a safe way.

Preserving and extending nuclear knowledge on fundamental and peaceful applications of ionizing radiation to serve society, is one of the key elements in SCK•CEN's research policy. Thanks to its thorough experience in the field of nuclear science and technology, its innovative research and the availability of large and unique nuclear installations, SCK•CEN is an important partner for education and training in Belgium as well as at international level.

1. Introduction

To enhance the coordination and to strengthen the education and training activities fostered by SCK•CEN during the past years, our research centre launched in 2012 the Academy for Nuclear Science and Technology. Within the Academy, 60 years of expertise and experience gained from our different research projects is collected. In order to maintain and extend a competent workforce in nuclear industry, medical, research, and governmental organisations, and to transfer this nuclear knowledge to the next generations, the Academy acts in the following four domains:

- (i) Guidance for young researchers
- (ii) Organization of courses
- (iii) Policy support regarding E&T
- (iv) Research on disciplinary aspects

2. Guidance for young researchers

Specifically towards young scientific researchers, SCK•CEN opens its laboratories and its experts are available to supervise Bachelor, Master and PhD students. In addition, initiatives are taken towards high school pupils (guided thematic visits) and teachers (update on nuclear topics and provision of certain illustrations to be used as course material). With these initiatives, SCK•CEN wants to contribute to the introduction of nuclear sciences at an early stage in young students' life.

2.1 Master thesis at SCK•CEN

Each year, about 20 Master students rely on guidance from SCK•CEN experts and perform their experiments in our laboratories. On an annual basis, SCK•CEN also awards the best and second best master thesis with a price of 1500 and 1000 euro. The SCK•CEN Scientific Council (SC) was asked to play an important role in the evaluation procedure, and for each applicant, two members of the SC are appointed as evaluators, next to the SCK•CEN mentor and one expert in the field of the thesis topic.

Some of the Master students are interested in deepening their nuclear knowledge and proceed with a PhD.

2.2 PhD research in collaboration with universities

In a conscious desire to increase its pool of highly specialized researchers and to tighten the links with the universities, SCK•CEN embarked in 1992 on a programme to support PhD candidates and post-doctoral researchers. Since then over 150 PhD students and about 60 post-docs entered the programme. Their research covers all the priority R&D topics of our research centre, in materials sciences, innovative nuclear technologies, and environment, health and safety issues.

Preparing a doctoral thesis at the Belgian Nuclear Research Centre offers the students the best of both worlds: they stay in close contact with the academic world and they enjoy a unique international research environment, with advanced nuclear experimental facilities and top-level guidance from our experts.

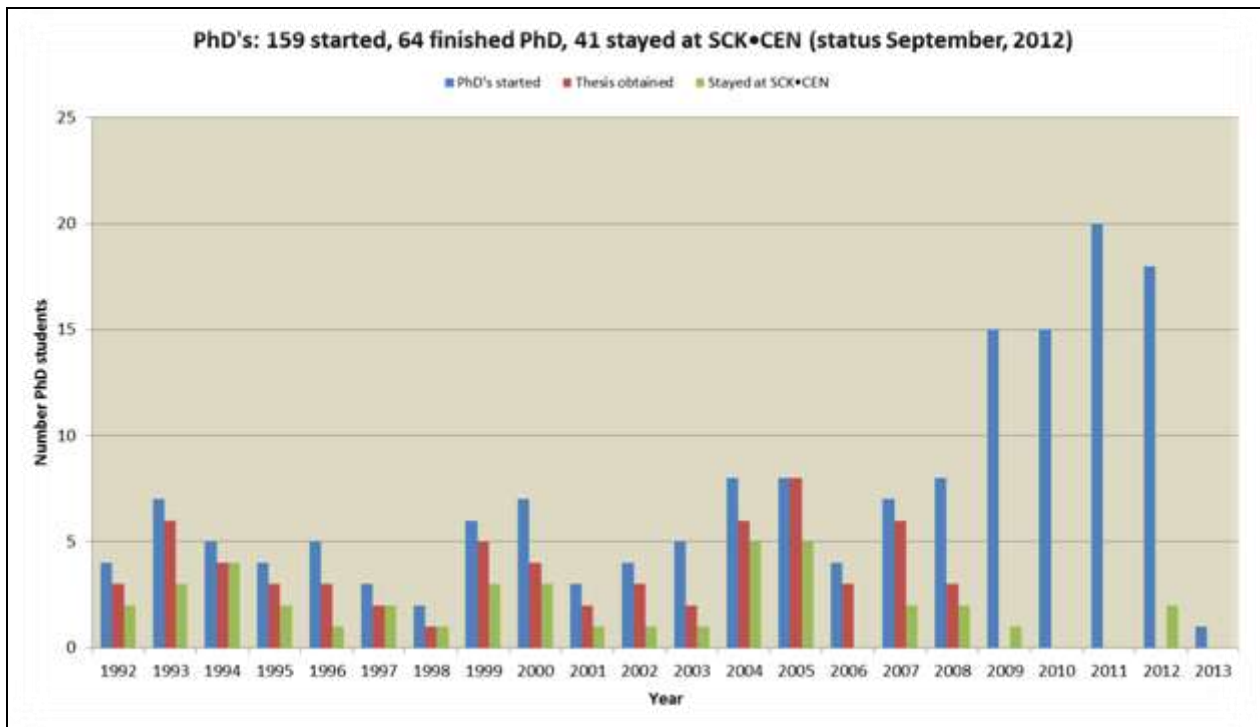


Fig. 1: Evolution of number of students starting a PhD at SCK•CEN.

The last six years, in order to increase the number of PhD students, the SCK•CEN Academy undertook a dedicated search for external financial support. This support was found with industry, but also with governmental institutions. Today, long-term collaborations with for

example GDF SUEZ and FWO/FNRS (Fonds voor Wetenschappelijk Onderzoek/ Fonds de la Recherche Scientifique) are established in support of our PhD programme. Also specific research projects are (scientifically and/or financially) supported on an individual basis by Belgian nuclear industry and governmental institutions (like IRE, Belgoprocess, Areva, NIRAS, AVN, FANC, BelV, ...), and by IWT, Belspo, ESA, 7FP, EFDA, etc...

3. Organisation of academic courses and customized training for professionals

The SCK•CEN Academy collaborates with several Belgian and foreign universities and contributes to academic learning. Furthermore, we foresee customized and modular training for professionals, in all nuclear topics we do research on (like radiation protection, nuclear engineering, nuclear materials issues, emergency planning, dismantling and decommissioning, waste and disposal issues, radiation biology, -ecology, -chemistry, ethical aspects of nuclear applications and nuclear technology assessment, ...).

3.1 Academic courses

3.1.1 BNEN

BNEN, the Belgian Nuclear higher Education Network, is a master-after-master academic programme in nuclear engineering, organised through a consortium of six Belgian universities and SCK•CEN. It is a joint effort to maintain and further develop a high quality programme in nuclear engineering in Belgium. The condensed programme (60 ECTS in one year, including a master thesis) allows students to acquire all necessary scientific and technical background and skills to develop a career in the field of nuclear applications. A modular approach facilitates participation of foreign students. The lectures are taught in English, at the premises of SCK•CEN in Mol, Belgium.

More information about BNEN can be found in a paper of T. Berkvens and M. Coeck, published in the proceedings of this conference.

3.1.2 Radiation Protection Expert course

The Radiation Protection Expert course is organised together with XIOS/UHasselt. It is an academic course of 20 ECTS, including all topics required by the Belgian law as described in the Royal Decree of July 20 2011, art. 73.2. This course is given in Dutch, a French version is organised by ISIB and IRE. All participants are (young) professionals who work in nuclear and who want to specialise their radiation protection competences. Although the course was set up for those who need to obtain a certification as radiation protection expert form the Federal Agency for Nuclear Control, we see that only a minority of the students actually follows the course with this aim.

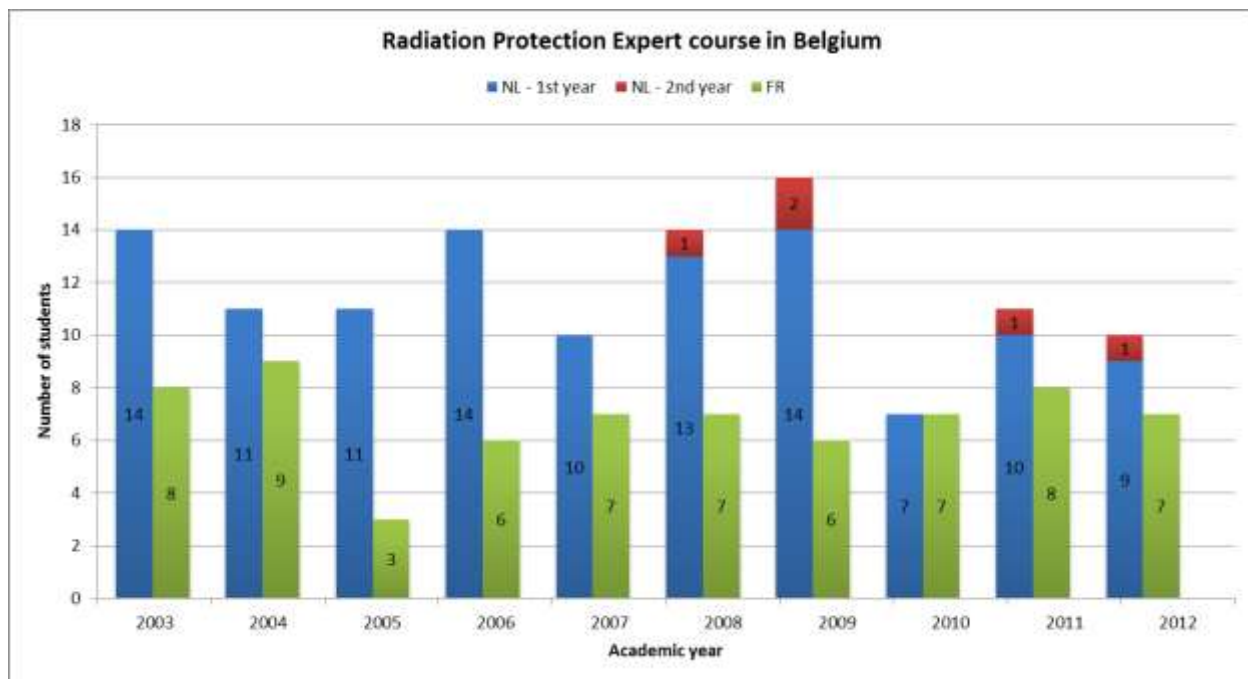


Fig.2: Evolution of student number in Belgium for the RPE course.

3.1.3 Other

Next to the two initiatives mentioned in the proceeding paragraphs, the SCK•CEN Academy is also active in many other academic courses, like for example the European Master in Radiation Biology, which is organised in the frame of the 7FP DoReMi initiatives. For a more detailed overview, we refer to the website academy.sckcen.be.

In addition, we receive students from all over Europe for apprenticeships or specific guided practical exercises at our nuclear facilities like the research reactor BR1, or the hot cells of the laboratory for high and medium activity.

3.2 Customized training courses for professionals

The SCK•CEN Academy foresees customized training in all nuclear topics SCK•CEN performs research on. Most frequently organised are courses in the following domains:

- Nuclear engineering
- Radiation protection
- Nuclear emergency planning
- Decommissioning of nuclear installations
- VISIPLAN ALARA planning tool
- Radioactive waste and disposal

All courses are tailored to the needs of the trainees in terms of programme, duration, level, language (Dutch, French or English), location, etc. Among the lecturers are technicians, physicists, biologists, medical doctors, engineers and social scientists who all bring insights and ideas from their specific background into the course programmes. As SCK•CEN staff members, they have a solid knowledge and experience in their field, and can thus directly transfer their theoretical knowledge and practical experience into the various courses.

The SCK•CEN Academy is currently working on the introduction of the ECVET approaches in its training courses. Learning outcomes in terms of knowledge, skills and attitudes are being introduced.

4. Policy support regarding education and training in nuclear domains

Covering electricity production, medicine and several activities within the non-nuclear sector, the spectrum of applications of ionising radiation is very wide. Although working with a variety of responsibilities and specific professional aims, practitioners have a triple common need:

- Basic education and training providing the required level of understanding of artificial and natural radiation
- A standard for the recognition of skills and experience
- An opportunity to fine-tune and test acquired knowledge on a regular basis

From an executive perspective, education and training are undoubtedly the two basic pillars of any policy regarding safety in the workplace. The radiological protection rationale that serves as the basis for this policy is the same all over the world, going beyond cultural differences and disciplinary applications. In this sense, a coherent approach to education and training becomes crucial in a world of dynamic markets and increasing workers' mobility.

The SCK•CEN Academy contributes to a better harmonisation of training practice and skills recognition. In this frame, specific issues of interest are: standard requirements for course programmes and educational material, development of transdisciplinary training programmes, E-learning and distance learning, the link between radiation safety and conventional safety, nuclear safety culture, organisation of experience feedback, international exchange of knowledge and experience, sharing of lecturers, training facilities and educational source material, ... These are the topics covered in European 7FP projects like ENETRAP II (dealing with radiation protection), TRASNUSAFE (safety culture), ENEN III (nuclear engineering), in which SCK•CEN is playing a prominent role.

Also on the academic level, SCK•CEN plays an active role in networks such as the ENEN Association (European Nuclear Education Network), dealing with the preservation and further development of expertise in the nuclear fields by higher education, through the cooperation between universities, research organisations, regulatory bodies, the industry and any other organisations involved in the application of nuclear science. While ENEN primarily focuses on the domain of nuclear engineering, European networks working on education programmes in other domains, such as radiation protection (EUTERP), radiobiology (Melodi), radioecology (Alliance) or emergency planning (Neris), can also count on contributions from SCK•CEN's experts.

5. Research on transdisciplinary aspects of education and training

Understanding the benefits and risks of radioactivity requires technical insight and training, but also a sense for the social, political and ethical aspects of the application context. In this sense, we argue that any decision on the justification of societal applications of nuclear technology should be organized as transparent and inclusive policy making and be based on transdisciplinary and inclusive research. In coordination with the Science & Technology Studies group of the SCK•CEN and with the wider academic sector, the research of the SCK•CEN Academy concentrates on how to integrate this transdisciplinary approach in education and training programmes for as well professionals as students and pupils. In this context, under the

headline of "exploring the science, politics and ethics of nuclear technology assessment", the SCK•CEN Academy reaches out to civil society by organizing reflection groups and specific training modules.

The idea of a needed transdisciplinary approach to nuclear E&T was first introduced by the SCK•CEN about 15 years ago, resulting from a close collaboration between the SCK•CEN PISA research programme (Programme of Integration of Social Aspects into Nuclear Research) and the SCK•CEN international school for Radiological Protection. This approach was unique at the time, and, still today, it is considered as a non-evident but effective way to broaden the viewpoints of nuclear professionals and to introduce them to critical reflections on the applications of nuclear technology in general.

Meanwhile, the SCK•CEN Academy contributes in this sense to training programmes of the IAEA and Erasmus Mundus initiatives like ICARO and SPERANSA/SARA.

6. Quality assurance

In December 2010, the SCK•CEN obtained the Qfor quality label. An audit was performed, and based on a client scan, which revealed an overall satisfaction of over 90%, SCK•CEN obtained a certificate for the organization of open and in-house training in nuclear science and technology.

7. Conclusions

The SCK•CEN Academy was established in order to coordinate in the best and most efficient way all education and training activities in which the Belgian Nuclear Research Centre is playing an important role. Due to this central coordination, more attention can be given to optimizing the overall quality (both in content and organisation aspects), a better link can be established between different activities and topics, and a more clear visibility can be generated towards the target public interested in improving nuclear knowledge, skills and attitudes, and towards all stakeholders in nuclear knowledge transfer in general.

As a consequence, the total number of activities, spread over the four Academy pillars (guidance for young researchers, organisation of academic and customized training courses, policy support and research on transdisciplinary aspects), has increased. It is the aim of the SCK•CEN Academy to continue strengthening our nuclear education and training activities, fostered by our high-quality research, in collaboration with international partners, in order to guarantee a future safe use of ionising radiation in benefit of society.

UNDERSTANDING BY SEEING THERMAL HYDRAULICS USING A GLASS MODEL OF A PRESSURIZED WATER REACTOR

MICHAEL SEEWALD, ESSEN (GERMANY)
*EXPERT LECTURER IN THE FIELD OF THERMAL HYDRAULICS, HEAD OF GLASS MODEL
DEPARTMENT*
KSG KRAFTWERKS-SIMULATOR-GESELLSCHAFT MBH
GFS GESELLSCHAFT FÜR SIMULATORFORSCHUNG MBH
DEILBACHTAL 173
45257 ESSEN (GERMANY)

ABSTRACT

The simulation centre runs a glass model of a two-loop pressurized water reactor using a 1:10 scale. The reactor cooling circuit, pressurizer, pressurizer relief tank as well as the steam generator are made of glass.

Tutorials in the area of operational control strategies, malfunctioning and incidents can be conducted and thermal-hydraulic effects in a nuclear power plant can be shown.

Licensed shift personnel from domestic and foreign nuclear power plants is trained as well as anyone else interested in technology, who would like to see thermal-hydraulic effects.

The official report of the commission appointed by President Carter on the reactor accident on Three Mile Island comes to the conclusion that the accident could have been avoided if the personnel had noticed the open valve on the pressurizer and closed it; the accident in TMI would have been an insignificant event.

We are prepared for a possible event that hopefully never occurs.

The simulation centre

All those who do not know the Essen-based simulation centre of KSG/GfS yet might find some key data and facts taken from our company profile useful to understand what we do:



Figure 1: The simulator centre

Here are some key facts:

Task:	Simulator training for 10 nuclear power plant units
First courses:	1977
Shareholders:	E.ON, RWE, EnBW, Vattenfall, EPZ (NL)
Staff:	145 employees (50 certified trainers/instructors)
Equipment:	8 simulators in operation 1 glass model
Courses:	approx. 400 / year (duration: 4-5 days)
Participants:	approx. 2,000 / year
Investment:	> €350m
Budget:	approx. €26m / year
Certificate:	DIN EN ISO 9001:2008

History of the Glass Model

On 28 March 1979 a serious accident (INES level 5) occurred at the nuclear power plant Three Mile Island (TMI). The Three Mile Island nuclear power plant is located on the identically named island in Susquehanna River in Pennsylvania, USA.

A partial meltdown occurred in reactor block 2, in the course of which about a third of the reactor got fragmented or melted. For a long period of time the shift team was not aware that, even though the filling level of the pressurizer was very high, more than half the core was not covered with coolant anymore.

Poor equipment of the control room as well as insufficient training of the shift team were stated as the main reasons for the accident. [1]

A wise man is able to learn from the misfortune of others.

Martin Luther (1483 - 1546), German theologian and reformer

On 12 October 1981 (3:52am) an emergency power situation occurred in block A of the Biblis nuclear power plant. The plant was shut down in accordance with the operation manual. While lowering the coolant pressure, the pressurizer filling level suddenly increased rapidly. The shift team witnessed a thermal-hydraulic phenomenon never seen before - the pressurizer cap bubble.

Those responsible for the Biblis nuclear power plant had a glass model built in the mid-80's which was capable of demonstrating thermal-hydraulic phenomena.

From 1985 onwards the glass model was used (on average) 40 days a year to demonstrate thermal-hydraulic effects in seminars for domestic and foreign power plant personnel.

The glass model

The glass model is a model of a two-loop pressurized water reactor (KWU production series) with deionized water (deionate) used as a coolant. It generally conforms to a 1:10 scale.

The theory of similarity allows for alterations with regard to the flow velocity and viscosity of the model fluids in a downscaled model of the reactor cooling system to an extent, where the resulting flow velocity equals the flow of reactor cooling systems in nuclear power plants.

This makes it possible - through experiments on a downscaled model with appropriately altered parameters - to make forecasts about the actual performance behaviour / reactions.

The PKL test facility (thermal hydraulics in the primary circuit) in Erlangen is an experimental facility, which is scaled down with regard to the important parameters in view of the theory of similarity.

The reactor cooling system of the glass model including the pressurizer and the pressurizer relief tank as well as the steam generator are almost completely made of borosilicate glass, which is highly temperature and chemical-resistant. We use, due to its obvious advantages, demineralized water as a coolant. The rules of the similarity theory require - if water is used - values regarding the properties of pressure and temperature which are not feasible with glass being used as a material.

The construction of the glass model is not based on the similarity theory!



Figure 2: The glass model

The maximum heat output of the reactor amounts to 60 kW. The maximum temperature inside the reactor cooling system amounts to 130°C, which equals a saturation pressure of 3 bar.

The phenomena observable in the glass model have provably occurred in nuclear power plants or experimental facilities, and can be demonstrated and kept in stable condition by skilfully selecting the frame settings.

A physical process within the original is transferred to a model process within the glass model, not vice versa!

“What is a steam engine?”

“Let’s pretend we are ignorant fools and put it this way: A steam engine is a big black room. It has one hole at the front and one at the back. The first hole is the firebox. The other hole - well, we shall come to that later.”

In the classic movie “Die Feuerzangenbowle” (“Brandy Punch” or “Fire Tongs Punch”), head teacher Bömmel sends his pupils on a mental journey of discovery by describing a steam engine in a more creative way. In a more formalized way, we would say that a heat engine is being explained in a physics lesson - how unromantic!

Most Germans know this movie scene very well. We chuckle and smile at the way Bömmel teaches. According to Vera Birkenbihl [2] we come to the following conclusion: He does it right!

If “dormant” associations inside us are “awakened”, less new subject matter / content needs to be learned and thus, the “effort” for our brain is reduced.

Associations inside us virtually are our resources that we ought to include / activate when learning!

In order to connect new information to our network of knowledge, strings can be attached to serve as mnemonics; these can disappear later on [2].

Now the question remaining is, who bears responsibility for ensuring that knowledge is conveyed and received, that it is incorporated and that it can be recalled later?

In communication theory, it has been assumed for decades that the sender is responsible for ensuring that the message is received and understood.

The sender must choose a language that is understood by the recipient.

"Language" does not only refer to words, of course. The term "language" expressly includes the method, i.e. an approach to systematically integrate new findings into the knowledge network of the recipient, the learner.

Nature offers - via physics - i.e. fluid mechanics in particular, but also via thermodynamics - context and a framework that describes changes of state in a power plant. This is absolutely possible by mathematical formulation. The Navier-Stokes equations are a system of non-linear partial differential equations of secondary order, and can, if the Nabla operator is applied, safely do this in regards to the thermodynamic parameters density, pressure and velocity (in their most generic form).

Interested readers will certainly realize upon first glance that it seems desirable to try and find a method which is easier to understand and possibly even more lively.

We, the glass model team, present thermal-hydraulic effects using our glass model!

The participants of our courses are licensed shift personnel of domestic and foreign nuclear power plants on the one hand, as well as a large number of interested people from all areas of technology on the other.

Staff from specialist departments

Non-licensed shift personnel (specialized craftspeople, shift fitters and shift electricians)

Authorities and expert organizations (Federal and county authorities, GRS [Gesellschaft für Anlagen- und Reaktorsicherheit - German association for facility and reactor safety], TÜV [Technischer Überwachungs Verein - German association for technical inspection])

Students from different subject areas

Participants of special conferences (e.g. "Druckstöße in Rohrleitungen" Haus der Technik - HdT [special event of a German institute on pressure surges in pipes])

Any other interested people (Lions Club, associations, fire brigade)

"Presenting" doesn't mean "performing tricks", it doesn't mean watching the circus with your eyes wide open and being stunned - we explain the observable events in a systematic fashion. Additionally, we always incorporate the background knowledge of the participants. This means we use lively and illustrative examples from our kitchen at home - coffee makers are used with particular pleasure - whenever necessary using background knowledge from mathematics and physics.

You quite rightly ask yourself "coffee maker?" Sure! As almost all thermal-hydraulic phenomena occurring in atomic power plants can be found in domestic kitchens, from the pressure cooker and the milk watcher to the coffee maker. If you've become curious, why don't you come and visit us?

Our courses are conducted in German and English.

The move

In 2002 investments were due for the glass model in Biblis. The "Siemens S5" control system had to be replaced. At the location of the Biblis nuclear power plant it was decided that the investment required, which amounted to several €100,000 would not be made any more.

But what should become of the glass model now? By decision of the supervisory board of KSG/GfS, the glass model was integrated into the simulator centre. Concrete ceilings were removed, new ceilings cast, fire protection areas defined, the air conditioning system reconstructed and - last but not least - upgrades for the glass model were installed to improve safety and broaden the thermodynamic spectrum.

A new control cabinet including the adaptation to the Siemens PCS7 control system was installed. The safety and availability of the glass model was improved through the installation of additional control equipment. Apart from the controls and mechanical safety valves, limitation systems were installed which protect the model from extreme conditions and overloads. Additional motor-operated valves as well as a condenser cooler with 9°C cold water have eased the operability and increased the cool-down speed significantly to 50K/h.

The seminar room is protected from the glass model by a 50 mbar pressure resistant anti-splinter screen and offers the possibility to monitor the condition of the model and the trends of selected status parameters at any time using three wide-screen projectors.

The total investment for the move and the upgrade of the glass model has so far amounted to €1m. Further upgrades to improve the observability of phenomena are scheduled for 2012 and 2013.

The language the glass model speaks has been and still is worth its price. This is the joint opinion of nuclear power station operators in Germany, the Netherlands, Switzerland and Belgium.

The team

The term “glass model team” has already been used in the previous paragraphs. During a seminar, this team is formed by an instructor and a technician. The instructor is an experienced engineer in simulator training. Besides extensive knowledge in the field of power plant engineering, which is comparable to that of a shift supervisor in a nuclear power plant, our trainers have the methodical and didactical abilities to breathe life into thermal hydraulics. The technician is a trained boiler attendant and he operates the model.

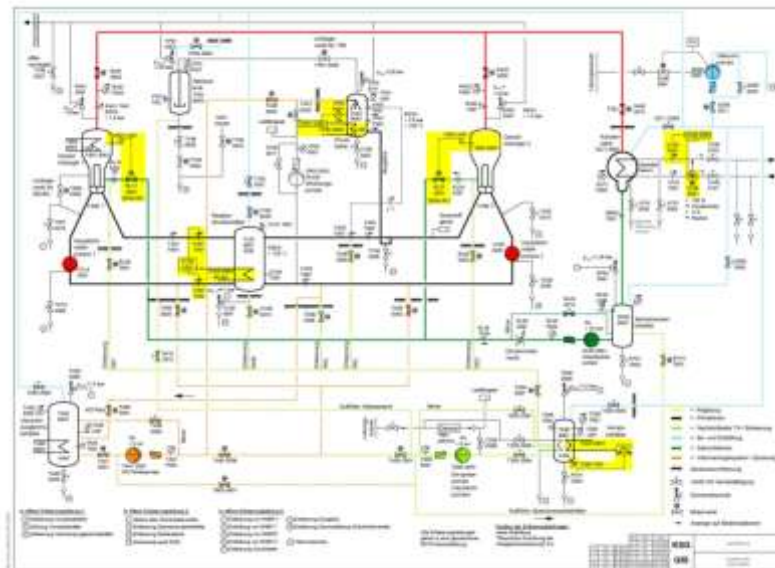


Figure 3: System circuit diagram of the glass model

The technician represents the entire operators team of our small power plant “Glasmmodell”. He heats up the reactor cooling system in the morning, degases the coolant (non-condensable gases are particularly troublesome at pressure levels <math>< 1 \text{ bar}</math>) and he supports the trainer during various exercises.

The exercises are described and set in the framework of power plant-specific control scenarios. The entire team consists of two instructors and two technicians and can be supported by the staff of the simulator centre if required.

Training areas and modules

Using the glass model, tutorials in the area of operational control strategies, malfunctioning and incidents can be conducted and thermal-hydraulic effects in a nuclear power plant using a pressurized water reactor can be shown.

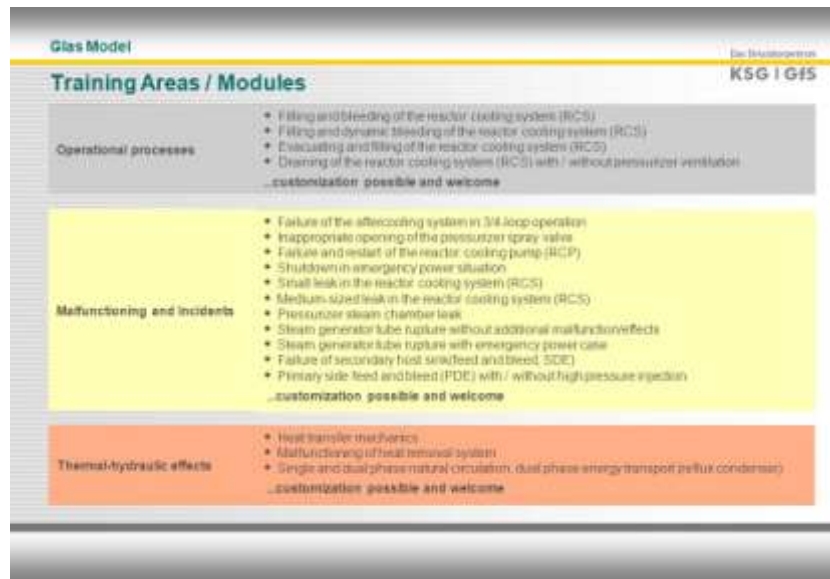


Figure 4: Training areas / modules at the glass model

Phenomena which require special operational control were developed for nuclear power plants in the Netherlands, Switzerland, Belgium and Finland and have successfully been applied in our seminars.

The following phenomena can occur in a nuclear power plant with a pressurized water reactor:

- Single phase natural circulation
- Dual phase natural circulation
- Dual phase energy transport (reflux condenser)
- Water hammers in the loop pipes
- Separation of water differing in density
- Convective heat transfer
- Subcooled boiling
- Nucleate boiling

Special phenomena occurring in nuclear power plants with pressurized but also with boiling water reactors are:

- Cavitation
- Problems cooling the pressurizer dome (pressurizer cap bubble)
- Evaporation within hot pipes
- Cold water bag
- Blow-down of chilled water receiver at different temperatures until boiling
- Flashing
- Cold creeping flows in hot pipes
- Suction vortices



Figure 5: A steam generator during secondary side depressurization (SSD)

The phenomena are not limited to one single reactor type and they are by no means complete.

Even nuclear power plants with boiling water reactors greatly appreciate the visualization possibilities of our glass model and use them frequently. Using the glass model, special courses for nuclear power plants with boiling water reactors are conducted, and the phenomena are adapted to the operation of boiling water reactors using exemplary operation control strategies.

The courses

Courses around the glass model are becoming more and more popular and required. Whilst courses in Biblis were limited to special courses, one or several-day courses including start-up process and shut down, additional and supplementary seminars take place at the simulator centre as well. These trainings at the glass model take place during the seminar room times of the simulator training (one simulator training usually consists of four hours at the simulator and four hours in the seminar room). In other words:

In the morning a steam generator tube rupture can be run according to the operator's manual at the power plant-specific simulator, and in the afternoon the shift team can "see" the same tutorial at the glass model.

The simulator centre offers special courses (1 to 4 days) at the glass model. Furthermore, "simulator accompanying courses" for the purposes of initial training, repeat trainings and special training courses can be planned at any time.

On average, we conduct more than 130 course days (90 days plus 40 days of summed up simulator course accompanying training) on 180 calendar days each year.

Conclusion

A clear trend is noticeable: Not only licensed shift personnel is trained at the glass model. It has become increasingly important for power plant operators to train the entire technical staff.

The physical context and reactions must be understood, even though a worker's personal contribution to a safe operation of the power plant might be negligibly small.

The official report of the commission appointed by President Carter on the reactor accident on Three Mile Island comes to the conclusion that the accident could have been avoided if the personnel had noticed the open valve on the pressurizer and closed it; the accident in Three Mile Island would have been an insignificant event.

Through our seminar at the glass model we make a contribution to demonstrating the complex phenomena of thermal hydraulics in a lively fashion, so that the shift personnel is prepared for a possible event that hopefully never occurs.

[1]Der Unfall von Harrisburg - Der offizielle Bericht der von Präsident Carter eingesetzten Kommission über den Reaktorunfall auf Three Mile Island. Erb Verlag, Düsseldorf 1979, ISBN 3-88458-011-6

(Documentary book on the incident in Harrisburg)

[2] Wer agiert als LEHRKRAFT? Jeder Mensch, der Dinge erklärt...

von Vera F. Birkenbihl

(Who acts as a teacher? Everybody who explains things...by Vera F. Birkenbiehl)

Maintaining a high quality nuclear engineering programme: future challenges for the Belgian Nuclear higher Education Network

T. BERKVEN, M. COECK
SCK•CEN, Boeretang 200, BE-2400 Mol, Belgium

ABSTRACT

The Belgian Nuclear higher Education Network (BNEN) is a master-after-master academic programme in nuclear engineering, organised through a consortium of six Belgian universities and SCK•CEN, the Belgian Nuclear Research Centre. 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. Already running for 10 years, BNEN is a good example of cross-border collaboration between universities, research institutions and industry. In order to maintain a high quality academic programme, BNEN faces a number of challenges such as the renewal of the inter-university agreement, the modification of its admission criteria and the implementation of novel teaching methods, among others. In the framework of an official accreditation process, the BNEN steering committee recently wrote a Self-Assessment Report (SAR) describing the different strengths, weaknesses, opportunities and threats of the BNEN programme. In this paper, the results of the accreditation process will be highlighted, together with the different actions BNEN has planned in order to preserve its high educational standards of an international master-after-master 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

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. Figure 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 the academic year 2011-2012 topics were (amongst others) 'Nuclear safeguards and 'Exploring the Science, Politics and Ethics of Nuclear Technology Assessment. Topical days organised by SCK•CEN are also recognised as advanced course.

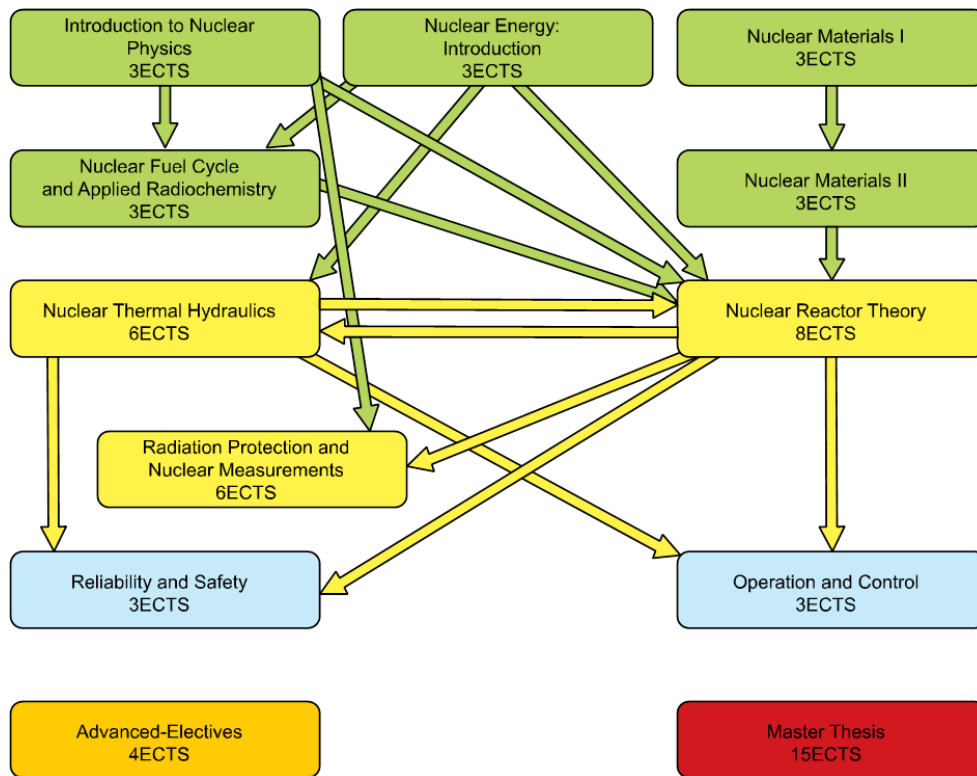


Figure 1: Structure and prerequisite relations of the BNEN programme [2].

The programme, student issues and general policy is governed by the BNEN Steering Committee (SC) in which each university has one member present, together with the Administration Manager of the BNEN, the BNEN secretary and two student members.

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. 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 [2]. Several of SCK•CEN's researchers provide valuable contributions to the programme through these seminars and practical exercises. From their daily tasks and responsibilities they give an expert view on the subjects that are being taught.

Currently, 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 2, 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 2011-2012. 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.

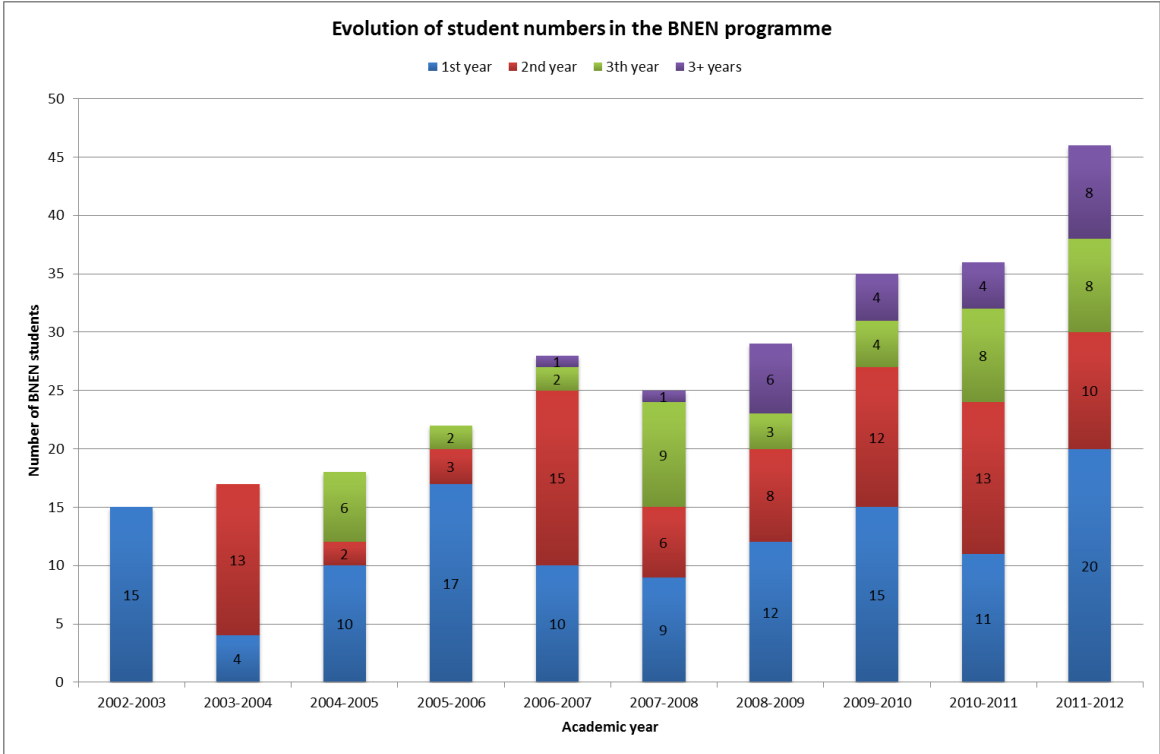


Figure 2: Student numbers

3. Development of the Self-Assessment Report

During the academic year 2010-2011, the BNEN SC wrote a Self-Assessment Report (SAR) [3] in the framework of a formal accreditation/quality audit by the Flemish Interuniversity Council (In Dutch: Vlaamse Interuniversitaire Raad – VLIR). For this occasion, the BNEN SC set up a formal working group composed of the six university representatives, the BNEN Administration Manager of SCK•CEN, the student representatives and two representatives of the assistants (employed by SCK•CEN).

For the initial input to this SAR, the working group relied on the in-depth international review that was organised by the BNEN in the framework of a European Project under FP6 [4]. The analyses, comments and remarks contained in the different documents published in the framework of this study have been updated and complemented by reflections of all the members of the BNEN teaching community and were subsequently translated in a SWOT document, reflecting the present status of the BNEN programme.

Recent reflections and comments by employers from the nuclear power related industries on the performance of and expectations on the Nuclear Engineering programme were obtained at one of the bi-annual stakeholders meeting and in the response on the organised hearing.

In parallel, hearings were organised to receive feedback from students, alumni, professors and teaching assistants. Also the conclusions of the bi-annually organised internal BNEN “quality meetings”, with participation of nearly all academic personnel and representatives of the employers were taken into account in establishing the SAR.

Finally, the text was submitted to the VLIR at the end of 2011 before a panel of international experts visited SCK•CEN in Mol on March 12, 2012 for the official part of the quality audit. During this day, the visitation committee had discussions with all the groups that were involved in drafting the SAR and also visited some of the facilities at SCK•CEN that are being used in the BNEN programme.

On April 27, 2012, the visitation committee gave its first feedback on the BNEN programme through an oral intermediate report. Most indicators were positive (going from “in order” to “adequate”, and peaking at “unique” for the material provisions) but the negative part of the report was the fact that the committee considered that the programme has an actual load that is much larger than the 60 ECTS of the study year, namely because of the limited number of credits dedicated to the master thesis. This could lead to difficulties for BNEN to be accredited by the NVAO, the Flemish accreditation body for the VLIR.

The full visitation report is only expected by the end of 2012, but the BNEN SC has already decided to create a new working group that will analyse the outcomes of the visitation process and prepare the BNEN programme for future reforms. The starting point of this exercise was a critical reflection on the SAR and the intermediate reporting of the visitation committee.

4. Lessons learned from the SAR

The main strengths of the programme can be found in the fact that a well-balanced programme is offered of which the contents and format were discussed at length with representatives of the major nuclear companies that are the first potential employers of the graduates. A set of objectives and learning outcomes was defined that encompasses in depth disciplinary specific competences as well as, but in a less pronounced way, transferable skills and competences that are needed for an efficient integration of a graduate in a larger engineering team. The fact that a nearly complete overlap is obtained through the curriculum mapping matrix between objectives and realized competences in courses, electives, exercises and master thesis can be ascribed to the following contributing factors:

- The competences of the teaching staff (lecturers and assistants) with respect to the theoretical background are strong.
- There is a good balance between theory and practical skills. This is implemented through an appropriate diversity of didactic formats, including exercises and/or labs for nearly all courses.
- There is a good balance between basic subjects and advanced subjects through elective course modules and topical days organized by SCK•CEN.
- There is appropriate care for multidisciplinary scientific competences and for transferable skills through the importance given to the master thesis and reporting on electives.
- There is a good mix of junior and senior lecturers.
- The educational programme is backed by world-class research at the universities, the research centre and the involvement of teachers working in international research institutes.
- The involvement of several professors who have their principal employment in nuclear companies.
- There is a large and dynamic group of young researchers involved in the course teaching (seminars), labs and exercises sessions and as mentors of master theses.

- Both the professors and the young researchers are very active in the major international research programmes and associations related to applications of nuclear phenomena.

Most students are very satisfied with their master programme in content, organisation and relevance for their job. The success rate is high as can be seen from the average scores of about 16 for full time students as well as for young professionals (Figure 3).

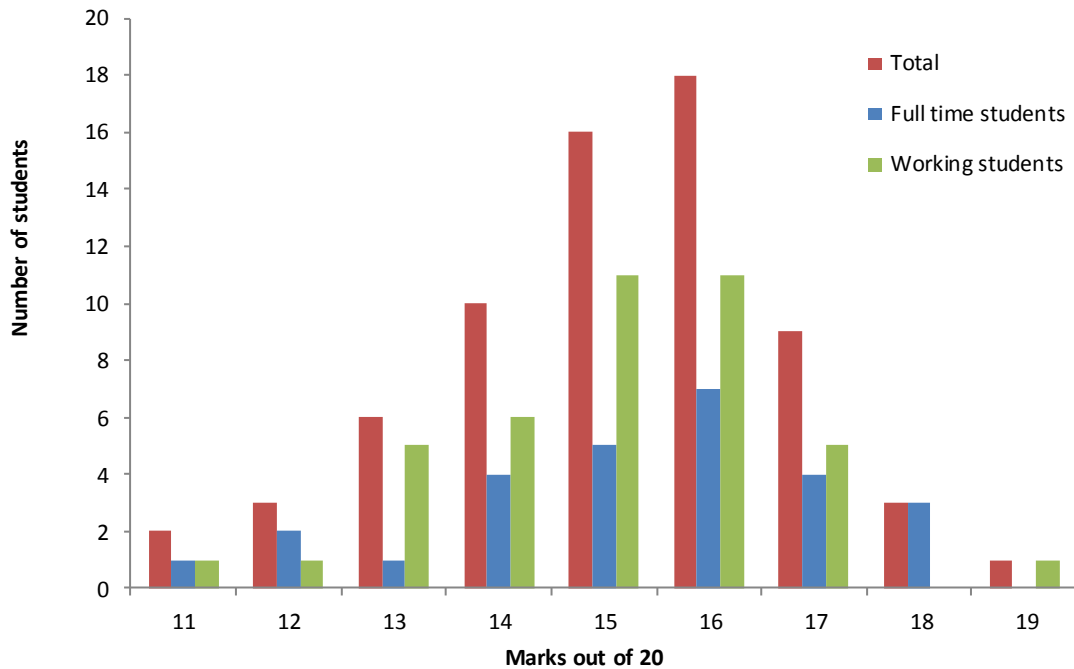


Figure 3: Distribution of marks for 69 defended master theses

A particular aspect of the BNEN programme is that the student population differs strongly from a traditional master public (see Table 1): About 65% of the students are young professionals. They have already obtained a master degree in an engineering discipline and are employed, to large majority, by companies in the nuclear sector. They are often encouraged or even sent by their employer to attend the specialized master-after-master programme, indicating the appreciation of the industrial stakeholders (and sponsors) for the BNEN. Accommodating this important number of working students asked for implementing the possibility in the programme to spread the studies in a structural way over two (or more) years and hence allowing the combination with a full time job.

The international flavour in the BNEN is obviously very strong by the presence of Erasmus students and students from extra-European countries, coming out of their own interest or through international cooperation agreements. The mechanisms to create the best possible conditions for effective study for non-EU students (housing, integration with local students, etc.) have been optimised throughout the first years of this programme.

Total number of "regular" students	110	
among them foreigners	19	
among these Erasmus	12	
Partial registration	35	
Full time students	38	35%
Working students	72	65%

Table 1: Student population (2002-2011)

The most important opportunities for improvement that are already identified and for which appropriated measures are discussed or planned are:

- More flexibility in the replacement of teachers and more involvement of faculties in teaching and research.
- Adaptation of admission rules to harmonise the level of incoming students and to select the best students as BNEN is reaching the capacity limit.
- The competence matrix will be refined and possibly new topics or redistribution of credits discussed especially the weight and time spent on the master thesis.
- Continuation of the use of nuclear infrastructure has to be assured with possibly an increase of practical exercises or closer contact with reactors needs to be organized.
- Quality assessment will be continued with particular attention to upgrading teaching materials and the introduction of novel didactic approaches.
- Optimisation of the calendar (equilibrium of semesters, efficient use of time slots) will be further discussed and strict respect of scheduled lab sessions by staff and employers will be adhered to so that young professionals can be present.
- Faster decision procedures for master thesis subjects, admission to the programme or any other request by students, staff or externals will be aimed at in the SC.

In order to implement these recommendations it is important to keep in mind that the BNEN programme is an interuniversity programme in which the formal participation of each university (and of the research centre SCK•CEN) is more or less rigidly fixed in an interuniversity agreement. Large scale reforms like the first three mentioned in the previous list require a modification of this interuniversity agreement. Belgium is a federal state where education is a regional matter in which the Flanders and Walloon region can have different legislations. In a consortium with universities from both sides of the country, modifying the interuniversity agreement will be a difficult exercise.

5. Conclusions

The main objective of the master-after-master in Nuclear Engineering *was to provide graduates with all necessary and technical background and skills to develop a career in the field of nuclear applications and to provide pathways to technically feasible solutions and societally relevant applications of nuclear energy in a sustainable environment.*

The strategic policy for the programme is to continue to meet this objective in the near future. On the medium term the role for programmes like the BNEN is a real intellectual and societal challenge, taking into account on one hand the rising demand for energy and sensitivity of the public to climate changes while on the other hand recent incidents involving power plants have seriously affected the burgeoning nuclear renaissance.

By continuing to propose a programme with an uncompromising academic quality and excellence in an inter-institutional and international context, BNEN will contribute to educate

and form young engineers who can tackle the specific problems posed in nuclear industry in all its aspects.

For this BNEN will continue to improve its already successful programme and plans to revise in the immediate future the rather strict interuniversity agreement in order to provide more flexibility in using available competences at the partner institutions and harmonise the programme content and format to the remarks and suggestions of the students and industrial stakeholders.

Acknowledgements

The author wants to acknowledge the work of Prof. A. Hermanne, former BNEN vice-chair and coordinator of the visitation process at BNEN. He also acknowledges all members of the BNEN Steering Committee and everyone who has contributed to writing a successful SAR.

References

[1] The BNEN programme: <http://www.sckcen.be/bnen>

[2] T. Berkvens, G. Van den Eynde and M. Coeck "10 Years of Experience with Nuclear Education in the Belgian Nuclear higher Education Network", NESTet 2011, Prague, Czech Republic.

[3] Self-Assessment Report 2010-2011, Master-after-master in Nuclear Engineering, Interuniversity Programme, BNEN, 2012

[4] BNEN, Deliverable No3 "Self-Assessment Report", FP6 project "Open Access to BNEN", contract number 012564, 2005

SIMULATION TECHNOLOGY FOR SEVERE ACCIDENTS TRAINING, ASSESSMENT AND MANAGEMENT

E.GIL, P. REY, F. ORTEGA, N. RIVERO
Simulators and Control Rooms, Tecnatom
Av. Montes de Oca, 1, 28703 – Spain

ABSTRACT

As what happened with the TMI and Chernobyl events, it is expected that the accident that took place at Fukushima will drive to important changes in emergency preparedness, and particularly in the training simulators scope and applications. Tecnatom is now working on a project consisting of the development of a severe accident module based on MAAP4 and its integration in an NPP classroom simulator. Other major points addressed by the project are the stimulation of Technical Support Center emergency management support tools also developed by Tecnatom, to facilitate the emergency drills performance, a simulation execution faster than real time, different configurations for different training sessions and automatic operation of the simulator from a severe accident guideline by a single click on the guideline document itself. These new features turn a classroom simulator into an efficient tool to support the training of the personnel involved in emergency management.

1. Introduction

As a consequence of the accident that took place at Fukushima, there has been an increase in the importance of reinforcing the training in severe accident management in nuclear power plants. Full scope training simulators are one of the primary tools the plants have available to address these new training needs.

From the point of view of severe accident simulation, the technology is fairly mature and available, with several previous experiences about the use of severe accident codes with training purposes. However, severe accident scenarios are hardly used in training.

On the other hand, Technical Support Center (TSC) members and other emergency centers staff need specific training and do not have the necessary skills to understand and operate, in depth, their plant evolutions in case of a major accident.

At Tecnatom we work on different activity areas related to nuclear safety, including simulation technology, control rooms design and modernization, plant operation support, plant staff training and safety management. This experience provides a multidisciplinary point of view to Tecnatom as well as a general approach to safe operation of a NPP and an effective response in the event of an accident.

The conclusion is that reinforcing severe accident management training is one of the challenges that NPPs have to face in the near future and severe accident simulation technology needs a new angle in order to be really useful.

2. Background

Back in 2005, Tecnatom developed a methodology for the design and integration of severe accident simulation models in training simulator environments. This methodology was applied and validated by developing a severe accident simulation model, based on the MAAP code (MAAP is a technology owned by EPRI: Electric Power Research Institute, Inc.) and by implementing it in a full scope training simulator.

3. Previous considerations

Project design criteria taken into consideration were:

- The control room simulator may not always be the most appropriate environment, for instance to train on severe accident phenomenology
- Plant staff, other than operation crew, is not qualified to operate the NPP from the control room
- Accident scenarios duration exceeds usual training sessions' time
- There are no specific support tools connected to simulators for nuclear emergency training purposes

These considerations lead to the conclusion that there is a need to integrate simulation technology supporting severe accident phenomenology within the specific training necessities of plants and Technical Support Center staff.

4. Project Scope Main Features

In the light of all of these considerations, Tecnatom embarked on a project aimed at extending the use of simulators to the emergency centers staff for training purposes in emergency drills. The project consists of implementing new features in available training simulators, enabling its use in emergency centers. Amongst others, the project has addressed the following major points:

- Extension of the simulation scope of available classroom simulators by integrating a severe accident module, based on the code MAAP4 (technology used by the Spanish NPP for PSA studies)
- Integration of a severe accident module in a PWR training simulator operated by Tecnatom. Simulation continuity has been guaranteed between normal operation and accident condition
- On-line switch between real time and faster than real time execution. This feature allows fitting a severe accident sequence within a training session timeframe by speeding up the simulation while the information is not relevant.
- Duplication of the most important classroom simulator displays in case of emergency. That way, the displays may show either the instrument values, so that the staff will receive the information in the same manner they would receive it in case of real emergency, or the physical values calculated by the model, which is of great help to understand the accident progression
- Adaptation of the display provided by MAAP4 to help understanding the accident.
- Stimulation of the emergency support tools SACAT-GGAS, developed by Tecnatom.
- Possibility of different type of training configurations, oriented to different type of training sessions. For instance, sessions only with control room operation crew, only with TSC members or mixed sessions, and a phenomenology training configuration, showing the physical values in the displays.

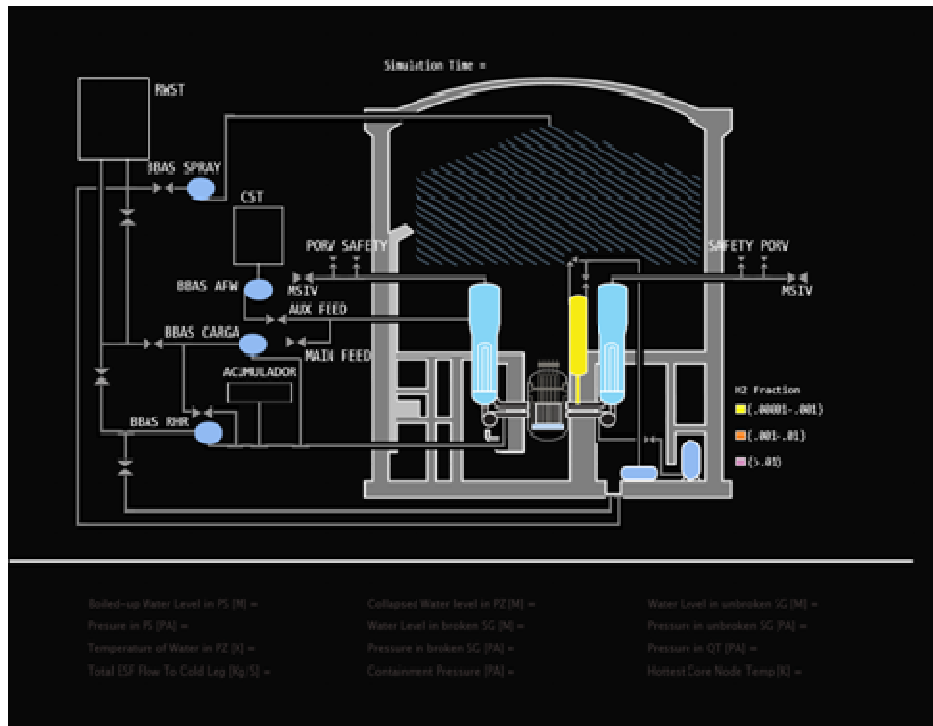


Fig 1. MAAP based containment model

5. Emergency support tools stimulation

5.1 SACAT – Technical Support Center Support System

Tecnatom has developed several computer-based tools for emergency training and management, named SACAT, running at the Technical Support Centers.

SACAT includes different modules and displays which show the main operation parameters, radiation monitors and external radiological impact estimates due to all possible leakage pathways.

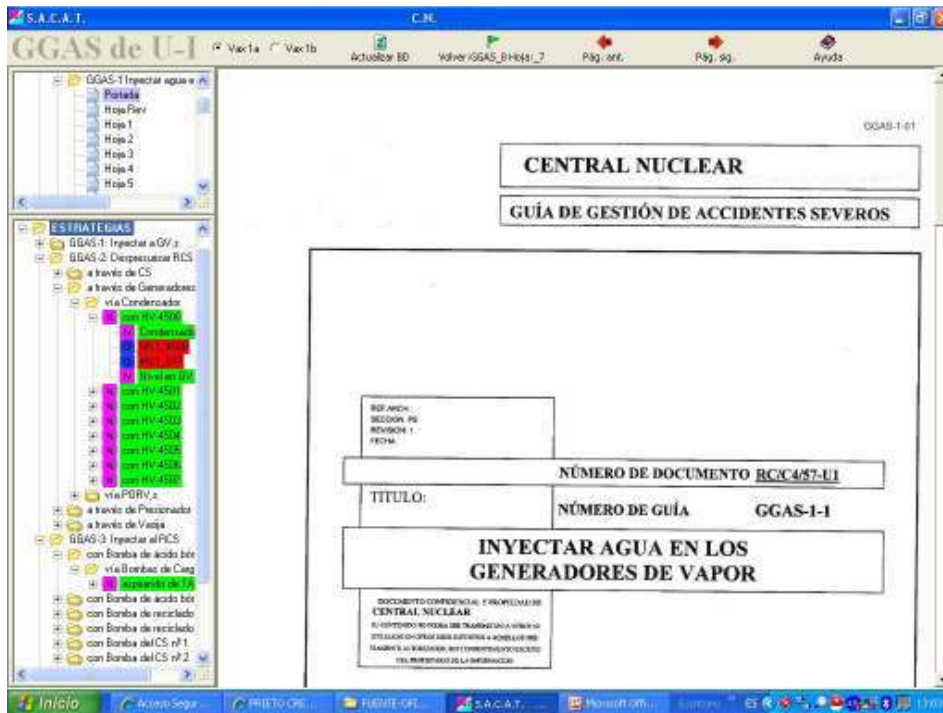


Fig 3. SAMG computerized module

Stimulating this tool will make possible the automatic operation of the simulator from a severe accident guideline, with just a single click on the guideline document itself. The simulator will execute all the necessary commands corresponding to the selected mitigation strategy, including control room and local panels.

This feature provides the possibility of a training session addressed to TSC members alone. They are responsible for the decision making during an emergency and although they do not know how to operate the plant, the simulator will execute all the actions to complete the decided strategy so that they can confirm whether the strategy was a success or a failure.

6. Different training configurations

Amongst the different training configurations:

- Session with operation crew alone, to train on their Control Room Severe Accident Management Guidelines
- Session with TSC members alone, to train on their Severe Accident Management Guidelines
- Session with TSC members and operation crew coordinated within the same scenario, making possible to develop team skills in emergency situations
- Phenomenology training session, following the data calculated by the severe accident module and the accident progression

7. Simulation validation

One of the most important phases of the project is validation. In this case two different kinds of validation processes were required.

The first step was to validate the integration of the severe accident module in the classroom simulator, checking that all the variables are correctly communicated. This validation was carried out according to the ANSI/ANS-3.5 standard. It establishes the functional requirements for full-scope nuclear power plant control room simulators for use in operator

training and examination. Ten sequences were executed and the main operation parameters compared between the simulator before and after the integration of the severe accident module. For instance, for the sequence of the opening of one pressurizer PORV, the following results were obtained, finding that both performances were qualitatively identical:

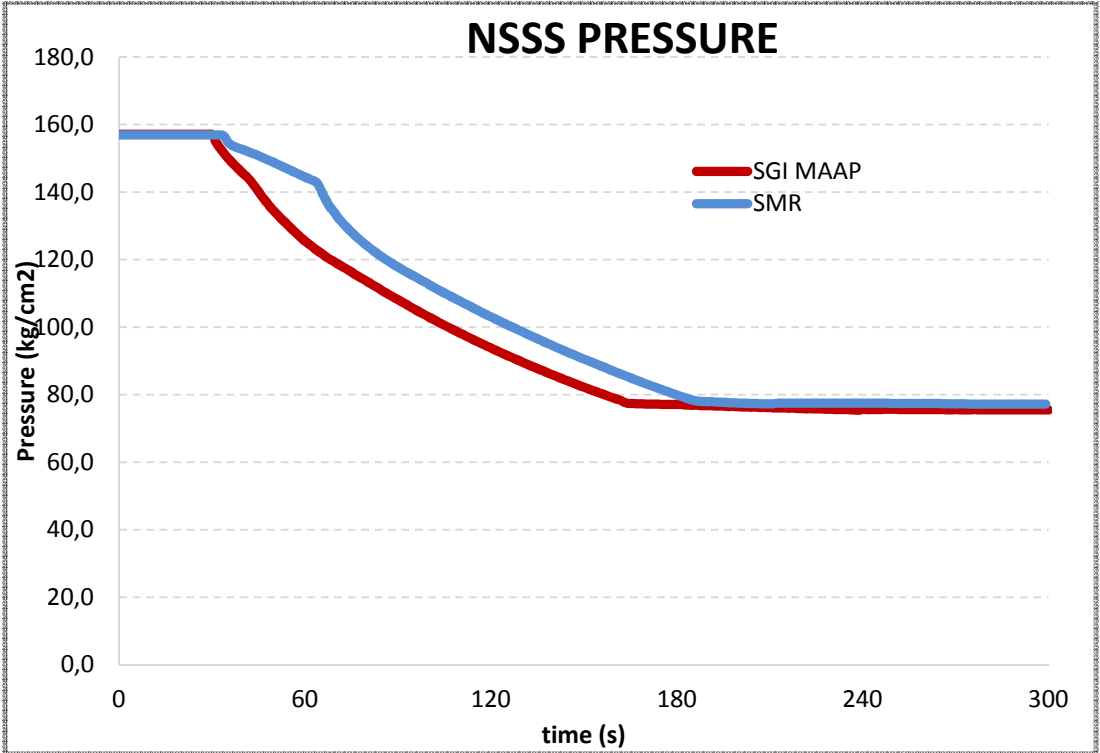


Fig 4. NSSS pressure compared results

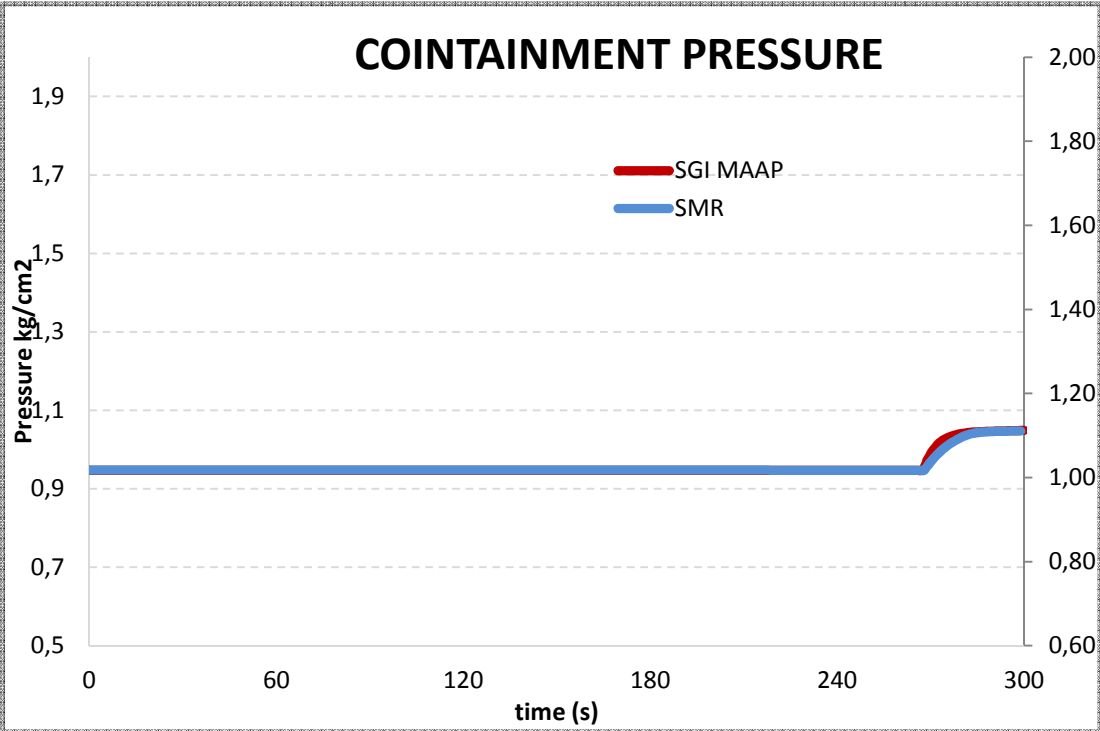


Fig 5. Containment pressure compared results

As second and final step it was validated the severe accident performance. For this purpose, a series of severe accident sequences were executed, including for instance prolonged Station Black Out, loss-of-coolant accident (LOCA) with failure of LPSI pumps or total loss of feed water accident with failure of HPSI pumps.

8. Conclusions

Although severe accident simulation is an available technology, a new approach is requested in order to get the most out of the training in severe accidents management

As identified in this paper, the new features implemented within the full scope simulators domain will make them efficient tools for such important points as the definition, assessment and training in severe accident management as well as the deep understanding of its complex phenomenology.

TRANSFERRING LESSONS LEARNED FROM OPERATING EXPERIENCE, INCREASING KNOWLEDGE

Ana Belén García
Cristina Bilbao
Carlos Macía
Francisco Gonzalez Añez
TECNATOM s.a

Abstract

Training is an essential tool for safety. Training oriented to plant performance improvement and the uses Operating Experience (OE) reinforces the training objectives.

Transferring lessons learnt increases knowledge of our organizations and makes our training more effective. The systematic integration of this operating experience in training sessions will improve the quality of training and thus improve safety.

Tecnatom has created an initial core of knowledge that is necessary for those organizations to use the OE effectively. And since then, we have been working under the expectation of "use of operating experience in all activities of the plant" and we have created a software tool to facilitate its work in trainers.

In this tool we can find not only OE document that are applicable, but instructors can find training materials that make them available to integrate OE in technical and human factor training sessions. All instructors can upload materials and feed the tool. Instructors can download and use these documents.

Objectives and strategy:

Tecnatom has been providing training for operating crews since nuclear plant commissioning, developing the necessary educational and training materials. After a number of years by optimizing the system of training of the operators, it was identified the possibility of introducing a breakthrough of the process of overall staff training. This would be an improvement of the results of the training, through the systematic introduction of the significant operational experience applicable to the training of the different plant positions, according to the best practices of the nuclear industry.

In this way, Tecnatom decides, after an analysis of the current state of the art, the development of a project EXPERT, designed as a methodology to include lessons learned from the most significant events of the nuclear industry in training. This project allows keeping standardized training materials, to ensure that the content of training is still a minimum standardization of training delivery, regardless of instructor. This tool will ensure a minimum knowledge

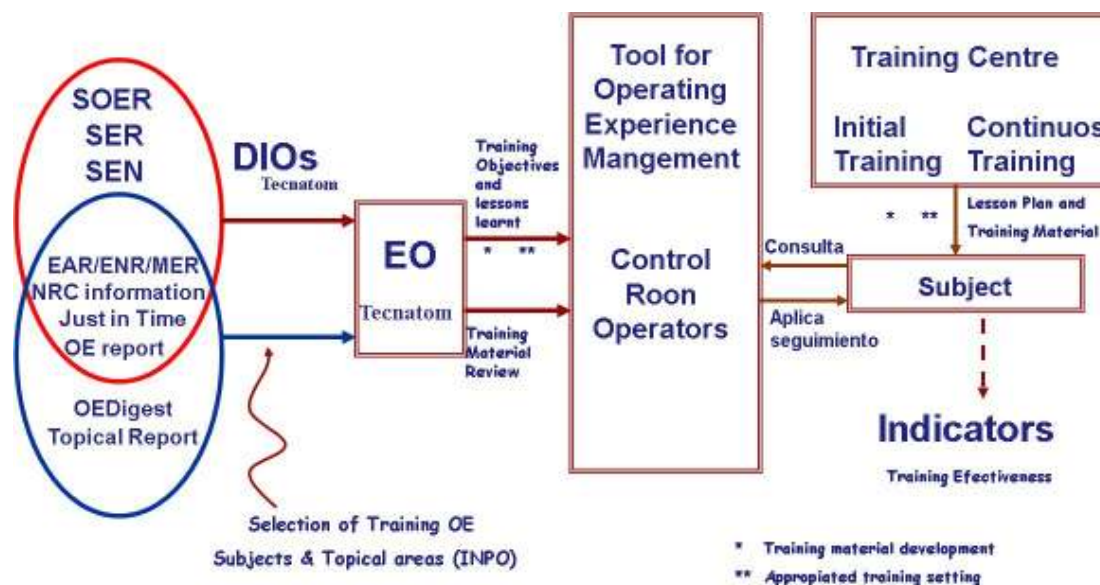
TRANSFERRING LESSONS LEARNED FROM OPERATING EXPERIENCE, INCREASING KNOWLEDGE

of training of trainers in the materials about significant events in the industry, lessons learned and action taken around the world.

To support these objectives has been developed a web-platform (EXPERT) that centralizes the significant documentation of the industry with the allocation of capabilities depending on the training programs. Instructors can identify the applicable material and registration of the information used in the education and training of NPP staff.

The EXPERT web-platform is conceived to be applied to the training of all plant personnel using the most significant documents and improving the applicability depending on the collective training, optimizing the understanding of the issues at hand and transferring lessons learned specific of each post, reinforcing expectations of the address and the desired behaviors of the organization.

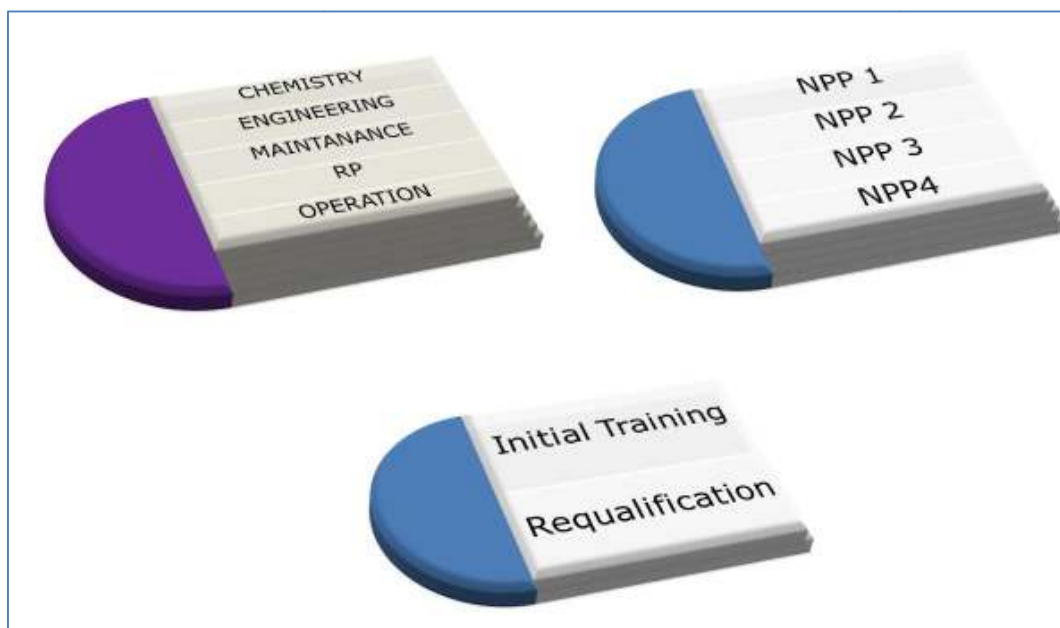
Also, the project includes the define and implement a methodology of teaching management of the operational experience for inclusion in programs of initial training and continued exploitation of the Spanish nuclear power plants personnel.



There are a large number of sources of information, but none centralizes more relevant information to training process classified on initial skills and knowledge for main NPP positions and initial training programs. This part includes basic knowledge of significant industry events, lessons learnt, what

TRANSFERRING LESSONS LEARNED FROM OPERATING EXPERIENCE, INCREASING KNOWLEDGE

operational experience is and how national and international organizations were created following the most significant events of the industry. In order to enhance learning process, operating experiences are used on continuing training programs. The available material on the platform is used in teaching lecture and full scope simulator sessions.



Elaboration of the instructor book:

Training objectives are developed and stored in the platform. Training material, lesson plan, instructor and student books can be used by all instructor and can be selected by different criteria: job position, subject....

Operating Experiences references and training material will be available for instructors for the necessary implementation preparation. They can be shared and improved by all instructors of Tecnatom, ensuring a continuous improvement of the material with the feedback of comments from students, keeping knowledge.

EXPERT platform will be accessible from any computer with access to the internet to facilitate the use of the materials in any training setting and training centre (NPP).

TRANSFERRING LESSONS LEARNED FROM OPERATING EXPERIENCE, INCREASING KNOWLEDGE



This will offer a more complete training service to students, increasing the competence of the staff.

EXPERT development:

The development of the project is divided into several activities, as shown below, although they can be conceptually grouped in design and development.

1. Development of the methodology for training management of the operational experience and incorporation into initial and continuing training programs. Application to a pilot plant
2. Review of the application to the pilot plant.
3. Development of specifications for the technological EXPERT platform.
4. Prototype development.
5. Initial testing of features.
6. Design and development of training materials.
7. Pilot courses, review, and improvements
8. Significant events applicable to the training selection.
9. Materials in the technological platform load.
10. Test platform times downloads search.
11. Training of trainers.

Conclusions and results:

- A standard methodology has been implemented to include lessons learnt from operating experience in NPP personnel training program
- EXPERT is providing a performance in OE training defining a methodology, unifying criteria and joining forces

**TRANSFERRING LESSONS LEARNED FROM OPERATING
EXPERIENCE, INCREASING KNOWLEDGE**

- EXPERT works in a website platform that made available instructors to access to training modules, and allow them the use of the most significant events of the industry to improve learning objectives in classroom and simulator sessions.

NEW IAEA TRAINING INITIATIVES IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT

P. ORMAI, J. KINKER

*Waste Technology Section, International Atomic Energy Agency
PO Box 100, 1400, Vienna, Austria*

1. Introduction

More than 50 Member States have requested assistance from the IAEA to help them develop the necessary competencies and skills that will allow them to implement technically viable, safe, secure and cost-effective radioactive waste management (RWM) solutions. At the present time the IAEA provides numerous opportunities for the training of managers and experts representing national programmes, regulatory bodies, and organizations related to RWM, and staff of national regulatory bodies responsible for licensing and inspection of such facilities, either through bilateral agreements or through the mechanism of International Communities of Practice. IAEA-organized training events may be lecture based or comprise hands-on training, or may be a combination of the two. However, it is recognised that there are some limitations in the current approach, because it is extremely resource intensive and presently can only be delivered to a limited audience.

In order to overcome these limitations, the IAEA has committed to identify and utilise alternative and more cost effective avenues for the delivery of training. To this end, a decision has been made to develop a comprehensive RWM curriculum that jointly covers aspects of both safety and operations with an appropriate balance that ensures the two dimensions are delivered in a complimentary and consistent manner, including integration where appropriate. The training materials that will result from the development of the curriculum will be delivered through the medium of the Internet and personal computers (eLearning) and also through extended face-to-face courses to be delivered in Regional Centres of Learning (which are being established). The curriculum will be developed collaboratively between the IAEA, international experts and the learning centres.

2. Target audience and users

The e-Learning programme being developed has been designed to accommodate a broad target audience, which can be divided into different constituent groups. Different groups clearly have different requirements. Therefore, to ensure efficiency and the effective use of our scarce resources, IAEA plans to develop the materials in stages with a particular level of professional audience as the basis rather than try to cover multiple audiences all at once. The following occupational groups were identified as key users:

1. Waste management operations personnel (Supervisors and operators, techs, etc.)
2. Design engineers
3. System engineers
4. Scientists and technology developers
5. Operation managers
6. Decision makers in government, electric utilities, and waste management organizations
7. Regulatory Authority personnel (including Auditors and Inspectors, Compliance Officers, Safety Case and Environmental Impact Assessors, Permit Writers, etc.)

Another way to segment the audience is to consider what their individual motivations are in relation to their professional backgrounds:

- A. Scientific and technical professionals who wish to be exposed to developments in other disciplines.
- B. Scientific and technical professionals who need exposure to alternative methods and technologies in their own disciplines for problem solving, e.g. as demonstrated in other Member States.
- C. Relatively inexperienced but qualified scientific and technical professionals who need exposure to more advanced information in their own fields.
- D. Technically interested stakeholders (students, commercial vendors, regulators).
- E. Other interested stakeholders, sometimes without scientific or technical background (senior managers, policy makers, public).

Based on the above segments, we have agreed that the primary target audience can usefully be described as a combination of 3 & 4 and B & C above as:

“Professional staff, both scientists and engineers, that through their normal employment responsibilities support the operation of waste technologies/facilities and who need exposure to more advanced information, including alternative methods and technologies e.g. as demonstrated in other Member States.”

These broad assumptions about user characteristics are likely to be sufficient to allow for the initial design of training and educational materials at a level of depth and breadth that is appropriate, without trying to meet absolutely every possible target audience requirement. On this basis, and given the typical resources available to such a group in the developing Member States, we can expand on our assumptions around three main factors (in addition to actual technical content) that should influence what materials and media need to be provided. They are:

- *Learning Environment*: The environment is likely to be both home and office. It is expected that there will be assistance from others to support understanding, e.g. senior co-workers, although this may not always be the case. We assume therefore that some mechanism must be provided to be responsive to queries. Also, there are currently technical issues such as a large degree of variation in the Internet bandwidth in different Member States and organisations. Consequently, the use of streaming video and memory intensive applications should be minimised where possible, or alternative options, such as downloadable or local content, optimized file sizes, etc., must be made available.
- *Individual User Profile*: The profile of the user relates to their computer literacy level, general education, cultural issues, native language, and the objectives for using the training material. It could be assumed that if most users are engineers and scientists, the level of computer literacy will be relatively high compared to a general population, and certainly acceptable with regards to the use of the Learning Management System (LMS) tools. We must be sensitive to any cultural issues when developing the training courses, but common sense should ensure this will not be a major issue. Another important factor is the variation in learning styles and relates to the best type of learning media to be used to present the material (e.g. visual, interactive, text-based etc.). IAEA is addressing this need through mixing the “media” of the course materials and also providing self-assessment tools, exercises, and tests.

3. Curriculum and course structure

IAEA has already developed a structured curriculum to present the range of topical areas covered under RWM. The first draft of such a comprehensive map of the modules is shown in Figure 1. This curriculum is the result of several iterations of a 6-week comprehensive summer course in RWM originally given at the Clausthal University of Technical (TUC) in Germany (in cooperation with and sponsored by IAEA). Each part of the curriculum is divided into training “Modules”, which are further divided into Segments. The term ‘module’

is used here to refer to the units of study which are the building blocks for a full course in a particular technical subject area. The training modules are intended to be relatively self-contained from a learner's perspective and the curriculum is structured to enable a progression in learning from basic principles through to advanced concepts.

To help students make choices, the IAEA training website area would operate a Learning Management System, or LMS, in which the modules and various supporting options would be described and indexed in a user friendly manner, and where users can track their progress and communicate with other learners, teachers, and course supervisors.

Each of the modules is specific to a particular, self-contained topic within the broader thematic technical area (e.g., Decommissioning). Together they define the broader syllabus. It is not expected that any one individual would undertake all of the RWM modules (except for interest), but it should be expected that for a comprehensive overview of relevant issues in any one technical area all of the modules in a particular RWM topic would eventually be completed. These topical areas relate to decommissioning, environmental remediation, management of sealed radioactive sources, management of radioactive wastes (pre-disposal and disposal), and information management in RWM.

The learning material itself is currently being designed and produced by technical experts in each of the above topical areas, with external support being provided through a project funded by the European Commission. The module design and presentation will take maximum advantage of current technology where this is cost effective and actually supports the learning process. Modules are envisaged to include a high level of embedded interactive functionality in order to enable learners to use the material with little or no external support and to make the learning experience as enjoyable and efficient as possible. The starting point for the provision of content is of course based on existing training materials, although there is substantial effort being put into the updating, expanding, and producing of new content from this substantial amount of existing source material

4. Development and implementation

The development and implementation process is aimed at (i) defining detailed learning objectives and an outline for each module; (ii) deciding how the materials in each module are to be presented (e.g. as lecture, video, data and information, animation of a process, still or moving images taken at a site, interactive exercises and self-assessments, etc.) and also plan for interaction with the user and determine how their interactive assessment will be undertaken; (iii) existing and appropriate reference materials; and (iv) any existing learning or lecture materials that may be useful for the Module.

A systematic approach to module definition, design, and development was agreed within IAEA and with the help of the TUC lecturers. This approach utilizes a template for the definition and development of content, which roughly follows the outline below:

Overview

- Title of the course and responsible person
- What the course is about (course outline and subject matter)
- Learning objectives
- Prerequisites – what knowledge the students must know to succeed in the course. What knowledge you expect them to have. What they should do if they do not have these prerequisites.
- Relationship to other modules

Framework

- How is the module organised (breakdown into Segments)

- Main lessons to be demonstrated in each section of the module

Detailed content

- Introduction – objective, background and contents
- Content (concepts, theory, examples, etc.)
- Recommended exercises and interactive activities
- Self-Assessment(s) (what are the specific questions or problems, how to be posed, how are answers to be given, how to grade).

Additional information

- Media to be employed in each section
- Design and appearance of the content for each section
- Reference Materials (both IAEA primary references and external references)
- Resource requirements (suggested lecturers, time required or suggested, etc.)
- Identification of existing materials that can or should be adapted for use in the module

To date, 3 thematic areas within the RWM Curriculum have been started: Safety Case Development, Disposal (Near Surface), and Information Management. Once these initial course materials are available on the network collaboration platform (the IAEA CONNECT platform), an evaluation of this pilot programme will be undertaken before further and significant use of scarce materials is undertaken to complete all of the modules. The intention is to assess the following through a field trial of the learning materials and feedback:

- Learning effectiveness:* Are the learning objectives being met? Is the material suitable? Are the media suitable? How does the online delivery compare with face-to-face or other distance delivery methods?
- Cost-effectiveness:* we need to take into account the initial set-up cost, and any on-going costs such as upgrading of equipment or software and compare against how many students are actually taking up the on-line training (through registration). Do the courses need further promotion and if so, how.
- Learning environment:* how do the students negotiate the online environment? Can it be improved?
- Maintenance:* Is the on-going maintenance and general availability sufficient?
- User assessment:* Is the online assessment meaningful to the user? Can it be improved?
- Further evaluation:* how do we improve the future and on-going evaluation (these bullet points)?

5. Conclusions

The IAEA is committed to assisting its Member States to develop the competencies and skills necessary to allow them to implement technically viable, safe, secure and cost-effective radioactive waste management solutions.

This new IAEA eLearning initiative in RWM will provide trainees with materials for self-learning at a pace to suit the individual, and has the potential to reach a vastly broader audience than the limitations of face-to-face traditional training course can. It is hoped that it can also serve as a method of preserving vital nuclear knowledge and expertise, and can also act as a way to facilitate “just-in-time” learning to professionals who simply lack experience, but not basic technical expertise.

Figure 1. Map of the RWM training modules (Part 1)

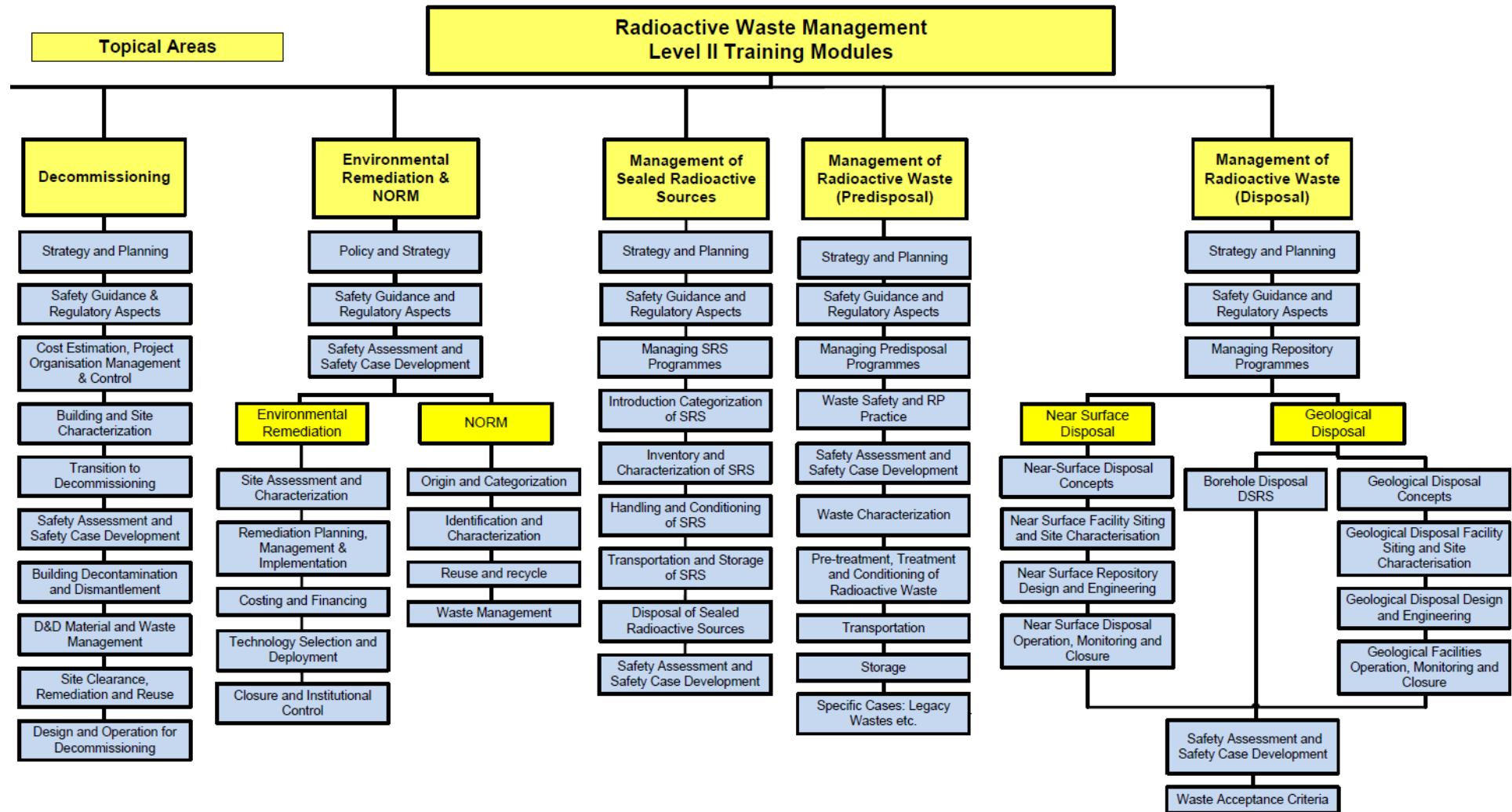
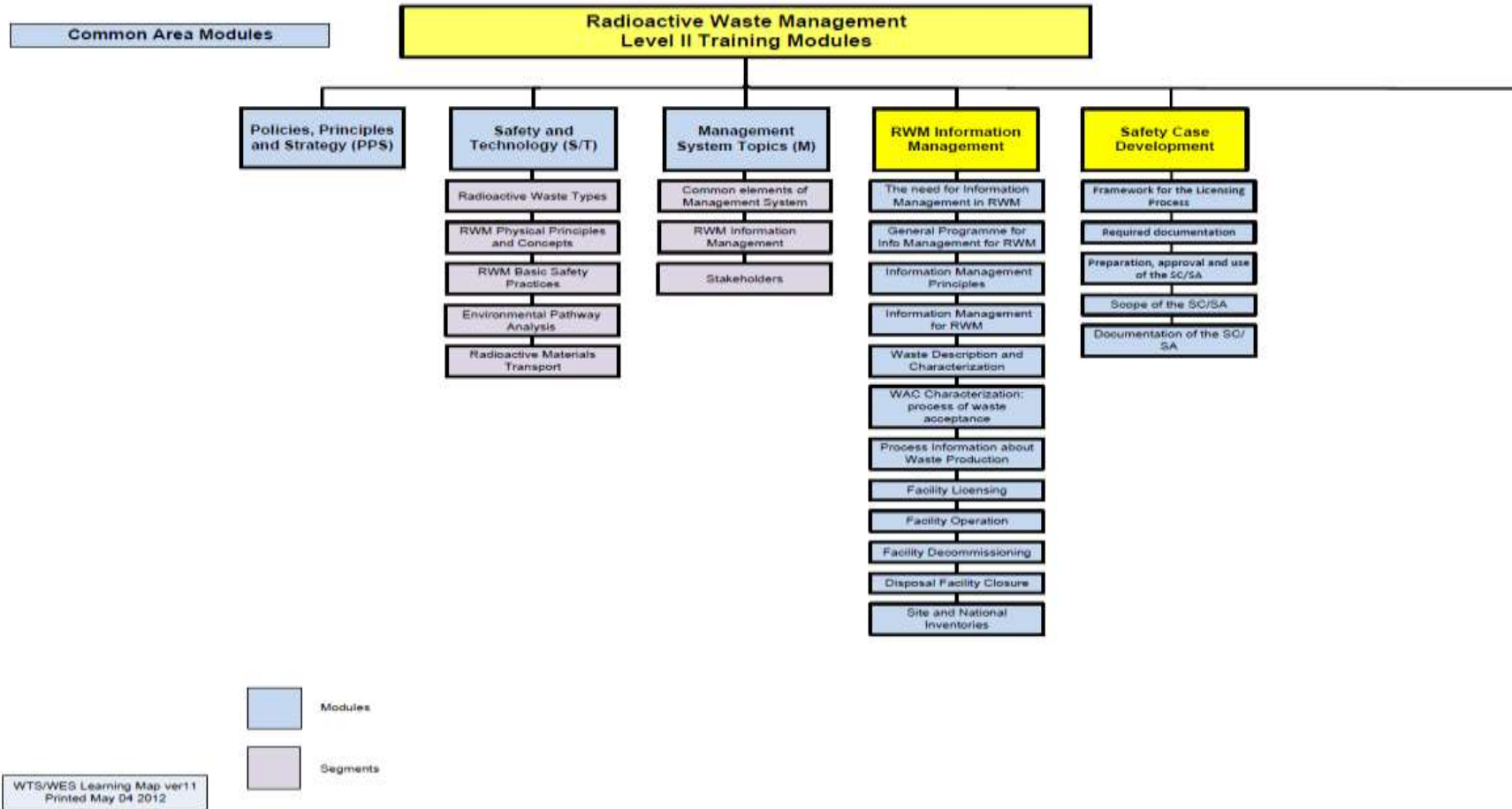


Figure 1. Map of the RWM training modules (Part 2)



3D VISUALIZATION AND SIMULATION TO ENHANCE NUCLEAR LEARNING

RAYMOND DIMITRI-HAKIM

L-3 MAPPS Power Systems and Simulation
8565 Côte-de-Liesse, Montréal, Québec, Canada H4T 1G5

ABSTRACT

The nuclear power industry is facing a very real challenge that affects its day-to-day activities: a rapidly aging workforce. For New Nuclear Build (NNB) countries, the challenge is even greater, having to develop a completely new workforce with little to no prior experience or exposure to nuclear power. The workforce replacement introduces workers of a new generation with different backgrounds and affinities than its predecessors. Major lifestyle differences between the new and the old generation of workers result, amongst other things, in different learning habits and needs for this new breed of learners. Interactivity, high visual content and quick access to information are now necessary to achieve high level of retention [4], [5].

1 Nuclear industry's HR & teaching challenges

1.1 Aging Workforce

While the nuclear power industry is trying to reinforce its safety and regain the public's support post-Fukushima, it is also faced with a very real challenge that affects its day-to-day activities: a rapidly aging workforce. A 2009 Nuclear Energy Institute survey indicates that 38% of the nuclear utility workforce is eligible to retire by 2014, leaving the US nuclear industry alone with about 21,600 new workers to educate and train [1]. The industry must also take into account the non-retirement workforce attrition which will account for a 10% reduction of the current workforce also by 2014 [2]. In Canada alone, it is estimated that 65% of all power industry workers are over 40 years old and almost 40% are within 5 years of retirement [3]. For New Nuclear Build (NNB) countries such as Vietnam and the UAE, the challenge is even greater, having to develop a completely new workforce with little to no prior experience or exposure to nuclear power.

1.2 New generation, new needs

The workforce replacement introduces workers of a new generation with different backgrounds and affinities than its predecessors. New generation workers entering the industry have been raised with modern digital technology integrated in everyday life. The wide-scale exposure to more and more realistic video games, readily available computers, tablets, smart phones and the internet has shaped the habits and minds of the Y (born 1980-1990) and Z (born 1990 onwards) generations. These generations are considered as "digital natives", people who are "native speakers" of the digital language of computers, video games and the internet and are extremely technology savvy, as opposed to older generations or "digital immigrants" who were not born in the digital world but have adopted many or most

aspects of the new technology era [4]. These fundamental lifestyle differences result, amongst other things, in different learning habits and needs for this new breed of learners. Some of these habits can be summarized as [5]:

- They are highly visual learners preferring to process pictures, sounds, and video rather than text.
- They are experiential learners who learn by discovery rather than being “told”. They like to interact with content to explore and draw their own conclusions. Simulations, games, and role playing allow them to learn by “being there” and also to enjoy themselves and have fun.
- They have shorter attention spans, so prefer bite-sized chunks of content.

1.3 Current Nuclear Training Programs

The typical nuclear training program in use around the world is composed of learning technologies and methodologies developed and refined in the 1980s. A typical training program structure consists of:

- **Classroom fundamentals** characterized by text books, lectures and PowerPoint presentations
- **Plant visits** allowing students to see actual power plant equipment
- **Full Scope Simulators** which duplicate control rooms with detailed mathematical modeling of all plant systems

Regardless of the generation being trained, the training profession clearly acknowledges that simulator training is the most effective learning phase of the three methodologies; simulator training allows “Practice by Doing”. The educational community has ranked learning techniques as shown in **Figure 1**, based on their respective retention rates.



Figure 1: Learning Pyramid [6]

The plant-specific full scope simulator however arrives late in the learning cycle and is largely intended for operator training, because it is dependent on actual plant data/information. Moreover, prior to immersive learning on a full scope operator training simulator, the student must understand the many physical systems, processes and their interactions before training on complex plant procedures can be productive and effective.

On the other hand, early training covered by classroom fundamentals falls in the “Lecture”, “Reading” and sometimes the “Audio-Visual” categories of the Learning Pyramid, showing very low retention rates.

L-3 MAPPS has received suggestions from colleges and utilities targeting the training of new students in basic nuclear plant concepts. In their opinion, full scope simulators present too much information and detail when a new student is first mastering fundamental concepts. This is the equivalent of studying about flying in the classroom and then attempting to fly a 777 or an A380 for the first time. In the aviation industry, learning to fly is a gradual process that begins in smaller basic aircraft and flight simulators, with complexity increasing over a period of years.

When teaching programs developed and carried out by “digital immigrants”, with methods resulting in fundamentally low retention rate, are combined with the highly different needs of a “digital native” audience, the result is likely to be a low success rate program. Therefore, the much slower and longer training cycle costs more money to the utilities without completely and rapidly fulfilling their need for a new workforce.

It is important to note that the curriculum itself is not the problem: no matter what generation the worker comes from, he must learn how a pump displaces fluids, how a relief valve controls pressure, how a particular system controls the nuclear reaction, etc. The material currently being taught is important and should remain the same. The difference however lies in how the curriculum is presented and how the students interact with it. In order to close the learning gap and effectively teach the new breed of students, the existing curriculum must be enhanced to:

- Create a rich learning environment in which students can interact, discover and feel in control of their learning experience
- Incorporate multimedia elements to complement plain text
- Use the “Practice by Doing” earlier in the conventional training cycle

2 3D visualization & Simulation to Enhance Learning

To resolve these dilemmas, L-3 MAPPS has devised a solution that addresses all of these issues and provides for the use of “Practice by Doing” earlier in the conventional training cycle. L-3 MAPPS has coupled computer visualization technology with high-fidelity simulation to bring real-time, simulation-driven, animated physical systems allowing immersive, participatory learning in the classroom. With this innovative approach to training, L-3 MAPPS is making it possible to increase student retention rates by making the learning experience that is typically at the top of the learning pyramid much more interactive and efficient.

2.1 3D Visualization

Where full scope simulators are focused on training students in how to operate nuclear plants, the 3D visualization is designed to instruct students in components, systems and fundamental operational behavior. The visualizations are easily reconfigured to address specific learning objectives in a staged approach that build students' knowledge in a systematic manner.

While advanced plant systems knowledge is transferred most effectively with simulation-driven visualization, it is equally valuable for component level or fundamentals training. The student not only can see the physical arrangements and their operating purpose, but can look inside specific components and learn about their inner workings.

The simplest level of 3D visualization is that of basic plant components such as valves, pumps, breakers, etc. as seen in Figure 2.

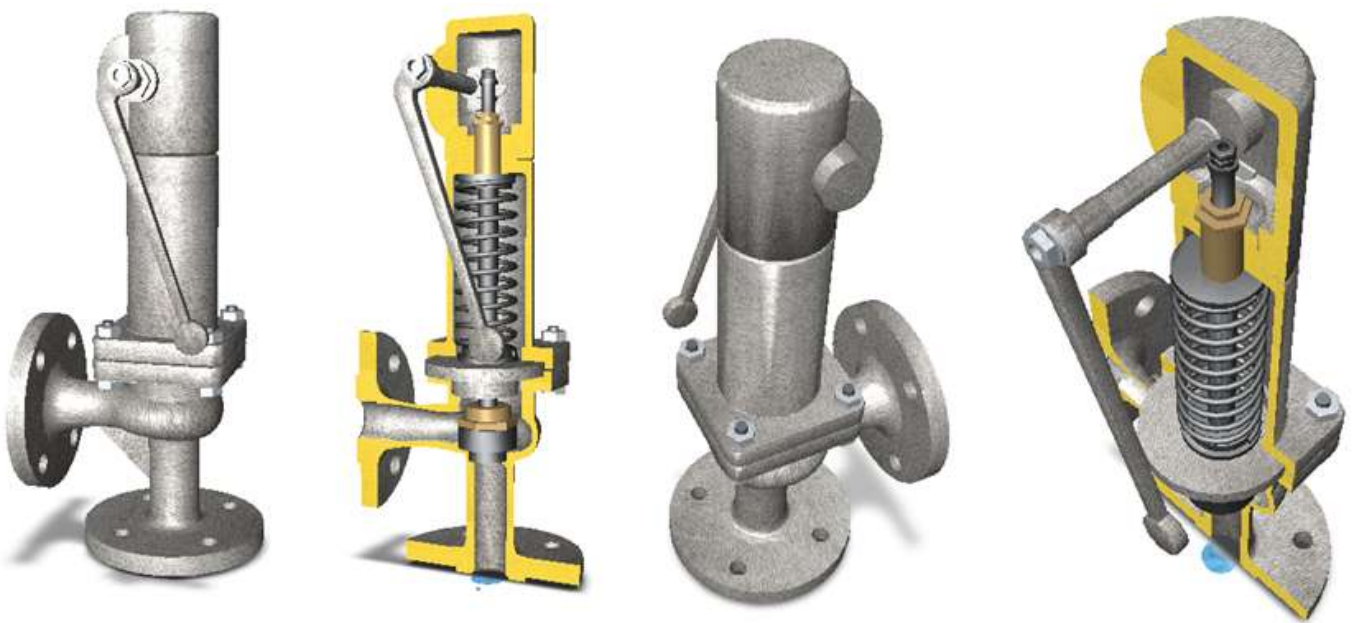
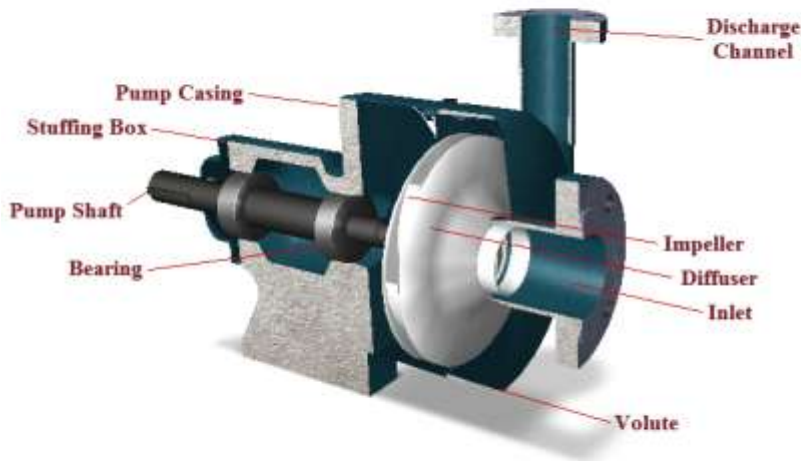


Figure 2: Various Views of a Relief Valve with 3D Visualization

The external casings can be dissolved, rotated and zoomed to display the inner workings of components (Figure 3). Not only are the components identified, but the physical operation is animated, avoiding the difficult task of trying to mentally picture equipment operation from a traditional static 2D presentation (Figure 4).

Single Stage Centrifugal Pump - Major Components



End of Animation. Press stop then play to restart sequence.



Options:

Principles of Operation

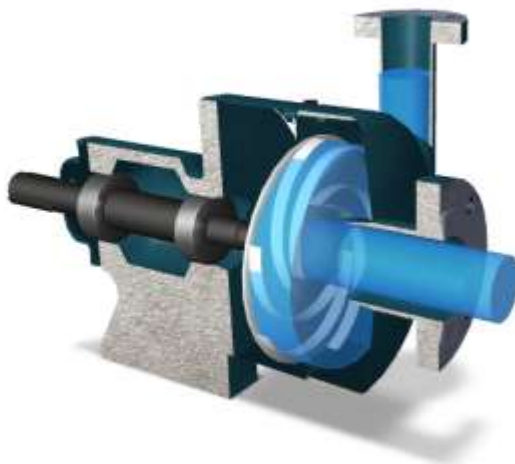
Major Components

Major Components:

- **Impeller**
 - Rotating vanes impart motion to liquid
 - Vanes rotate at high speeds
 - Vanes throw liquid outward
 - Velocity of fluid is converted to pressure
 - Designs are: open, semi-open, enclosed
 - Types are: single-suction, double-suction
- **Volute**
 - Collects liquid discharged from impeller
 - Increases flow area
 - Reduces fluid velocity
 - Converts velocity head to static head
 - Can have two, independent volutes
- **Diffuser**
 - Stationary vanes that

Figure 3: 3D Visualization of Centrifugal Pump Major Components

Single Stage Centrifugal Pump - Principles of Operation



Paused



Options:

Principles of Operation

Major Components

Principles of Operation:

- **Key Features**
 - Moves fluid from one place to another by imposing a differential pressure on the fluid which forces it to flow through a piping system to an area of lower pressure
 - Flow rate is dependent on the differential pressure or head
 - The lower the pump head, the higher the flow rate
 - Liquid being pumped serves as coolant and lubricant
 - Operating without liquid flowing can cause pump damage
 - Must be primed before started
 - Can operate continuously
- **How It Works**
 1. Pump is primed

Figure 4: 3D Visualization of Centrifugal Pump Principles of Operation

This 3D visualization differs from ordinary static images or video animations by providing control to the student, who can move, rotate or zoom the 3D model at will. The user can even

select a particular component from the 3D model and manipulate it independently. This interactivity allows the student to be empowered and immersed in the learning process.

3D can also be used to visualize major plant components and systems where relative spatial orientation and geometry or internal structure is important. Examples are the relative spatial orientation and geometry of the major NSSS components (Figure 5).

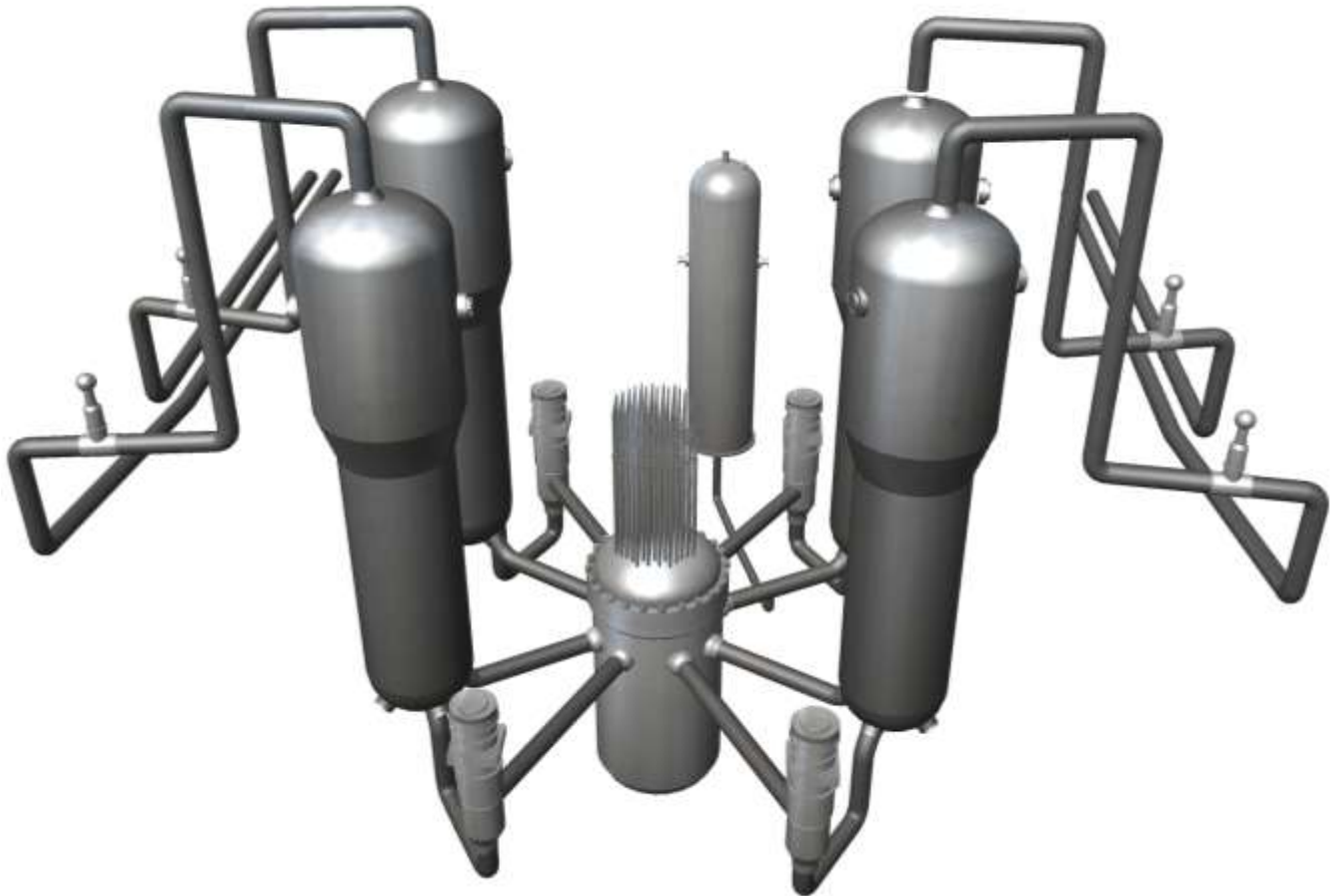


Figure 5: 3D Visualization of a 4-Loop PWR NSSS

3 3D Visualization & Simulation

After the generic fundamentals phase of the training program, students must learn about complete systems, their physical behavior and interactions with other plant systems. To do so, 3D visualization will provide an unparalleled insight into the physical layout of the system. That visualization alone won't however teach the students how the system works. To do so, the visualization must be enhanced to provide information that will depict and explain the physical behavior of the system itself.

L-3 MAPPS has close to 40 years of proven experience in nuclear power plant simulation. The high fidelity simulation models are extremely detailed calculations which provide a huge amount of information and data on plant systems. The full scope simulation is so detailed and contains so much information that it would overwhelm students with no operations or plant systems knowledge. The simulator driven data can however be used to enhance 3D visualization of plant systems, providing the information that 3D visual models alone lack.

The properties calculated by the simulation models are used to drive the dynamic elements of the 3D models, where different properties are displayed in relation to a working animated component. Physical properties such as temperature, enthalpy, pressure, etc. are displayed as color gradients within the 3D plant components themselves, allowing students to easily visualize and understand thermal-hydraulic processes (Figure 6).

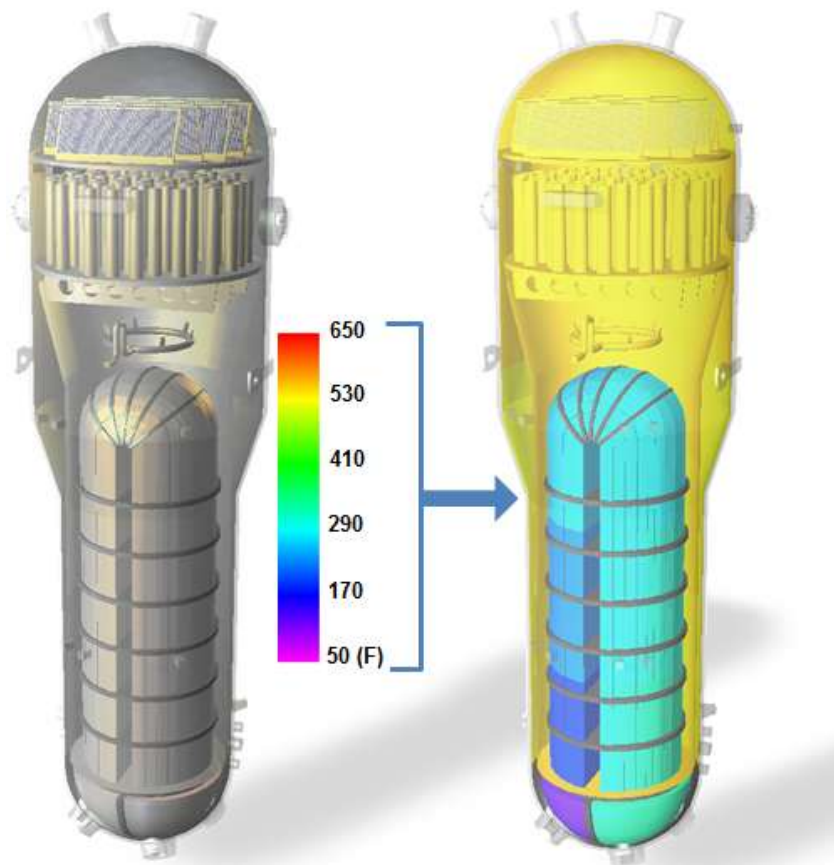


Figure 6: Color Gradients to Display Physical Properties in a Steam Generator

With this overlay of simulation data on 3D models, students can see animated, real-time physical operation versus hearing or reading a description which they would then in turn have to translate into a working model in their mind.

The simulation can actually be used in two distinct manners, depending on the course objective:

- The simulation can be used to collect data during a particular operation or transient, to be used offline with the 3D models in predefined scenarios
- The simulation can be linked in real-time to the 3D models so that any instructor or operator action is automatically and realistically reflected in the visualization

In the first case, which can be called “offline simulation” visualization, lessons can be created for important plant events. Data is collected from the high fidelity full scope simulation to ensure a realistic response. This data, in conjunction with the 3D models, is then used to run the scenario over and over again. This method would be used when no operator action is required or when the curriculum has not yet reached the system operation training. Lessons

or predefined scenarios can then be enhanced with textual descriptions and narrations of particular events of interest to reinforce the learning material and increase retention rates further. Once again, interactivity is important for student retention and with offline simulation, students can control the playback of the lesson as well as interact with the 3D models. These simple controls clearly separate the interactive and engaging lesson from a standard and rigid classroom description.

In the second case, which can be called “real-time simulation” visualization, a bridge is used to communicate the simulation data to the 3D models in real-time (and vice versa). With this bridge in place, malfunctions can be inserted and panels can be operated at will while the visualization models provide instant feedback. This method can be used in a classroom approach by combining the 3D visualization with animated 2D plant system diagrams and real-time plots to better explain complex system behavior (Figure 7).



Figure 7: 3D & 2D Combined with Simulation in a Classroom Environment

This real-time link can also be used in a classroom environment, whether using glasstop virtual panels (Figure 8) or the plant-specific full scope simulator (with its wholly reproduced control room), to provide valuable feedback to the operators being trained, particularly those in initial license training. This key concept emphasizes the importance of system knowledge in daily operations. By combining the “real-time simulation” visualization with standard operator training sessions, which currently is largely procedure-based, the operators are shown the consequences of their actions as they perform them. This allows students to combine their procedural instructions with valuable in-depth system knowledge which will enable them to better interpret and respond to information provided by the control room instrumentation.



Figure 8: 3D Visualization Used in a Glasstop Simulation Environment for Operator Training

4 Conclusion

As the nuclear power industry workforce ages and retires, a new breed of workers needs to be educated and trained. With this audience of highly different habits and needs, the existing methods and tools for teaching become less efficient and maybe even counter-productive. 3D visualization and simulation provide a modern medium that will not only fill the students' need for technology and interactivity in the classroom but also provide rich and valuable information that was hard to convey in the first place. L-3 MAPPS believes that these new tools will help the nuclear power industry to train a knowledgeable workforce more efficiently.

5 References

- [1] NEI, Congressional testimony August 31, 2010,
<http://www.nei.org/publicpolicy/congressionaltestimony/august-31-2010>

- [2] NEI, Congressional testimony August 31, 2010,
<http://www.nei.org/publicpolicy/congressionaltestimony/august-31-2010>

- [3] Canadian Nuclear Association, "Human Resource Workforce Challenges Facing the Nuclear Industry in Canada and Worldwide"

- [4] Prensky, Marc. "Digital Natives, Digital Immigrants." On the Horizon (MCB University Press), Vol. 9 No. 5, October 2001.
<http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf>

- [5] Jane Hart, "Understanding Today's Learner", Learning Solutions Magazine.
<http://www.learningsolutionsmag.com/articles/80/>

- [6] "Learning Pyramid", National Training Laboratories, Bethel, Maine

THE IMPORTANCE OF KNOWLEDGE MANAGEMENT SUSTAINING A FULL EDUCATION & TRAINING SYSTEM ALL OVER THE CAREER OF NUCLEAR ENGINEERS

CLAUDE BARBALAT, JACQUES FIGUET,
CLAUDE GUET & MARIE-FRANÇOISE DEBREUILLE

International Institute of Nuclear Energy (www.i2en.fr)

France, Paris-Saclay Campus

On behalf of the French Nuclear Industry

1 Nuclear Power in France

The French nuclear industry was born in the historical context of the 1970s, with the main goal of meeting the specific needs of the nuclear power generating programme being carried out by EDF. The industrial fabric was then developed and structured coherently for the creation of 58 nuclear reactors and the fuel cycle installations, from back end to front end. The nuclear industry thus consists of French groups of international size and a network of several hundred SMEs which have developed capacity dedicated to the operation of the facilities.

The performance of these facilities and the corresponding safety and security requirements, demand a high degree of technical expertise on the part of the companies and staff operating them.

France has developed a range of industrial and research skills to ensure the completely safe operation of these facilities and their gradual renewal, as well as to prepare for the nuclear industry of the future and the long-term management of radioactive waste.

These skills were acquired over the years, building on experience based in part on the handing down of know-how from one generation to the next.

2 New challenges and new requirements

In recent years, nuclear energy has become an option for many countries, in order to meet the challenges of energy security and climate change. More than ever, safety and sustainable development are the keys to the future development of nuclear energy.

Some countries have therefore decided to reactivate their nuclear energy programmes (USA, Finland, China, Great Britain, Russia, South Africa, etc.) or to start their own (UAE, Poland, Vietnam, etc.).

For its part, the French nuclear sector is faced with a two-fold challenge:

- ensure the replacement of staff nearing retirement age, which will concern a significant percentage of the 120,000 direct jobs in the sector by the 2020 time-frame;
- create new jobs, whether to meet its own needs or those of the export markets: France is involved in the supply of facilities and services and will see an increase in its manpower needs, owing to the growth of these activities for export, the major ten-yearly maintenance programmes to be initiated for the existing reactors, and through large-scale research projects.

It will need to find human resources in adequate numbers and with appropriate skills and ensure the transmission of the acquired know-how between generations.

3 How is France organised today

The French industrial sector is aware that any nuclear activity, whether for the production of electricity or for the back end and front end cycles, implies particular requirements in terms of education and training and it today relies on well-trained staff in sufficient numbers.

Over the decades, France has developed a specific nuclear energy training programme leading to diplomas, closely linked to the research institutes and industry, in order to take full advantage of the latest technological advances and experience feedback.

The French industrial sector is aware that there are various degrees of “nuclearisation” of the industry’s professions, and that specific know-how is necessary in order to supplement the purely academic skills.

The management of know-how and skills involves more than just handling individual expertise: the turnover of manpower must take account of the complexity of the management of nuclear knowledge. Collective competence and the safety culture, also referred to as tacit knowledge, constitute far more than the sum of the individual skills.

So that they can acquire this knowledge over the years, it is essential that the new recruits receive training in their new job through apprenticeship in the field.

The industrial firms systematically train their staff, in order to ensure that technical know-how is transferred from one generation to the next. Most of the companies employ tutoring programmes to train their staff, either in the facilities or on simulators.

4 What levels of training are required

The professions throughout the nuclear industry are characterised by a high level of qualification when compared with conventional industry: about 26% are managers, 38% are technicians and supervisors, 36% are workers.

The professions linked to the operation of nuclear facilities demand the highest level of qualification in the sector, with 34% managers, 49% technicians and 19% workers.

5 Who is concerned

The diversity of the professions needed to run a nuclear power generating programme goes further than the purely technical and scientific. In addition to research, one can differentiate between four macro-activities which each require specific skills:

- The operational part comprises the staff of the nuclear power plants and nuclear fuel cycle facilities, as well as those who design, build and maintain the facilities. These staff have primarily technical and project management expertise.
- The staff of the regulatory bodies (safety regulator, safety and radiation protection analysis and support organisation) must be doubly competent: they are tasked with checking compliance with the nuclear rules and procedures in force. They must be familiar with the regulations but also able to analyse the design and behaviour of the nuclear facilities, with extensive technical expertise in how they function.
- Fewer in number, but with a specific profile, the legal experts help draw up and ensure implementation of the body of regulations and legislation related to an activity as specific as the nuclear sector. They are neither technicians nor engineers, but they must be able to assimilate a large quantity of nuclear-related information, bearing in mind the complexity of the related technical and human contexts.
- Finally, in the light of the political and social implications, staff are needed to promote and publicly implement strategies designed to meet society’s energy needs, while guaranteeing maximum safety and information of the general public by all players in the nuclear power generating system.

It is thus clear that management of know-how in the nuclear field is in itself a highly complex system: a large number of extremely varied skills, the transverse nature of the skills, knowledge and know-how, attitudes and approaches, as well as transmission through

training and tutoring are all parameters on the basis of which the skills that have to be transmitted can be analytically and exhaustively classified.

Overall, safety depends on the correct working of each of the macro-categories and their ability to function together. This is why knowledge management is particularly strategic. In the name of safety, knowledge management requires significant investment (human and financial) which must be taken into account at the highest level of government, regardless of the country concerned.

6 Coordination between supply and demand

As retirement approaches for a large number of the staff hired when the vast nuclear power generating equipment programme was launched, the authorities have become aware of the risk of the loss of skills and the need to ensure that the skills of job-seekers are in line with the demands of industry, while increasing the supply of academic training. To do this, a Nuclear Energy Training Council (CFEN) was set up in 2008 and was tasked with coordinating the industrial and academic players, with the particular duties of:

- optimising the new training programmes and evaluating any overlaps or gaps,
- giving an opinion prior to accreditation of the new training curricula by the Ministry for Higher Education,
- promoting new sectors appropriate to the needs of industry.

The CFEN consists of members from various backgrounds, government, academia, industry, research institutes, etc. It led in 2011 to the creation of the International Institute of Nuclear energy (I2EN) which provides operational support.

Close cooperation with these players, under the supervision of the ministries, led to the creation of new teaching programmes which, after three years, has nearly tripled the annual number of engineering and master's graduates.

In 2011, a strategic committee for the nuclear sector (CSFN) was created, bringing together all the nuclear players, with significant participation by industry, one of its roles being to promote the nuclear professions and perform a qualitative and quantitative check that the existing training courses are compatible with the needs of industry and research organisations for the next 5 to 10 years.

7 Academic training

These training courses cover all the disciplines of use to and necessary for the experts – engineers, technicians and senior technicians – but also to the trainers who, through the expertise they have acquired after training – will contribute to the start-up and long-term operation of the future facilities.

At present, just over twenty French schools and universities provide nuclear training at Master's level or higher, covering a broad range of specialities. Most of these courses enable the students to enter the future management employment market with a broad and detailed view of the nuclear energy field and with know-how that is not only technical, but also economic, organisational and managerial. Some classes are given in English and are therefore open to non-French speaking students, in particular as part of the international exchange programmes. Every year over 1,100 students complete a Master's degree in nuclear energy. Around a fifth of these students come from abroad.

In this respect, two courses devoted in particular to the nuclear programmes should be mentioned:

- The 2-year Master of Nuclear Energy (MNE), taught entirely in English, is open to French and foreign students from around the world. It trains about a hundred students a year and enjoys support from industrial firms in the sector, particularly EDF. The basic disciplines are covered in the first year (nuclear physics, fluid mechanics, heat transfer, materials science, process engineering and chemistry of reactive media, electrotechnical aspects,

mechanics) along with energy savings and project management. The second year proposes a common curriculum and 5 majors: reactor physics and engineering, nuclear reactor design, functioning and operation of nuclear reactors, fuel cycle (engineering or radiochemistry) decommissioning and waste management. Each of these majors is supported by one or more establishments in the consortium.

- Either alone or jointly with universities and engineering schools, the INSTN provides diploma level training in technological fields opening up career prospects in research or industry. This institute for instance issues diplomas such as the engineering diploma with atomic engineering (GA) specialisation, Master's degrees, professional diplomas in the fields of decommissioning, waste, pollution clean-up and industrial risks, and radiation protection degrees for technicians and senior technicians.

The disciplines taught have been adjusted over the years to meet the needs of the engineers and technicians working in CEA's design centres, design and construction companies using nuclear technologies, teams of analysts and experts supporting the nuclear safety regulators and operating engineers for the French NPPs in operation.

The training which is given primarily through long-duration courses leading to diplomas (Atomic engineering, Master's, PhD), can also take the form of specialist, short-duration, complementary courses, either chosen from a catalogue or tailored to the particular student (study sessions) and they are accessible, either in full or in part, to employees undergoing continuing vocational training.

8 Professional training

The nuclear sector industrial firms in France have set up in-house training structures enabling them to meet the specific training needs of their professions, sometimes on a very large scale. The main industrial players offer the following courses:

- EDF: Since its nuclear programmes started, EDF has developed a complete professional training organisation, in particular for the operators, who receive both initial qualifying training and periodic refresher or advanced training courses. EDF thus dispenses about 2.4 million hours of training every year, with more than 850 courses in its catalogue of reactor processes, operation and maintenance: these classes are given by a team of 870 instructors. Some of this training is given in English. EDF brings to bear its training experience, acquired on its 58 reactors in operation, on new nuclear development projects in France and abroad. The cost of this training represents ~10% of the total labour cost for the nuclear sector. EDF also took part in creating international Master's degrees and has developed strategic partnerships with various selected universities and engineering schools.
- Areva: In addition to the training courses intended for its staff, Areva proposes training solutions to support the projects of its customers and partners both in France and internationally, based on the experience and know-how developed by the group, in particular for its in-house needs. The range of training courses is dispensed by the international network of training centres and comprises more than 1000 courses given by more than a hundred expert trainers. The range of teaching resources is also particularly vast: classroom teaching, E-Learning, simulator training, study trips with visits to sites, internships, etc. Areva also has the ability to set up and manage "turnkey" training centres. This offering is made available to all its partners and shareholders: government authorities, nuclear industrial firms, customers and suppliers of Areva, electrical utilities, fuel cycle operators. The proposed courses cover all the phases of a nuclear project: from project management to the maintenance and decommissioning of nuclear facilities.
- The Cetic is a technical centre which designs and validates techniques for working on PWR nuclear steam supply systems. This centre, unique in France, was set up by EDF and Areva. It reproduces the access and working conditions for the main components of a pressurised water reactor (PWR) and is the platform on which EDF carries out its fuel handling training.

- The Burgundy Nuclear Partnership (*Pôle Nucléaire Bourgogne* - PNB) set up in 2009, launched the “International Nuclear Academy” (INA) to offer training programmes, refresher courses and retraining for the staff of companies working in the nuclear sector. The INA is a public-private partnership. Alongside the PNB, the partnership includes institutional and university organisations, representatives of public service companies, as well as local firms. INA offers a broad range of training programmes, short seminars and a summer workshop.
- Other certified training organisations, such as *Bureau Véritas* or *Techman Industrie*, provide a wide range of training intended for the nuclear professions, in the form of inter-company training services for the employees, with customised content, classroom teaching or e-learning, personalised educational resources and practical work.
- The INSTN provides continuing vocational education in a variety of forms:
 - inter-companies training, consisting of nearly 200 courses, which in particular meet the need for refresher or skills development training;
 - help with the creation or construction of a training programme;
 - the design and provision of “customised” training within a company, in French or in English;
 - the organisation of international actions within a variety of frameworks: European ENEN association, European projects, requests by the public authorities, support for industrial firms in the nuclear sector, bilateral collaboration engaged by CEA, IAEA (International Atomic Energy Agency) technical cooperation programmes.

9 International services

France has clearly stated its desire to help countries wishing to start a civil nuclear programme, to create the institutional, human and technical conditions such as to provide all guarantees of safety, security, non-proliferation and environmental protection.

Skills development is one of the very first challenges to be met by the new nuclear states. In this respect, France offers foreign nationals the opportunity to take high-level initial training, whether through curricula in French for French-speaking students in universities and higher education establishments, or through specific Master’s programmes taught in English.

Specific professional training programmes are also accessible, in French and English. New and personalised programmes can be created, either through bilateral relations, or through international partnerships (IAEA or ENEN for example).

Higher education classes focusing on nuclear matters are also taught abroad. This approach is a means of reinforcing the relations between France and the partner country, as well as of enhancing the outreach of French culture and know-how.

Together with the France International Nuclear Agency, I2EN is the lynchpin of this strategy and the training portal for countries looking to build a civil nuclear electricity production capacity.

Built around the partnership created by all the French training players, universities and schools, the leading research organisations and industry, the institute is able to provide the best answer to the requests it receives, calling on a variety of players as and when necessary, to ensure that the teaching given is consistent and coherent.

Below are examples of the solutions already implemented and liable to be reused:

9.1 Train the trainers

This is a training programme for about twenty teachers, run between France and Poland, in preparation for its industrial nuclear programme.

During the first phase, in 2009, Polish scientists took part in a “tour de France” of the French nuclear sector, visiting the most significant French industrial sites and laboratories, over a 6-week period. Training specialists from research and industry – from mining to waste management, from the design to the decommissioning of facilities – discussed technical questions with them, as well as the issues of public acceptance (relations with the citizens,

the public and the local residents around the facilities). During the second phase, in late 2010, the Polish scientists received an intense 12-week training course at the National Institute for Nuclear Science and Technology in Saclay. The most fundamental aspects of nuclear science were covered, along with radiation protection, security and safety, operation and waste management. The trainees had access to plant operation simulators. In the last quarter of 2011, and then during 2012, all the Polish lecturer-researchers were offered internships by CEA in Saclay, Cadarache and Marcoule, Areva at La Défense, EDF in Lyon, Andra in Chatenay-Malabry and the CNRS in Orsay, while some of them went to the sites of the industrial partners abroad.

To facilitate the training, I2EN contacted the research organisations and companies and, with them, identified the most pertinent study subjects. The institute intervened under a contract signed between the France International Nuclear Agency (AFNI) and the nuclear energy department of the Polish Ministry for the Economy.

9.2 Reception of foreign students under bilateral agreements

Within the framework of bilateral agreements applicable to its establishments, and more particularly its international Master's courses given in English, France is able to welcome a predetermined number of students from clearly identified sectors in the country. I2EN takes part in setting up the agreement, selecting the candidates, looking for co-financing and helping the students get settled and deal with the various formalities.

9.3 Organisation of seminars

As part of the collaboration between the Czech Republic and France, I2EN and the Cenec organized a seminar in May 2012 on the topic of nuclear safety.

Designed to foster collaboration between students and young French and Czech researchers, the seminar was held near Prague with 16 participants, students at Master's or doctoral level, post-doctoral researchers, or full-time employees in the early stages of a career in the nuclear field.

The sessions were devoted to presentations by experts (ASN, EDF, I2EN and their Czech counterparts) on the methods of analysing accident scenarios, the role of barriers and the management of a nuclear accident. With regard to the Fukushima accident, the role of the protection barriers was examined, as were the resulting safety steps taken in Europe's nuclear power plants. Visits to facilities have been organized, as well as workshops to examine case studies and debates, plus presentations by the participants concerning their work and their activities.

9.4 Contribution to new training in the host country

Backed by its expertise, I2EN is able to help define and set up new training programmes (definition of curricula and syllabuses) in a partner country. On a case by case basis, I2EN can examine the possibility of provisionally sending out French teachers as backup, or even better, offer a targeted, accelerated course for scientists identified by this country to eventually take over this teaching. For these scientists, this assistance may take the form of a search for the most appropriate French laboratory providing this type of teaching and enabling them – through research work – to enhance their expertise in the field they will be teaching.

In a related field, I2EN can also help define and set up experimentation laboratories, enabling the intended teachers to be immersed in a research environment, through theses and work carried out, as necessary, in cooperation with French organisations.

9.5 Help to define curricula, and facilitate the choice of the best curriculum

I2EN has produced the first edition of its French energy training course database. For 2012, this base contains the description of 54 Master's or equivalent degrees and 82 data sheets, corresponding to the different training options. This base enables I2EN and its partners to gain a complete view of the possibilities available, in order to define the best solutions in response to the requirements expressed by foreign countries.

Each sheet contains information about the training organisations, the number of students, their nationality and what they went on to do subsequently, as well as the content and the precise nature of the teaching, level, intensity, structure and volume per topic (33 topics selected), classwork/practical work/tutorials, internal or external origin of teachers. For the time being, the base mainly contains the Master's degree and engineering diploma courses. It will subsequently be supplemented with the other levels, from baccalaureate up to doctorate.

10 Conclusion

France is well-positioned as a key player in the nuclear field. It can at present justifiably claim lengthy experience and a commitment to education and training. It is ready to share its experience with countries seeking to develop a nuclear project within the framework of the safe and sustainable development of nuclear energy.

The I2EN, which brings together the French players involved in nuclear training, is one of the access portals for training assistance requests. Through its own expertise and the extent and high level of its network of partners, the I2EN is able to define the best targeted solutions for the needs expressed by its partner countries. To do this, it can call on its extensive experience in this field.

LINKING EMPOWERING LEADERSHIP TO SAFETY PARTICIPATION IN NUCLEAR POWER PLANTS: A STRUCTURAL EQUATION MODEL

Mario Martínez-Córcoles, Francisco Gracia, Inés Tomás, José M. Peiró

Research Institute on Personnel Psychology, Organizational Development, and Quality of Working Life (IDOCAL), University of Valencia, Spain

Markus Schöbel

Center for Economic Psychology, University of Basel, Switzerland

ABSTRACT

Safety participation is of paramount importance in guaranteeing the safe running of nuclear power plants. The present study examined the effects of empowering leadership on safety participation. Based on a sample of 495 employees from two Spanish nuclear power plants, structural equation modeling showed that empowering leadership has a significant relationship with safety participation, which is mediated by collaborative team learning. In addition, the results revealed that the relationship between empowering leadership and collaborative learning is partially mediated by the promotion of dialogue and open communication.

1. Introduction

Motivating organizational members to participate in safety systems and initiatives is a major concern in High Reliability Organizations (HROs). Although these complex technological systems are highly standardized in terms of safety rules and procedures, safety participation is of prime importance, since it makes it possible to identify and detect dysfunctionalities in system behavior that are not anticipated by the system design. Thus, compliance with safety rules and procedures provides reliability, whereas safety participation improves the capacity for safe conduct under less predictable circumstances (Zohar, 2008).

The academic literature provides few answers about how to strengthen employees' safety participation in high reliability environments, roughly linking the impact of leadership and safety climate on safety participation (e.g. Simard and Marchand, 1995). The present study explores how managers can specifically influence participative safety behavior in nuclear power plants. The assumption is that empowering leadership will improve safety participation, but its impact will be mediated by collaborative team learning. In order to strengthen collaborative learning, empowering leaders should also promote dialogue and open communication. In the following sections we introduce our research constructs and develop our hypotheses.

1.1. Safety participation

In the last 12 years, safety research differentiates between two types of safety performance behaviors in High Reliability Organizations: Safety compliance and safety participation. *Safety compliance* refers to work activities that individuals need to perform in order to establish workplace safety. These behaviors include adhering to standard work procedures and wearing personal protective equipment. *Safety participation* describes behavior that does not directly contribute to an individual's personal safety, but that helps to develop a safe work environment. It includes activities such as participating in voluntary safety tasks, helping coworkers with safety-related issues or attending safety meetings. Whereas safety compliance describes work activities that contribute to an organization's primary task and are prescribed by formal job descriptions, safety participation describes voluntary activities that contribute to strengthening safety in the organization.

Empirical safety research has identified several factors as principal antecedents of safety participation such as safety climate or safety knowledge. However, leadership has been identified as the most influential one for safety performance, at least in high reliability organizations such as offshore plants, aviation, or chemical industries (Mearns et al., 2003; Flin and Burns, 2004). Within the nuclear field, research about leadership and its relationship to safety performance is rare. Kivimaki et al. (1995) found that participative management (communicating and giving feedback to subordinates) was positively associated with safety performance. According to Flin and Yule (2004), some leadership techniques, such as stimulating certain styles, considering them individually and rewarding them, were found to foster leaders' impact on workers' safety behaviors. In a nuclear power plant, Martínez-Córcoles et al., (2011) conducted a study that assessed the impact of an empowering leadership (EL) style on the perceived safety behavior of employees. Focusing on individual leadership, they found that leaders' empowering behaviors (i.e. leading by example, participative decision making, interacting with employees, etc.) enhanced perceived safety behaviors through their influence on safety climate. Moreover, these authors showed that empowering leaders positively influence employees' safety climate in both strong and weak safety cultures. However, the effect of this relationship was different depending on the strength of the safety culture. Surprisingly, a positive relationship was greater in weak safety culture conditions. However, better safety results were obtained when empowering leadership was embedded in a strong safety culture.

1.2. Empowering leadership

In line with the aforementioned study, we want to examine the impact of an empowering leadership (EL) style on safety participation. The empowering leadership model developed by Arnold et al. (2000) claims that the main function of a leader is to increase the team's potential for self-management. They distinguish five dimensions corresponding to different behaviors that empowering leaders should show. "Leading by example" refers to a set of behaviors that demonstrate the leader's commitment to his or her own work and to the work of his or her team members. The leader serves as a role model and stands up for what he/she thinks is the right way to perform the job. "Participative decision making" refers to the leader's use of members' inputs in decision-making. The leader's behavioral repertoire may range from delegating decisions to his team members to encouraging them to express their ideas and opinions. Tjosvold (1990) found that members of a flight crew performed more effectively in risky situations when team members were motivated by their leaders to contribute to team performance with their ideas. "Coaching", another relevant dimension, involves the ability of leaders to encourage their team members to solve problems in a self-managed way, thereby providing members with opportunities to share and increase their knowledge. Yule et al., (2007) found that as team knowledge

increases, the propensity to engage in risk-taking behaviors decreases. The fourth dimension is “informing”, which refers to the dissemination of information by leaders about the organization’s mission, philosophy or other important information. Finally, “showing concern/interacting with employees” focuses on behaviors such as taking time to discuss members’ concerns or showing concern for their welfare. Katsva and Condrey (2005) highlight individual treatment and feedback as crucial in obtaining good safety outcomes in nuclear power plants. Although the EL style (by Arnold et al., 2000) was originally composed of five different dimensions, other dimensional structures have been studied due to the high correlations detected by these authors among the five dimensions. For instance, a one-dimensional model which encompasses the five dimensions was recently chosen as the best dimensional model, using an adapted scale within the nuclear field (Martínez-Córcoles et al., 2011).

The EL model embraces leadership behaviors that might be especially relevant for nuclear power plants. It not only encompasses task-focused behaviors such as facilitating the understanding of task requirements and motivating task compliance (Burke et al., 2006). Moreover it integrates person-focused behavior (e.g., showing concern/interacting with employees) which facilitates behavioral interactions and, therefore, should motivate team members to contribute to (informal) safety discussions and (formal) safety systems. Although enforcing compliance with rules and procedures is an important function of leaders in establishing safety system in nuclear power plants, person-focused leadership behavior has the potential to enhance employees’ safety performance by going beyond mere compliance with safety standards (e.g., by reporting near-misses or minor events). Since nuclear power plants are highly standardized work settings, safety participation helps to shed light on inconsistent rules and procedures or deviations from specified technical operations.

The purpose of this study is to extend this line of research by analyzing the role of empowering leadership (Arnold et al., 2000) in safety participation and identifying the potential mechanisms and processes that may lead to improving safety participation behavior. In contrast to existing studies on safety participation, which have predominantly been conducted in industrial domains where personal safety is at stake, our study is located in a work setting (nuclear power plants) where safety participation behaviors have hardly been studied. In these kinds of organizations, safety participation is embedded in a systemic organizational approach (i.e. safety management system) that mainly aims to optimize process safety. Due to the complex nature of safety in these systems, identifying, being aware of, and reporting dysfunctions in plant behavior are extremely important practices. Moreover, safety participation challenges the safety routinization that results from high levels of standardization in terms of rules and procedures, but produces the risk of not paying enough attention to critical and unanticipated safety issues (Frischknecht, 2005).

In order to better understand the leadership-safety participation link, we assume that several factors have to be in place and developed. In the following sections, the paths through which EL may positively influence employees’ safety participation are considered, and corresponding hypotheses are stated. We assume that safety participation is strongly embedded in a team learning context where team members collaboratively learn from each other. Thus, enhancing team learning is a privileged way for leaders to promote participative safety behaviors.

1.3. Leadership, collaborative learning and safety participation

As stated above, the EL model aims to increase teams’ self-management skills. Empowering leaders foster group processes that facilitate the exchange of information among team members and the development of team knowledge. According to Srivastava et al. (2006), empowering leaders have the potential to enhance knowledge

sharing in groups by giving team members autonomy. Whereas autocratic leadership mainly initiates instructed learning¹ processes (with less autonomy) in teams (Yukl, 2002), empowering leadership provides conditions that allow for collaborative learning processes among team members. According to Tomasello et al. (1993), collaborative learning involves the transmission and co-construction of knowledge². It takes place when symmetrical (i.e. neither team member is seen as the only authority) and reciprocity-based interactions are established. Moreover, team members have to accept responsibility for group actions, such as the management of work methods, peer process monitoring and the assignment of group members to work tasks (Panitz, 1997). The most important outcome of collaborative team learning is the development of shared or co-constructed knowledge.

With regard to safety research, Griffin and Neal (2000) showed that safety knowledge is a mediator between safety climate and safety performance. In their study, safety knowledge predicts safety compliance and safety participation, with a stronger empirical relationship between safety knowledge and safety participation. Similarly, the recent meta-analysis by Christian et al. (2009) on the antecedents of safety performance highlights safety knowledge as a potential direct antecedent of safety compliance ($M_p = .60$) and safety participation ($M_p = .61$). Both studies lead to the conclusion that teams' collaboratively-developed safety knowledge (neither study specifies the context in which safety knowledge is developed) is an antecedent of safety participation.

Therefore, empowering leadership should be positively associated with safety participation behaviors through collaborative learning interactions among the team members:

Hypothesis 1: Collaborative learning will mediate the relation between empowering leadership and employees' safety participation.

1.4. Leadership, dialogue and open communication, and collaborative learning

The EL model provides a broad range of behavioral actions that have the potential to promote collaborative team learning. For instance, empowering leaders coach team members to solve problems in a self-managed way, or they show commitment to their work. Therefore, our first hypothesis states that empowering leadership has a direct influence on collaborative team learning. However, we assume that empowering leadership also exhibits an indirect influence on collaborative learning. Some dimensions of the EL model, such as encouraging team members to contribute their opinions or displaying a participative decision-making style, clearly involve communication between the leader and team members. In order to facilitate collaborative team learning about safety, empowering leaders must communicate openly and honestly about safety topics and motivate their team members to do the same. The promotion of dialogue and open communication is extremely relevant in safety performance settings in terms of: (1) reporting problems or deficiencies in one's own performance or other team members' performance; (2) recognizing one's own lack of knowledge about different topics or about how some tasks must be done; (3) favoring the exchange of different opinions and points of view that can lead to better

¹ Instructed learning refers to the learning process in which learners internalize the instructions of the teacher and subsequently use them to self-regulate their own attentional or other cognitive functions (Tomasello et al., 1993).

² Co-construction of knowledge refers to the process in which an individual adds knowledge to the knowledge which has been previously developed by others.

team coordination; and (4) avoiding group thinking (Bresó et al., 2008). From this perspective, empowering leaders indirectly contribute to creating a collaborative learning environment within a team through the promotion of dialogue and open communication. For this reason, our second hypothesis reads as follows:

Hypothesis 2. Dialogue promotion and open communication will partially mediate the relation between leadership and collaborative learning.

2. Method

2.1. Participants and Procedure

Our sample was composed of 495 workers from two nuclear power plants. The total size for both organizations was 760 employees. Data were collected in March 2011. A response rate of 65.1% was obtained. All responsibility levels and functional areas in the nuclear facility were included. Responsibility levels included the nuclear plants general manager, department managers (operation, maintenance, technical support, and radiological and environmental protection), supervisors from each unit within departments (for example, maintenance department is composed by mechanic maintenance unit, electric maintenance unit, etc.). Anonymity and confidentiality were guaranteed. The questionnaire was administered in the workplace as part of a set of questionnaires designed to evaluate safety culture.

2.2. Measures

Empowering leadership. An adaptation of the “Empowering Leadership Questionnaire (ELQ)” (Arnold et al., 2000) was used. Internal consistency reliability for the scale was .98. The scale contained a total of 17 items, after omitting some items from the original scale due to time constraints (the original scale contains 38 Items). A 5-point Likert response scale ranging from 1 (*never*) to 5 (*always*) was used.

Dialogue promotion and open communication. We used 5 items with a 5- point Likert response scale ranging from 1 (Never or almost never) to 5 (Always or almost always). Items were extracted from the original scale by Bresó et al. (2008). Internal consistency reliability for the present scale was .87.

Collaborative team learning. To measure collaborative team learning 4 items were used. These items were extracted from the original scale by Bresó et al. (2008). Internal consistency reliability for this scale was .83.

Safety participation. We used the original safety participation scale by Neal and Griffin (2006). The scale consisted of three items, with a 5-point Likert response scale ranging from 1 (*Completely disagree*) to 5 (*Completely agree*). Internal consistency reliability for the safety participation scale was .86.

2.3. Analyses

The first step in the data analysis was to test the factorial structure of the scales used in our sample in order to obtain evidence of their validity. For this purpose, we performed confirmatory factor analyses (CFA) using LISREL 8.8 (Jöreskog and Sörbom, 2006). Robust Maximum Likelihood (ML) was used to estimate model parameters (as the large number of items involved and the sample size impeded the use of weighted least square estimation), and both the polychoric correlations matrix and the asymptotic covariances matrix were used as input for the analyses, considering the ordinal nature of the variables.

In order to assess the fit of the models, we examined the RMSEA (root mean square error of approximation), CFI (comparative fit index), and NNFI (non-normed fit

index). The interpretation of these indexes is as follows: RMSEA $<.08$ = acceptable model (Browne and Kudeck, 1993; Browne and Du Toit, 1992); CFI $>.90$ = acceptable model, and $>.95$ = excellent model (Marsh et al., 2005); NNFI $>.90$ = acceptable model, and $>.95$ = excellent model (Marsh et al., 2005). In order to test differences between models and decide which one presents a better fit, a modeling rationale was considered. Some criteria have been proposed in the literature to interpret differences in practical fit indices based on modeling rationale criteria. Thus, for example, differences not larger than 0.01 between NNFI and CFI values (Δ NNFI and Δ CFI) are considered an indication of negligible practical differences (Cheung and Rensvold, 2002; Widaman, 1985). Chen (2007) suggests that when the RMSEA increases by less than .015, one can also claim support for the more constrained (parsimonious) model.

Finally, with the purpose of providing support for our hypotheses, we executed a structural equation model (SEM) with observed variables by using LISREL 8.8. As we were introducing continuous variables, we used maximum likelihood methods (ML) to estimate the model parameters. All the variables assumed a normal distribution; thus, we used a Pearson correlation matrix as input for the analysis. We also employed the RMSEA, CFI and NNFI indexes to determine the fit for the model. The interpretation of the goodness of fit indexes was the same as in the confirmatory factor analysis.

3. Results

3.1. Confirmatory factor analyses

Two Confirmatory Factor Analyses (CFA) were performed: A four-factor model (one for each scale) and a single-factor model (associated with all the items on the four scales). The four-factor model provided an excellent fit ($\chi^2 = 1335.671$, $df = 371$, $p < .01$; RMSEA = .076; CFI = .985; NNFI = .984), and all the estimated parameters were statistically significant ($p < .05$). Results indicated that each item saturated in its corresponding scale. However, the single-factor model did not show such a good fit ($\chi^2 = 3773.049$, $df = 377$, $p < .01$; RMSEA = .141; CFI = .949; NNFI = .945). Results showed that a single-factor model did not explain our data as well as the predicted model (four factors), in which our variables were considered different constructs. All the goodness of fit indexes are satisfactory for the four-factor model, whereas the single factor model shows a poor fit to data (cut-off values in RMSEA are not reached). Moreover, the incremental fit indices indicated significant differences between the two tested models on the NNFI and CFI indexes. In sum, the four-factor model was chosen as the best model.

3.2. Structural equation model

The structural equation analysis performed to test the proposed hypotheses revealed an excellent fit ($\chi^2 = 4.542$, $df = 2$, $p < .01$; RMSEA = .053; CFI = .996; NNFI = .989). All the estimated parameters were statistically significant ($p < .01$) and showed the expected sign, supporting our hypotheses. Paths between variables and standardized parameters are presented in Figure 1.

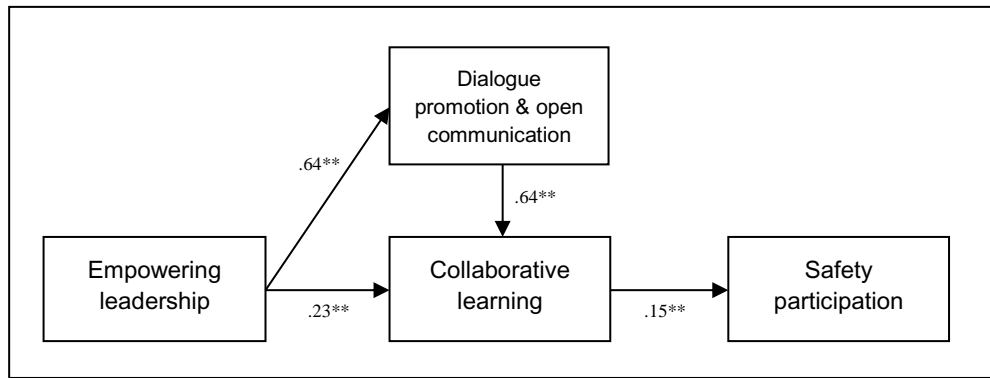


Figure 1. Paths between variables and standardized parameters. ** $p < .01$.

Results indicated that the two tested hypotheses were clearly confirmed. Collaborative learning turned out to be a mediator in the relationship between leadership and employees' safety participation (Hypothesis 1), and dialogue promotion and open communication partially mediated the influence of leadership on collaborative learning (Hypothesis 2). In other words, collaborative learning is the path through which empowering leaders heighten employees' safety participation behaviors. At the same time, the impact of leadership on collaborative learning is enhanced by an atmosphere of open communication promoted by empowering leaders.

4. Conclusion

In light of our empirical findings, we can conclude that empowering leadership is an important lever to promote safety participation when leaders succeed in strengthening collaborative team learning. In other words, when leaders show empowering behaviors, they facilitate collaborative learning processes which result in increased safety participation (Hypothesis 1). We also tested the way empowering leaders might indirectly contribute to creating a collaborative learning environment. We obtained support for our second hypothesis, which stated that open and honest communication partially mediates the relationship between empowering leadership and collaborative learning (Hypothesis 2). Thus, empowering leaders promote collaborative learning not only directly, but also by encouraging dialogue and open communication in their teams.

4.1. Impact on nuclear industry

Nuclear power plants are hazardous environments where irregularities can have devastating effects. Besides establishing safety through technical systems and barriers, a lot of interventions and approaches have been developed to optimize the human factor in these systems. One important factor is leadership, which is generally assumed to have the potential to influence the safety performance of organizational members. Although this implication is stressed in a lot of nuclear industry publications (e.g. INSAG-4, 1991; INSAG-15, 2002; SCART-Guidelines 2007, 2008), the ways managers should behave in order to optimize the safety performance of their subordinates are relatively vague. The present study examined an empowering leadership style and its impact on safety participation. It becomes evident that (1) empowering leadership promotes collaborative learning, which in turn enhances safety participation; and (2) the promotion of dialogue and open communication is another important way to strengthen collaborative learning. Therefore, safety participation is an important way to tackle unexpected system behavior, which has the potential to strengthen an organization's resilience. Moreover, safety participation complements the popular rule compliance approach, as it can help to detect possible rule inconsistencies or misunderstood procedures and make workers aware of critical safety information

and issues. In addition to safety systems and initiatives in nuclear power plants, an important pre-condition is for organizational members to collaborate on safety issues and develop and co-construct their safety knowledge, thus enhancing their motivation to participate. And leaders can have a positive impact on this process.

5. References

- Arnold, J.A., Arad, S., Rhoades, J.A. & Drasgow, F. (2000). The empowering leadership questionnaire: the construction and validation of a new scale for measuring leader behaviors. *Journal of Organizational Behavior*, 21, 249–269.
- Bresó, I., Gracia, F.J., Latorre, F. & Peiró, J.M. (2008). Development and validation of The Team Learning Questionnaire. *Comportamento Organizacional e Gestao*, 14 (2), 145-160.
- Browne, M.W. & Cudeck, R. (1993). Alternative ways of assessing model fit. In: Bollen K.A., Long J.S., (Eds), *Testing structural equation models*. Newbury Park, CA: Sage, pp. 136–162.
- Browne, M.W. & Du Toit, S.H.C. (1992). Automated fitting of nonstandard models. *Multivariate Behavioral Research*, 27, 269-300.
- Burke, C.S., Stagl, K.C., Klein, C., Goodwin, G.F., Salas, E. & Halpin, S.M. (2006). What type of leadership behaviors are functional in teams? A meta-analysis. *The Leadership Quarterly* 17, 288-307.
- Chen, F.F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modelling* 14, 464–504.
- Cheung, G.W. & Rensvold, R.B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modelling* 9, 233–255.
- Christian, M.S., Bradley, J.C., Wallace, J.C. & Burke, M.J. (2009). Workplace Safety: A Meta-Analysis of the Roles of Person and Situation Factors. *Journal of Applied Psychology*, 94 (5), 1103-1127.
- Flin, R. & Yule, S. (2004). Leadership for safety: industrial experience. *Qual Saf Health Care* 13 (Suppl. II), 45–51.
- Flin, R. & Burns, C. (2004). The role of trust in safety management. *Human Factors and Aerospace Safety*, 4, 275-288.
- Frischknecht, A. (2005). A changing world: Challenges to nuclear operators and regulators. In: Itoigawa, N., Wilpert, B., Fahlbruch, B., (Eds.), *Emerging Demands for the Safety of Nuclear Power Operations*, pp.5-15. CRC Press LLC, Florida.
- Griffin, M.A. & Neal, A. (2000). Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation. *Journal of Occupational Health Psychology*, 5, 347–358.
- International Nuclear Safety Advisory Group, *Safety Culture*, Safety Series No. 75-INSAG-4, IAEA, Vienna, Austria, 1991.
- International Nuclear Safety Advisory Group, *Safety Culture*, INSAG-15, IAEA, Vienna, Austria, 2002.
- International Atomic Energy Agency (2007). *SCART Guidelines: Reference report for IAEA Safety Culture Assessment Review Team*. IAEA Service Series No. Vienna: IAEA.
- International Atomic Energy Agency (2008). *SCART Guidelines: Reference report for IAEA Safety Culture Assessment Review Team*. IAEA Service Series No. 16. Vienna: IAEA.
- Jöreskog, K.G. & Sörbom, D. (2006). *LISREL 8.80 for Windows [Computer Software]*. Lincolnwood, IL: Scientific Software International, Inc.
- Katsva, M. & Condrey, S.E. (2005). Motivating Personnel at Russian nuclear power plants: a case-study of motivation theory application. *Public Personnel Management*, 34 (4), 343–356.

- Kivimaki, M., Kalimo, R. & Salminen, S. (1995). Perceived nuclear risk, commitment and appraisals of management: a study of nuclear power plant personnel. *Risk Analysis*, 15 (3), 391–395.
- Marsh, H.W., Hau, K.T. & Grayson, D. (2005). Goodness of fit in structural equation models. In: A. Maydeu-Olivares and J.J. McArdle (Eds.), *Contemporary Psychometrics: A Festschrift for Roderick P. McDonald*. Mahwah, NJ: Lawrence Erlbaum Associates, pp. 225-340.
- Martínez-Córcoles, M., Gracia, F., Tomás, I. & Peiró, J.M. (2011). Leadership and employees' safety behaviors in a nuclear power plant: A structural equation model. *Safety Science*, 49, 1118-1129.
- Mearns, K., Whitaker, S. & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science* 41, 641-680.
- Neal, A. & Griffin, M.A., (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and groups levels. *Journal of Applied Psychology* 91 (4), 946–953.
- Panitz, T. (1997). Collaborative Versus Cooperative Learning: Comparing the Two Definitions Helps Understand the nature of Interactive learning. *Cooperative Learning and College Teaching*, 8 (2).
- Simard, M. & Marchand, A. (1995). A multilevel analysis of organisational factors related to the taking of safety initiatives by workgroups. *Safety Science*, 21, 113-129.
- Srivastava, A., Bartol, K.M. & Locke, E.A. (2006). Empowering leadership in management teams: Effects on knowledge sharing, efficacy, and performance. *Academy of Management Journal*, 49, 1239-1251.
- Tjosvold, D. (1990). Flight crew collaboration to manage safety risks. *Group and Organization Studies*, 15, 177-191.
- Tomasello, M., Kruger, A. & Ratner, R. (1993). Cultural learning. *Behavioral and Brain Sciences*, 16, 450-488.
- Widaman, K.F. (1985). Hierarchically nested covariance structure models for multitrait-multimethod data. *Applied Psychological Measurement* 9, 1–26.
- Yukl, G. (2002). *Leadership in organizations*. Upper Saddle River, NJ: Prentice-Hall.
- Yule, S., Flin, R. & Murdy, A. (2007). The role of management and safety climate in preventing risk-taking at work. *International Journal of Risk Assessment and Management*, 7 (2), 127–151.
- Zohar, D. (2008). Safety climate and beyond: a multi-level multi-climate framework. *Safety Science*, 46, 376–387.

ADVANCED METHOD FOR A REALISTIC TRAINING DEDICATED TO THE RADIATION PROTECTION IMPROVEMENT

E. COURAGEOT, E. GAILLARD-LECANU, S. JAHAN, R. KUTSCHERA
R&D/STEP, EDF
6 Quai Watier, 78400 Chatou – France

A. RIEDEL
DPN/UNIE/GPRE, EDF
1 place Pleyel, 93200 Saint-Denis, France – France

B. THERACHE
DPN/CNPE Civaux, EDF
Centrale de Civaux, BP 64, 86 320 Civaux – France

ABSTRACT

Each personnel involved in activities within the controlled area of a nuclear facility must be provided with appropriate radiation protection training. Using real sources induces limitations and logistics constraints. Conventional simulation techniques may have drawbacks in terms of realism. EDF has been working on a new approach to ionizing radiation simulation, as an integrated training solution based geolocalization hardware and a 3D simulation code. During the training, the worker/trainee performs his activities as if he were in a real situation, wearing realistic personal training dosimeter and radiation monitor. The particle transport code calculates in real-time, for each position of each monitoring device, the dose or the dose rate that would have been received due to virtual radioactive sources, taking into account the deployed shielding. The value of the dose/dose rate is displayed on the monitoring device and stored for later training debriefing. As sources are virtual, it is possible to program extra behavior to allow interactive enriched scenarios.

1 Introduction

Each personnel involved in activities within the controlled area of a nuclear facility must be provided with appropriate radiation protection (RP) training. An evident purpose of this training is to know the regulation dedicated to workplaces where ionizing radiation may be present, in order to properly carry out the radiation monitoring, to use suitable protective equipments and to behave correctly if unexpected working conditions were to happen.

It was once common to use real radiation sources whilst performing training, as no suitable realistic alternative did exist as a replacement, especially in representing the actual effect of protective equipment. Using real sources helped in demonstrating how optimization of the time of exposure, distance to the source, and use of protective equipment shall contribute on reducing the overall dose received by the worker.

Beyond the natural fact that volunteered exposure, even to low dose, contradicts the overall training objective of managing and reducing the on-site received dose, using real sources is not effortless. Managing, using, and storing the sources themselves requires qualified personnel and dedicated infrastructures.

EDF has been considering alternative training methods that would allow for propagation similarities to ionizing radiation, and could be suitable replacements for RP training.

Those solutions were mostly based on infrared or ultrasound emissions and have been in use at some EDF facilities for a few years.

2 Drawbacks of current RP dose exposure simulation methods

2.1 Hiding a source

Depending of the training being performed, it may be requested for the trainee not to know the actual specifics of the simulated environment he will perform in. This may be the case for instance concerning dedicated cartography training, for which the objective is to assess the work conditions inside the facility and establish a dose map.

In such a scenario, the trainer would need to conceal the simulated source, for the trainee not to obviously see an actual simulation device, representing a source.

Given current simulation technologies, such concealment may prove difficult. Using infrared technology may seem easier, as one can deport tiny IR emitting LEDs from their battery pack, but ultimately this pack and the wires would still require to be concealed. Alternatively, hiding an ultrasound emitter may prove even more difficult, as it's of a bigger size.

Being concealed, the equipment may also work in a degraded manner, as its emitted signal may be partially blocked.

2.2 Effects of protective equipment

As stated before, the training should focus on demonstrating the effects of time of exposure, distance and use of protective equipment.

Whilst simulation technologies do exist that behave similarly to ionizing radiation declining in inversed square ratio to the distance, like ultrasound, it is difficult to perform in a realistic manner whilst demonstrating the impact of protective equipment. Using ultrasound or infrared simulation techniques, a simple sheet of paper will already induce a noticeable attenuation on the signal. A standard lead shield may hence completely block the ultrasound signal, instead of applying only it's given reduction ratio.

2.3 Changes on the dose rate / Having a mobile source

To demonstrate the impact of mere distance, it is easy to let a trainee approach a source installed at a fix position with his dose-rate monitor. On such a specific use-case it would seem illogical to have the trainee stand on the spot and to let him be approached by a moving source.

Considering what may happen on an actual worksite, the second approach may not be that illogical anymore. Worksites are being mapped and a risk assessment is being performed providing some radiation conditions to be expected on a worksite. Protective equipment is then installed when needed. But the reactor building may get very crowded during outage, both by personnel and equipment. Risk is not only attached to one's dedicated worksite, but also comes from the interaction between worksites.

For example, once used, potentially contaminated waste may be stored at collection points for later processing. On its own, each contaminated element may constitute a low activity

source; if considered as a whole, the constituted source may not be negligible anymore. Once transported to processing, it now becomes a mobile source, which may pass near other worksites.

Additionally, local hotspots may arise due to the actual maintenance task being performed, for instance, opening a circuit has for side-effect to partially removing the natural shielding provided by a valve or pipe. The received dose rate may hence be different between open circuit and closed circuit. It could be meaningful to simulate this in training.

Such examples illustrate how having the capacity of moving a source, or changing its activity may prove useful. Given current simulation technologies it's not that easy. Changing a dose rate could be done by using some remote control on the simulated source, but would still require manual intervention of the trainer. Moving a source has to be associated with the difficulties of concealing the source, like the waste bin example, and may prove difficult. A manual intervention of the trainer would also be very obvious to the trainee.

2.4 Complex scenes

The work under ionizing radiation is not finality in itself. The main objective is to perform a task, as required for the industrial maintenance of the facility. Ionizing radiation is but only an element of the environmental working conditions.

As per regulation, workers may only perform their task if they have received dedicated training to work under ionizing radiation, but they also still undergo classic training to their actual work task. Whilst it is necessary to perform separate trainings, with dedicated training objectives, it is not how they will have to perform on the real job. Hence, it could only seem natural to let them pursue on a fake/training maintenance, on real equipment, and having realistic radiation simulation at the same time. This would require complex RP simulation, linked and synchronized with the task being performed.

One complex example could be illustrated with a mobile source inside some piping. The source is being kept mobile as there is water flowing. Additionally, the water also provides some extra shielding to the source. Once the circuit has been tagged out and purged, a source's impact on the worksite's dose rate should be higher. It could be expected from the trainee to seize several opportunities to realize the abnormal situation and to take the initiative of interrupting the work until further analysis. The training could pursue with finding the actual hotspot.

No conventional radiation simulation known to EDF would be able to easily allow for such an approach.

2.5 Simultaneous training sessions

Using conventional simulation methods, which stay based on the propagation of IR or ultrasound as a replacement to gamma emission, it is only possible to play a single RP scenario at the same time, as the RP environment would be dedicated to this scenario.

It is hence difficult to organize training sessions simultaneously inside a room, or to split the training facility into training subsets.

3 Training through numerical simulation: CERNUM

3.1 Concept

EDF has been working on a new approach to ionizing radiation simulation, as an integrated training solution based on a 3D simulation code.

The main idea is to compute one's dose given an avatar inside a 3D particle transport code exploiting a model of the actual training facility. The avatar of the trainee will be moved in real-time inside the simulation and will follow the movements of the localized trainee in the actual environment.

Radioactive sources can either be purely virtual, existing only in the simulation without any tangible element, or can be associated to a localization tag. This allows for enriched source interaction, based either on a movement model (for example flowing source in a pipe) or on user interaction (localization tag inside a waste bin). The simulated dose-rates and integrated dose shall be transmitted to local display devices, as realistic dose-rate meters and dosimeters.

The 3D particle transport code is based on state of the art RP simulation technologies, performs in real-time and takes into account attenuations induced by water or lead-shielding. The lead-shields are also being localized, and movement of the virtual shields shall follow the movements of the actual shields, hence providing a realistic impact on the dose rate.

During the training, the worker/trainee performs his activities as if he were in a real situation, wearing his personal dosimeter and using a workplace radiation monitor. The particle transport code calculates in real-time, for each position of each monitoring device, the dose or the dose rate that would have been received due to the virtual radioactive sources, taking into account the extra shielding added by the worker or previously present, or natural shielding which happen as a consequence of operations (flooded pipes). The value of the dose/dose rate is displayed on the monitoring device and stored for later training debriefing.

The worker shall perform his task in realistic working conditions.

3.2 Architecture

The system has been built upon several components.

To be evolutive and to ensure for flexibility, each function has been decomposed to their hardware requirements.

The functions are identified on Figure 1.

The system is built around the open source *Global Sensor Network*¹ middleware. It allows for interaction with specific hardware, by the means of specific *wrappers*². Data manipulation or forwarding can be achieved by the mean of *virtual sensors*³.

¹ <http://sourceforge.net/apps/trac/gsn/> and <http://sourceforge.net/projects/gsn/>

² GSN component. A Wrapper (Wrapper) is a piece of Java code that does the data acquisition for a specific type of device.

³ GSN component. A Virtual Sensor (VS) is the main component in GSN. It receives data from one or more Wrapper. It can combine their data, process and finally store it. A VS is defined in a single VSD and combines different pieces of software.

It is hence possible to set up a complete data workflow, starting from an embedded geolocalization tag inside the trainee's local display device. The real positioning of the trainee is transmitted in real-time to the trainee's avatar inside the 3D simulation code MODERATO⁴, which computes a virtual dose-rate and integrated dose at the given position. Depending of the type of local device, either a dose rate monitor or a dosimeter, the dose rate or the dose are being displayed.

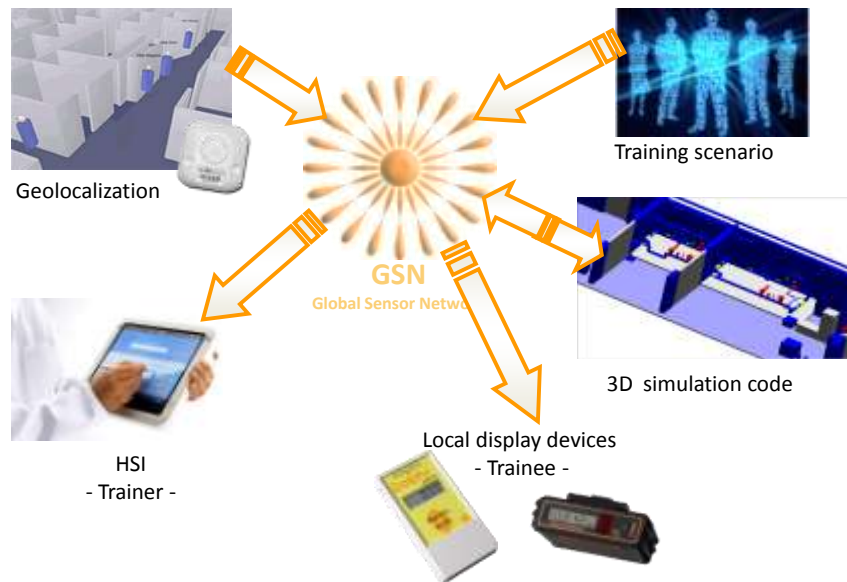


Figure 1 – Functional view of CERNUM

The local display devices are based on a custom implementation of an open hardware / open source Arduino⁵ layout encased in realistic casings to actual tools being used at EDF. As a first step, implementations of the *Dolphy* dose rate monitor by *Carmelec* and the *Saphydose Gamma i* by *Saphymo* have been produced.



Figure 2 - Dolphy : Real device (left) and simulated batch (right)

⁴ EDF 3D Simulation software programmed by R&D/SINETICS Division

⁵ <http://www.arduino.cc/>



Figure 3 – Saphydose Gamma i : Real device (left) and prototype of simulation device (right)

Custom implementation of other devices is easily achievable by producing a suitable Arduino layout which implements a LCD screen, the required in and outputs (pushbuttons, buzzer, leds, etc...) and a ZigBee transmitter in order to receive display commands from GSN. The device's behavior shall be implemented as C++ code using the user friendly Arduino IDE or other environments, as there is possibility for Arduino integration inside Eclipse or Visual Studio.

4 Deployment at NPP Civaux

EDF is currently deploying a CERNUM prototype in the training facilities of the nuclear power plant Civaux.

The site has a training facility in which several live mock-ups are being used to perform training of regular NPP maintenance. The training facility is located in the administrative area of the power plant, outside the industrial facilities.



Figure 4 – Map of Civaux training facility

Three rooms on the upper side of the map (Figure 4) are covered with geolocalization sensors, and are hence useable to achieve RP simulation. The system is still under deployment and Civaux trainers are still working on new training scenarios.

When using RP simulation, as sources may be purely virtual, or linked to scenario dedicated tags, it is possible to have several RP cartographies in the same perimeter at the same time, without them to interfere with each other.

Using three separate rooms, the system has been set-up in order to allow two separate training sessions simultaneously, if required.

CERNUM's prototype shall begin to be used Q1 2013.

5 Perspectives

Using realistic RP simulation without the constraints due to using real radioactive sources makes this approach very flexible and versatile. Pending the deployment of a geolocalization system and the modelization of the facility, it is possible to deploy the system practically anywhere. There is no requirement for source storage or any controlled area associated to the training facility.

EDF R&D is counting on the prototype on-site at NPP Civaux to gain some feedback on the actual benefits one can expect by using such a system.

Trough the initial interview with future end-users EDF R&D has already established a road-map of enhancements. These mostly cover adding new simulated hardware, being either sensors (other dose-rate monitors) or associated to the work process (entering and exiting the controlled area). Some users are also asking for an extension to more environmental monitoring than only RP inside the simulation perimeter, such as O₂, CO₂ or other gases.

It is also under consideration to link the CERNUM system to the instrumentation and control of the training systems, in order to implement event based interaction, for actual actions on the equipment to trigger RP events.

It has been easy for the trainers to project themselves in using the CERNUM system. They have easily converted their current training scenarios into the new tool. Additional brainstorming has lead to the emergence of new training scenarios, which weren't achievable up to now using conventional RP simulation hardware.

These "enriched" scenarios can cover basic RP training, but mostly cover advanced courses or training to emergency situations. While deploying the prototype at NPP Civaux, our team got approached by the on-site Firemen as they were interested in using the system for their "locating hotspot" training.

At another simulation level, such a system could be applied for high dosage activities were training could be envisioned as active pre-job briefing. The workers could train for an actual task until they are satisfied by their RP performance.

THE USE OF LEARNING AND TRAINING TOOLS FOR NUCLEAR EDUCATION AND TRAINING

F. FOULON, E. ROYER, O. COMPAIN, H. GOLFIER, H. GRARD
B. LESCOP, M. MOIRON

*National Institute for Nuclear science and Technology
CEA Saclay, 91191 Gif-sur-Yvette, France*

ABSTRACT

As a part of the French Alternative Energies and Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution. Its objective is to provide to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications. The INSTN offers both academic and vocational programs. We present here the various learning and training tools that are used at the INSTN to ensure a practical and comprehensive understanding of the reactor physics, design and operation. These tools include software applications, computational codes, research reactors and simulators. The feedback obtained from the trainees shows that the use of such training tools has a very positive impact on the development of the trainee's competences and skills. Thus, the INSTN is continuously promoting the use of such tools for the development of the human resources needed by the nuclear industry and the nuclear programs.

1. Introduction

As a part of CEA, the National Institute for Nuclear Science and Technology (INSTN) provides to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear science.

Over the last 5 years, the INSTN's involvement in nuclear education and training at an international level has strongly increased with the development of both academic and vocational programs. This includes the development of :

- A Nuclear Energy Master Course [1] run by a consortium of several academic institutions (Université Paris-Sud 11, ParisTech, Supélec, École Centrale Paris, INSTN) with the support of several industrial partners (EDF, AREVA, GDF SUEZ).
- A large panel of international courses covering the different aspects of nuclear reactor science and technology (reactor principles and operation, neutronics, thermal-hydraulics, fuel cycle, dismantling, ...) which are proposed on a regular basis, typically once a year.
- International courses that have been developed to respond to the specific needs of the nuclear industry and nuclear programs (for example, courses for project managers or young engineers and courses to train-the-trainers). This includes the organisation of international courses in nuclear engineering, covering nuclear reactor principles, neutronics, thermal-hydraulics and operation, as well as fuel cycle and reactor dismantling issues.

In all these programs, the INSTN use a large set of learning and training tools that play a major role in ensuring a practical and comprehensive understanding of the nuclear reactor design, principles and operation.

The following sections present these practical tools and their use in INSTN education and training programs: computer codes, research reactor and PWR simulators.

2. Training courses on software applications

Nuclear engineering requires a detailed understanding of reactor physics. Numerical simulation has made important progress during the last decade. Multi-scale and multi-physics computations are now the state-of-the-art in nuclear industry for design, safety and operation studies. To be well prepared to such type of work, students and professionals need to practice the basics of neutronics, thermal-hydraulics and mechanics with computer codes.

2.1 Use of industrial codes

For this purpose, INSTN uses the main CEA codes:

- APOLLO2, which is a 2D neutronic code used for assembly calculations [2]. It solves the multi-group transport equation in space and energy and is a good introduction for reactivity calculations, differential rod worth and depletion effects.
- CATHARE, which is a system code for thermal-hydraulic analysis during reactor accidental transients [3]. It is used to model the full plant (e.g. primary and secondary circuits of a PWR). It is based on a two-fluid model validated on a large set of experiments.
- FLICA4, which is a 3D two-phase flow code for thermal-hydraulics [4]. It calculates the fuel temperature and the coolant properties. It can be used to provide the feedback parameters (moderator density, Doppler temperature, boron concentration) for a neutronic calculation at pin or assembly level.
- TRIPOLI4, which is a general purpose radiation transport code using the Monte Carlo method to simulate neutron and photon behaviour in three-dimensional geometries [5]. It can be used in various areas of applications including nuclear criticality safety as well as fission and fusion reactor design. In the training courses, several core geometries are used to compute the criticality.

Hereafter, basic practical reactor-physics exercises are briefly presented to illustrate their pedagogical objectives:

- APOLLO2 exercises are aimed at calculating the most relevant neutronic parameters of fresh and depleted UO_x or MO_x cells by using the Collision Probability method. Moreover in the case of the Loss Of Coolant Accident, some “voided” cases are analysed from neutronic point of view.
- FLICA4 sub-channel exercises are aimed at determining the maximum power before reaching the Onset of Nucleate Boiling or the Critical Heat Flux (DNB or dry-out) for a wide range of PWR and BWR configurations and operating conditions. Fuel temperature, pressure drop, and void fraction are also analysed and several models can be compared (e.g. Homogeneous Equilibrium Model versus drift flux).

2.2 In-house softwares

In addition to these industrial codes, INSTN has developed two software applications in order to study :

- (1) the neutron kinetics, with a two to six precursors of delayed neutrons model,
- (2) the core poisoning by Samarium and Xenon. These softwares are run on PCs with an ergonomic interface.

The kinetic model computes the solution of the differential equations using a Runge-Kutta method in order to draw the time evolution of the neutron and precursor concentrations as a function of the reactivity changes imposed by the trainees. Practical works are conducted to

show the influence of the delayed neutrons on the neutron generation time and thus on the reactor control.

The poisoning model computes the kinetics of the poison density that depends on the evolution in reactor power, taking into account poisons production and removal. It is used for example to study the safety issues related to the Xenon peak.

3. Training courses on research reactors

In order to illustrate the principles and operation of nuclear reactors, low power research reactors from CEA are used for training courses. The use of low power reactors for training started in 1961 with the use of ULYSSE reactor (100 kW Argonaut type reactor) at the INSTN.

Since 2007, ISIS research reactor at CEA Saclay is mainly dedicated to E&T activities. For this purpose, the reactor went through a major refurbishment from 2004 till 2006 [6]. ISIS reactor is an open core pool type reactor with a nominal power of 700 kW. The refurbishment of the reactor included the design of a new control room and the development of a supervision software used to display different screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor.

Training courses on ISIS reactor are addressed to a wide range of public including students from universities and engineer schools, operators of research reactors (qualification of reactor personnel), professionals with interest in reactor theory and operation (operators, personnel from the regulator body, engineers, researchers,...).

A large panel of experiments, which are listed in figure 1, have been developed. These experiments are integrated in nine courses, each course with duration of 3 hours. Depending on the public and on the pedagogical goals, the trainees can follow programs that exhibit from 3 up to 24 hours of training courses on ISIS reactors.

Every year, about 400 trainees participate to the training courses on ISIS reactor. E&T activity on ISIS research reactor represents about 360 hours distributed over 70 working days. One third of this activity concerns international courses that are taught in English. With an increase in the need for E&T, especially at an international level, the E&T activity on ISIS reactor could easily be increased up to 600 hours distributed over 120 working days.

-
- Control of the reactivity during fuel loading
 - Approach to criticality
 - Reactor start up and stabilization
 - Drawing of the calibration curve of a rod
 - Evaluation of the global worth of a rod by the rod drop technique
 - Influence of experimental devices on the core reactivity
 - Reactivity change in the core – shadow effect
 - Demonstration of the role of precursors (delayed neutrons) for the control of the reactor
 - Study of the temperature effects (temperature coefficient, self-stabilisation)
 - Radiation protection applied to reactor operation
 - Study and setting of the neutron detection systems
 - Neutron cartography / Neutron activation analysis
 - Reactor operation under the supervision of ISIS staff and INSTN instructors

Figure 1 : ISIS training course content

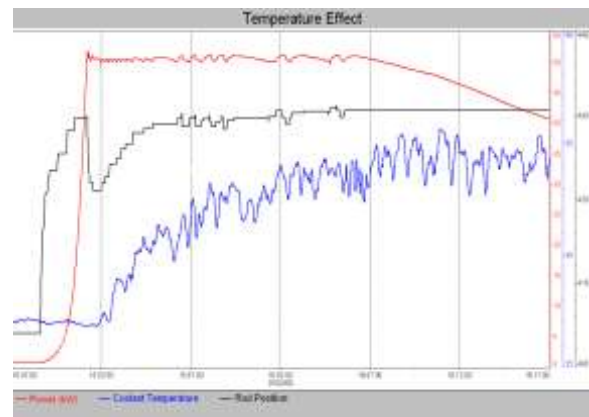


Figure 2 : Study of temperature effect on ISIS reactor

As an example of the experiments carried out by the trainees, figure 2 shows the recorded parameters (control rod position, power and water temperature) during the study of the temperature effects. In this experiment, the reactor power is increased from 500 W to 50 kW

and maintained at this power under automatic control for 15 minutes before the reactor is switched to manual control without any modification of the rod position. The analysis of the recording can be used to illustrate and characterise the Doppler and water expansion effects, the temperature coefficient, reactor self-stabilisation as well as the safety issues related to the temperature effect.

4. Training courses on simulators

The use of simulators has been promoted since 1986 at INSTN to train the students and professionals with the operation of a pressurised water reactor (PWR).

4.1 Normal operation

SIREP, a simplified PWR simulator for normal operating conditions was developed by Corys in 1992. The targeted goal is to understand the basic principles that determine how a reactor responds during all modes of normal operation:

- During the start-up of the reactor, simulation focuses on parameters evolution such as temperature, pressure and reactivity.
- During power operation, trainees are invited to observe the control of the flux shape.
- After the shutdown they must be care to ensure adequate cooling of the core needed by the fission process that generates heat.

Thus, seven main basic simulations are proposed in the training courses:

1. Presentation of the simulator
2. Neutronics of PWR – Temperature effects
3. Sub-critical state
4. Physical tests for start-up
5. Reactor power levels - Operation
6. Study of pressuriser and steam generators
7. Incidents of reactivity – Core protections

4.2 Accidental transients

For the study of abnormal transients including Anticipated Transients Without Scram (ATWS), SIPACT, a simulator based on the CATHARE code was developed by EDF and implemented at INSTN in 1996 [5].

Recently INSTN acquired a new simulator, SOFIA (see figure 3), used by AVERA and IRSN for PWR safety analysis. It offers a powerful interface to understand the physical behaviour of the reactor and to navigate among the reactor systems (RHRS, ECCS...).

An extensive training programme has been developed on SIPACT for students. This program includes seven main simulations:

1. Cooling of the primary circuit when the Steam Generators (SG) are in operation,
2. Cooling of the primary circuit when the steam generators are no more available,
3. Large break Loss-of-coolant Accident (LOCA),
4. Small break LOCA.
5. Station black out and loss of the feed water turbo-pump,

6. Anticipated transient without scram (ATWS),
7. Steam Generator Tube Rupture (SGTR).

At the present time, INSTN has more than 14 years of experiments with the simulations of post-accidental conditions.

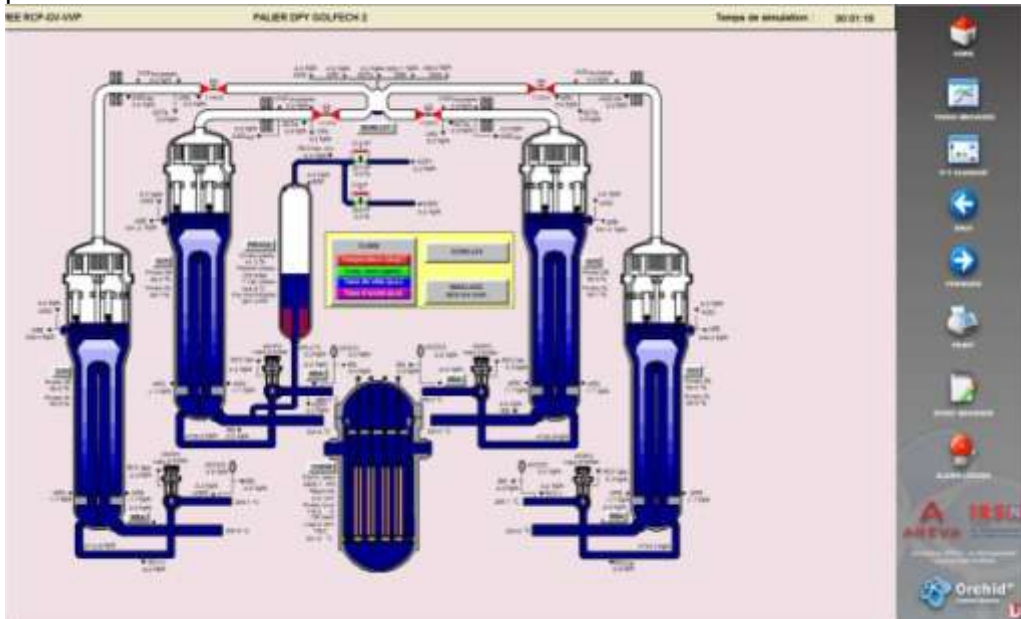


Figure 3: Snapshot of the primary circuit on SOFIA

5. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides to students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses by training courses on software applications, research reactors and simulators. The experience gained shows that such tools bring tremendous benefits for all trainees, including students, engineers, researchers, reactor personnel and personnel from the regulator body. The training courses ensure a practical and comprehensive understanding of the reactor physics, design and operation. They also contribute to an improvement of the safety of the reactor operation especially when emphasis is given to the impact of each operation and effect on the safety of the reactor design and operation, both in normal and incidental situations.

References

- [1] Master Nuclear Energy, <http://www.master-nuclear-energy.fr/en>
- [2] R. Sanchez, I. Zmijarevic, M. Coste-Delclaux, E. Masiello, S. Santandrea, et al. "APOLLO2 YEAR 2010", Nuclear engineering and technology, vol. 42, No. 5 October 2010
- [3] G. Geffraye, O. Antoni, M. Farvacque, D. Kadri, G. Lavielle, B. Rameau, A. Ruby "CATHARE 2 V2.5_2: A single version for various applications", Nuclear Engineering and Design, Volume 241, Issue 11, November 2011, Pages 4456-4463
- [4] E. Royer et al. "FLICA4: Status of numerical and physical models and overview of applications" NURETH 11, Avignon, 2005
- [5] C. M. Diop, E. Dumonteil, F. X. Hugot, C. Jouanne, Y. K. Lee, F. Malvagi, A. Mazzolo, O. Petit, J. C. Trama "An Overview on the Monte Carlo Particle Transport Code TRIPOLI-4" Trans. Am. Nucl. Soc., 97, 694-695 (2007)
- [6] B. Alvado, F. Foulon, "Training Courses on ISIS reactor at Saclay Research Center", Nuclear Engineering Science and Technology Conference, Budapest, Hungary, 4 -8 may 2008

TECNATOM, NUCLEAR TRAINING SERVICES IN A GLOBAL WORLD

JAVIER MORENO HERRERO, IÑIGO LOIZAGA DIAZ

International Training Centre, Nuclear Training; TECNATOM

Av. de Montes de Oca 1, 28703 San Sebastián de los Reyes, Madrid-Spain

ABSTRACT

Over the 1960's Tecnatom became an integral engineering company, mainly in the areas of training and inspection. In the early 70's PWR and BWR full scope simulators (FSS) were acquired to provide adequate training services on each technology - Tecnatom became the Reference Nuclear Training Centre in Spain. In the 1990's, the construction of a brand-new FSS with high physical and functional fidelity to each Spanish nuclear power plant was undertaken. Only own technology was used, setting a milestone for Tecnatom and the Spanish industry. During more than 40 years of operation, the Nuclear Training Area has been gaining expertise and achieving national recognition within Spanish electric utilities. At the end of the last decade, Tecnatom made the decision to offer its training expertise and services overseas through the establishment of the International Training Centre.

This paper attempts to share Tecnatom's expertise throughout an historic point of view and how they have evolved to become global

1. Tecnatom begins

The Studies Service run to support and promote the development of new industrial activities in Spain, recommended that the use of nuclear energy be investigated for power generation in the country. As a result of this proposal, **Tecnatom** was set up in 1957.

Tecnatom was established to analyse the overseas situation about nuclear energy and to make the country and the utilities realise its benefits. It also studied its viability in the Spanish electricity market. Afterwards, the company helped to develop its introduction into Spain and to solve all the technical difficulties that arose in this process. These were the founding principles of the company which have remained until today.

During the early 60's, Tecnatom took part of a preliminary project to construct a 160 MW nuclear power plant (NPP), José Cabrera. In the second half of this decade, testing procedures, inspection procedures, radiological handbooks, emergency plans, operating handbooks and so on were developed by Tecnatom experts in Pressurised Water Reactor (PWR) technology. They became the germ of the Nuclear Training Area.

The *Plan Energético Nacional (PEN* - Spanish National Electricity Plan) was put together in the late sixties and amended at the beginning of the seventies. It envisioned the supply of 15,000 MW of nuclear power coming from the construction of 11 units. In order to provide the services that such a fleet would require, Tecnatom became an integral engineering company in 1973, mainly in the areas of training and inspection, for the seven electric utilities participating in the Spanish Nuclear Programme. These companies eventually became the Tecnatom's owners.

Among Tecnatom's commitments to its owners were to provide training to operational personnel. To do so, a group of engineers were selected to travel to the USA to follow a cold licensing process. Afterwards, training materials and methodologies used in operation personnel training for the two widely spread technologies, PWR and BWR, were developed. Since these years, theoretical training has been carried on in Madrid. However, some training still need to be sought overseas due to the lack of the appropriate simulations tools. A niche in the market was spotted and during the course of the 70's two **full scope simulators** (FSS) were acquired to provide adequate training services on the two existing technologies, PWR and BWR. With the acquisition of these high level training tools Tecnatom became the Spanish **Reference Nuclear Training Centre**.



Figure 1. Training at ZION NPP (USA, 1972).

This milestone boosted the nuclear training area. At this point, it split into one area for PWR technology and other focused on BWR technology. Not only did all Spanish NPP operation personnel received initial training and requalification using Tecnatom's training facilities but also several requests for courses from foreign utilities were received. Thus, crews from Caorso, Trino and Garigliano from Italy, Döel from Belgium, Leibstadt from Switzerland, Laguna Verde from Mexico, Angra from Brazil, Quin Shan from China just to name some, have received training in Tecnatom headquarters. These courses were full of enriching experiences but also setbacks. The cultural differences as well as language difficulties were overcome thanks to the restless spirit, creativity and goal orientated instructors. The rapid expansion along with the high quality and professionalism of the instructors positioned the company as a world reference in nuclear training.



Figure 2. QUIN SHAN crew training at Tecnatom FSS.

The training area never has lost the spirit of improvement. By this time, being in constant contact with the requirements of Spanish NPPs, along with the different training courses delivered to locals and foreigners, widely enriched instructors experience and capabilities. Since then, sharing experiences, lessons learnt and knowledge among Tecnatom personnel has become a *leitmotiv*. Instructors have always felt part of a team aimed at achieving excellence.

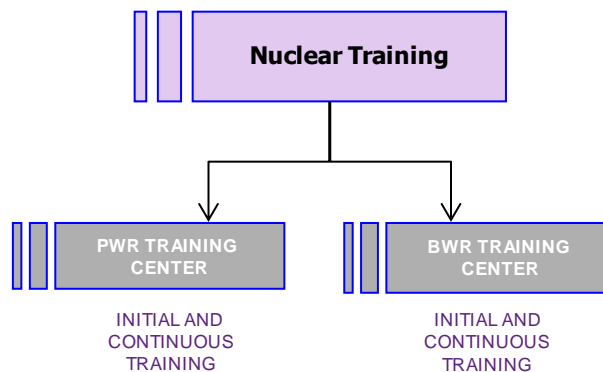


Figure 3. Tecnatom Training area, 80's.

2. Ahead of nuclear industry standards

Excellence could not be achieved working isolated. Indeed some of the most striking events within the industry may have been avoided if a better **international collaboration**, sharing information and best training practices worldwide, had occurred. Tecnatom has always encouraged these principles while trying to work side by side with international organisms such as INPO, WANO, or IAEA. For instance, during the 90's Tecnatom training area was involved with the IAEA's TACIS programme. The scope was designing and developing a training centre located in Romania with the aim at enhancing personnel training and improvement of design of FSS for the Russian NPP VVER. Another example is the collaboration with WANO for gathering and sharing all the Spanish NPPs operating experiences to the International Organizations through training courses and computing-aid tools.

After more than 10 years of successfully running of the PWR and BWR training areas along with a highly enriching international collaborations; next evolution was possible thanks to the improvement of computational calculation capabilities.

During the mid 90's, the Spanish Nuclear Plants decided that each one shall have its own physical and functional high fidelity FSS. The construction of a brand-new fleet of **plant-referenced FSSs** led to a deep transformation in the nuclear training area throughout the next years. The PWR and BWR nuclear training areas eventually split into Garoña, Almaraz, Trillo, Cofrentes, Ascó and Vandellós. In most cases they were established in Madrid headquarters with a reduced group of instructors deployed at the nuclear site - except for Ascó and Vandellós training areas. A different approach was followed here. It was decided that their new FSS will be placed close to Ascó and Vandellós sites, both in Catalonia. This led to establish the **Tecnatom Tarragona Centre** which becomes Tecnatom's first decentralised training facility and a reference for future overseas Tecnatom developments

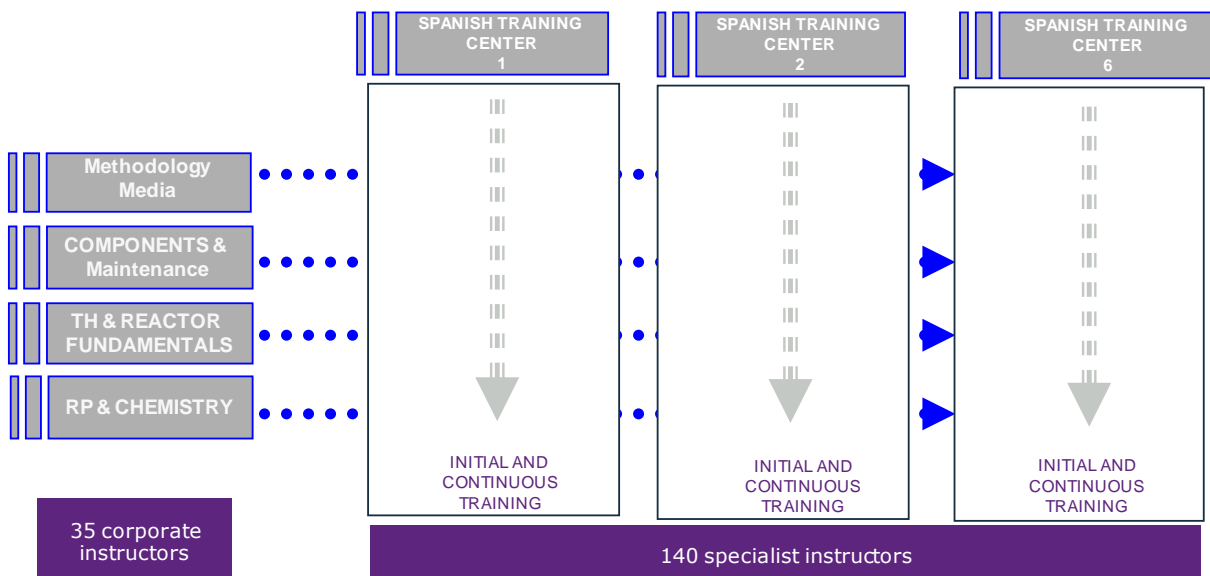


Figure 4. Tecnatom training model.

Tecnatom constantly seek to improve training services and in collaboration with INPO assessments, identified some areas to improve personnel knowledge and on-site practices. While the building was envisaged to be a state-of-the-art training facility and in order to give answer to the improvements spotted. Not only were filled with two brand-new plant-referenced FSS but also with a new training tool; a **Human Performance Simulator (HPS)**.

The HPS start-up at Tecnatom Tarragona is other of the most noteworthy milestones of the nuclear training activity in Spain. This first-of-a-kind Spanish simulator is designed to improve nuclear workers performance as well as to reinforce their behavioural expectations

while working at facilities in which safety is fundamental. One of its main points is that it allows the simulation of work performed at such installations by recreating quasi-real working environments.



Figure 5. HPS general view.



Figure 6. HPS lecture area.

3. Gone Global

Today nobody questions the importance for instructors to be technically competent in their field of knowledge. However, the **human factors** involved in properly conveying instructors' knowledge to operation personnel have recently gained special importance. Indeed human factors have achieved special relevance during FSS sessions. That is to say, today, it is not enough to detect if the operator made a mistake but also to analyse why they did not perform well. The problem may be unclear procedures or maybe the operator is not in the best psychological condition to do the task.

During more than fifty years of operation, the Tecnatom Training Area has been gaining expertise and subsequently achieving national renown within Spanish NPP utilities. Therefore, at the end of the last decade, Tecnatom took the decision to offer a more personalised attention to its international customers and, at the same time, offering its training expertise and services wherever they could be needed. The outcome of this commitment was the establishment of the **International Training Centre (ITC)** as a new branch of Tecnatom's Nuclear Training area.

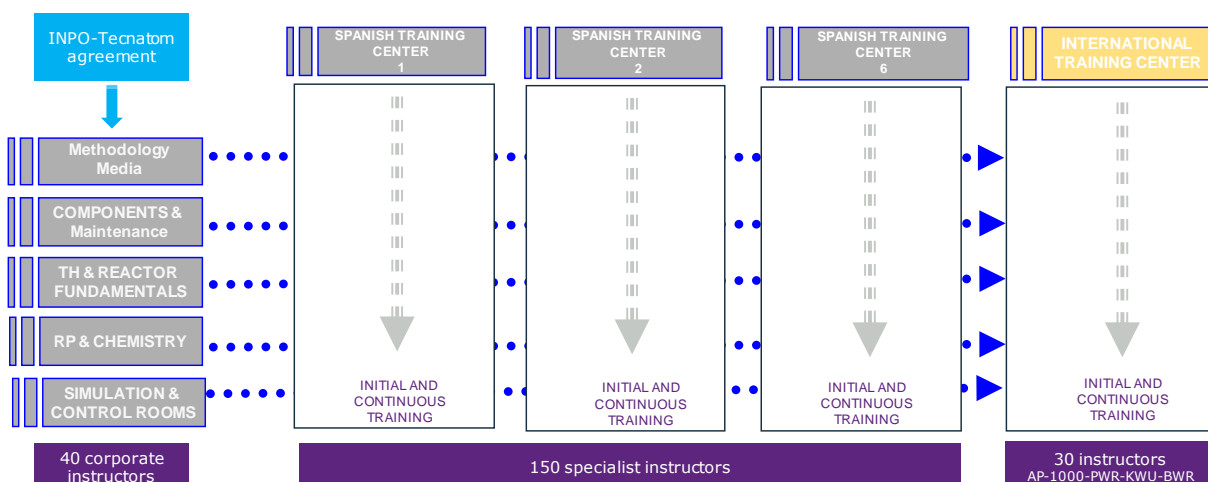


Figure 7. Tecnatom current training model.

30 instructors trained in the state-of-the-art nuclear technologies - AP-1000, KWU, PWR, BWR, who jointly hold more than 350 years of nuclear experience, are the core of the team. However, support from other training centres along with the availability of assistance from subject matter experts makes the ITC fully capable of undertaking any project. The bulk of the international instructors have started their careers within one of the Spanish training

areas and after a successful time were considered to become part of the thrilling ITC project. Here there is only room for highly motivated, globally available and goal-oriented instructors that face each overseas project as an opportunity to increase nuclear safety and spread their knowledge and cultural heritage.

Today we are present in 5 different areas – Europe, Middle East, Asia, North America and South America. Becoming a trustworthy company has required consistent but innovative approaches to problems faced but keeping their confidence would be even more demanding. Performing a better job every day is our vision and our challenge.



Figure 8. Business areas.

The international unit has access to all Tecnatom full scope simulators, interactive graphic simulators, human performance simulators, hydraulic loops and mock-ups. With the aim at placing training settings as close as possible to the work environment, enormous efforts were undertaken to provide instructors with a set of cutting-edge training tools such as, virtual training simulators, virtual reality simulators and online training courses through Tecnatom virtual campus. It would be unfair to not mention the supportive organization that backs up all the training labour. It counts with more than 150 people from financial departments to clerical personnel and from human resources to IT departments, all which help out to deliver everything in place and in time.

The constant contact with different processes and cultural behaviours is enriching our cultural and technical knowledge background. However, this help us to achieve even higher performance, becoming more solution oriented and increasing our decision making capacity through a better understanding of our customers' needs and concerns.

4. Global World Challenges

Since its foundations Tecnatom has always strived to align its organizational structure with the changing environment and the new business opportunities.

From an instructor's point of view, delivering training overseas is full of challenges. Working immersed in a new country; with different weather conditions, cultural traditions, gastronomy

and contrasting learning environment are some circumstances that may interfere with the instructor performance and welfare. Dealing with them has become a first order issue.

From a managerial point of view neither it is an easy issue. The difficulties of managing decentralised units in different time zones along with coaching instructors with different native languages make it difficult to keep the unit united and focused on the common objective - giving customised and outstanding training for each customer no matter how different the requirements were.

To address these challenges the principles and the personality of each ITC member are highly valued. Their resilience, their social skills and their ability to manage relationships are specific aspects that along with technical competence shall be assessed in a selection process. Such profiles are likely to be found in an adaptable young team with a sense of adventure.

5. Instructors Team

The ability to deliver good training courses comes from the junction of two processes: selection process and instructor training process.

5.1 Selection Process

Tecnatom runs an in-house selection department to carry out the screening, selection, and hiring people with the particular qualities sought. The selection process takes as its basis a well-defined **Job Profile**. Here, intellectual aptitudes, personality, attitude towards work, and organisational culture style are analysed.

In relation to **personality** features that define how candidates are, such as their social skills and their performing, we look for high emotional stability, sociability, fitting in and adaptability, moderation, good sense and team work capacity. In the case of an International Instructor the degree of self sufficiency, the capacity to make individual decisions and act within individual criteria without needing or relying on the team's approval should also be taken into account. With respect to **attitude towards work** features like working capacity, organizational capacity, motivation to assume task, capacity to work with energy and vigour should be highlights.

Their Organizational Culture Style should be 'constructive style' oriented, 'self-actualizing', 'affiliative' and 'humanistic-encouraging', people who are good at motivating, helping and developing others but also respectful and good listeners.

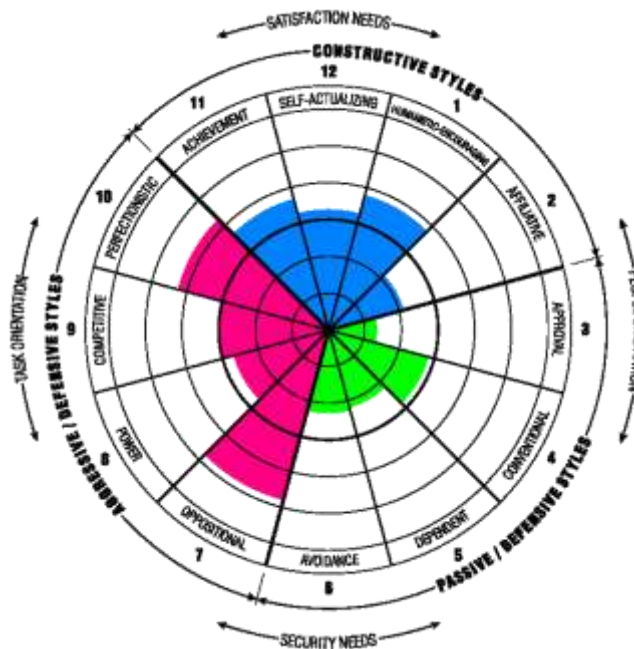


Figure 9. Ideal culture.

The selected instructors also have Masters level qualifications in engineering or science which gives them extensive knowledge about the technological foundations and deep analytical skills.

5.2 Training process

To become instructors, trainees shall follow a training process similar to that followed by a control room operator. The technical training is complemented with specialisations in teaching skills, social skills, emotional control and training methodology.

The instructor qualification process reaches over 2,200 hours of training. It spreads over theoretical classroom sessions, workshop tasks, full scope simulation training and in-plant training. The whole instructor programme is a very demanding period not only because the trainee's progress is being assessed on a weekly basis but also due to the final exams, where all the topics are re-evaluated. These final exams spread out for 3 days. During this time a written exam, a FSS exam and an in-plant exam are carried out. Instructor's capacity for learning, ability and motivation have a direct influence on the success of the training process.

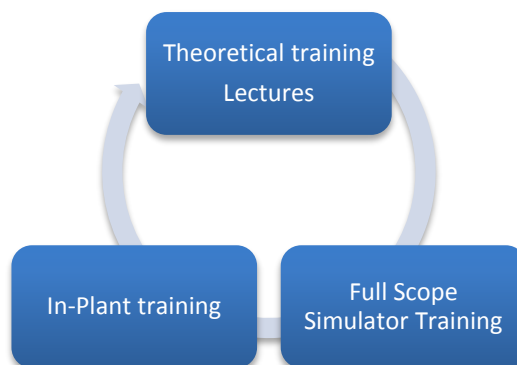


Figure 10. Three pillars of training

The terminal objective is to provide the instructor with an ample professional training and a deep knowledge of plant operation. From this point the instructor's career will evolve considering variables such as time, experience and the instructor's own capabilities.

In summary, as the instructor is the main guarantee of the quality of the training courses delivered, the selection process is carried out with the maximum rigor and the training process becomes a very demanding time for the future instructor.

6. Conclusion

Tecnatom's training area has successfully overcome so many hurdles throughout more than 50 years of existence mainly because of the personnel commitment, working capacities and innovative solutions. Tecnatom's vision has always been to contribute to the peaceful development of nuclear energy in the world. To implement this vision, a highly motivated, committed and experienced team were gathered under the name of International Training Centre.

The ITC's mission is to deliver training with the best technical and pedagogical quality, in the most efficient time periods and at the best cost-benefit for customers. This demanding objective can only be achieved thanks to a flexible structure, team-work, decision-making ability and independency from other internal structures. Putting these qualities together led us to answer to any training request, anywhere and, in most cases, exceeding customer expectations.

The outlook of the ITC is thrilling. It is full of new challenges and opportunities but with such a committed, well trained and experienced group of people to lead us, we face the future with confidence.

EDUCATING AND TRAINING THE NEXT GENERATION OF NUCLEAR SECURITY EXPERTS

HOWARD L. HALL
*Institute for Nuclear Security
University of Tennessee
Knoxville, TN USA*

JAMES N. SUMNER, ALAN ICENHOUR
*Oak Ridge National Laboratory
Oak Ridge, TN USA*

CHRIS CLARK, JOSEPH STAINBACK IV, CHRIS ROBINSON
*Y-12 National Security Complex
Oak Ridge, TN USA*

ERIC ABELQUIST, ARLENE GARRISON, CATHY FORE
*Oak Ridge Associated Universities
Oak Ridge, TN USA*

ABSTRACT

The University of Tennessee (UT) developed its first formal efforts in nuclear security in 2009 with its graduate certificate program in nuclear security in the Department of Nuclear Engineering. Building on this work, UT in 2011 established the UT Institute for Nuclear Security (INS) as a collaborative center at the university. Oak Ridge National Laboratory, the Y-12 National Security Complex, and Oak Ridge Associated Universities have joined with UT as charter members of the INS. The INS was established in recognition that the ability to sustain efforts in nuclear security is eroding as the population of skilled personnel in this field declines, yet the national/global need for expertise and new capabilities in this area is growing.

The INS focuses its efforts in five principal thematic areas: policy, law, and diplomacy; education and training; science and technology; operational and intelligence capability building; and “real world” missions and applications. The educational objectives for the INS are to establish a robust set of collaborative projects in nuclear security across the members that foster and sustain new educational and training offerings in nuclear security across multiple academic units at UT and among the INS members, building on the collective expertise and capabilities of the institute.

1. Introduction

The University of Tennessee, Knoxville (UT), in collaboration with the Oak Ridge National Laboratory (ORNL), the Oak Ridge Associated Universities (ORAU) and the Y-12 National Security Complex (hereby referred to as ‘regional partners’) has established the UT Institute of Nuclear Security (INS) [1]. The INS is organizationally located within

the UT Howard H. Baker Jr. Center for Public Policy, and reaches across the many UT disciplines and academic departments that can contribute to the nuclear security field. The INS deliberately decided to place the INS outside the traditional academic units of the University so as to encourage cross departmental collaboration and cooperation with industry involvement while providing a nonpartisan establishment devoted to education and research concerning policy, law and diplomacy; education and training; science and technology; operational and intelligence capability building; and “real-world” missions and applications. Our concept of a systems approach to nuclear security, graphically captured in Figure 1, is designed specifically to encourage cross-cutting efforts and collaborations between academia, government, the private sector, and the public.

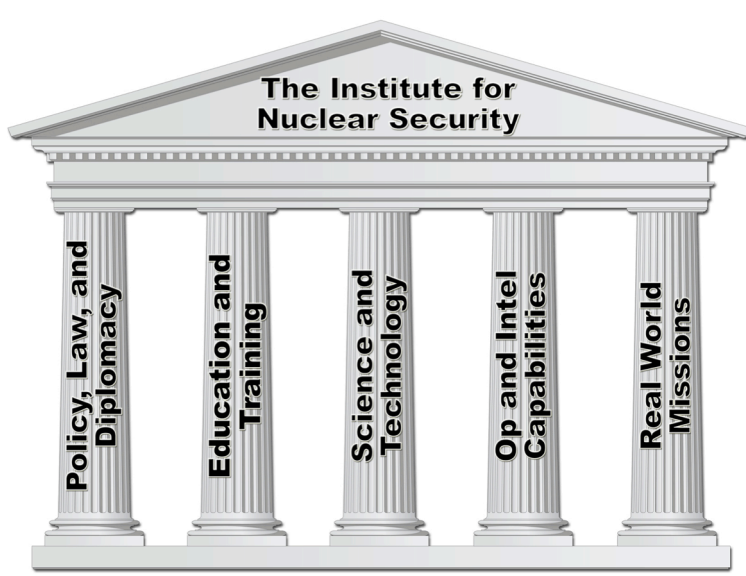


Figure 1. The "pillars" of INS.

UT is working toward expanding contributions to nuclear security from the original nucleus of activities in UT’s Department of Nuclear Engineering [2] to a much broader, multidisciplinary base in which many academic units can both contribute to the global challenges but also develop distinctive and successful programs within each unit. As UT is a research-intensive university, the development of a robust and impactful research portfolio is an important success metric for the INS. UT is also Tennessee’s land grant university, and hence has a firm commitment to teaching, research, and service across the university. As a result, fostering research, development, service, teaching, and related scholarly activities across the membership is a core function of the INS. The INS will focus on those activities that capitalize on partnership and collaboration among the member organizations. The INS also supports the development of enhanced educational capabilities for nuclear security within the academic units of the UT, and more broadly through partner memberships.

The INS and regional partners are developing combined academic and professional development learning opportunities to sustain efforts in nuclear security as the

population of skilled personnel in this field declines. In the US, the ability to sustain national and international efforts in nuclear security is eroding as the population of nuclear security skilled scientists and engineers declines. For example, Wogman et al. noted [3] (in 2004) that 75% of the nuclear personnel in the U.S. Department of Energy national laboratories will be eligible to retire by 2010. This decline is exacerbated by the contraction of programs and facilities wherein hands-on experience with security-significant quantities of nuclear material and its related processing can occur. Programs like those offered by UT are intended to bridge this gap by accelerating intense academic classes with equally intense professional development programs yielding strong academic programs, accredited certificates and Continuing Education Units (CEUs) within this field of study.

The educational and training offerings take advantage of the strong synergies between UT and our regional partners, all of whom have significant nuclear operations and experience in implementing best practices in nuclear security. Through collaborative engagement with these institutions, the institute will provide students not only with academic instruction from the well-respected UT program, but also valuable experiential learning opportunities from visits and interactions with these working facilities.

2. Defining Nuclear Security

We take a very broad view of the span of activities that fall under the rubric “nuclear security.” In our usage, we mean it as a field of education and research that encompasses all the activities that support the following objectives:

- Beneficial applications of nuclear or radiological materials and devices are not diverted to illicit or malicious purposes. Potential threat materials are secured or replaced where feasible so as to reduce opportunities for malicious use.
- Nuclear weapons and related technology are appropriately controlled and monitored. Nuclear arms control and reduction priorities are supported and enabled.
- The proliferation of nuclear weapons or other nuclear/radiological threats is discouraged, detected, and/or dissuaded. Systems that support the peaceful uses of nuclear energy are increasingly proliferation resistant.
- Efforts to acquire or use nuclear/radiological threats by malefactors are anticipated, stopped, investigated, and effectively countered.
- Consequences of radiological or nuclear incidents, including attacks, are mitigated or minimized through prior planning and engineering, as well as effective response, emergency management, and remediation.

Many applications in nuclear security are found at the intersection of the policy and technology communities. For example, the negotiations of new treaties require the implementation of verification and inspection regimes. These negotiations require technology advice to inform the agreed frameworks, and the agreements also define research and development activities to improve the effectiveness of inspection and verification activities. Likewise, the evolution of new technology for supporting law enforcement efforts creates new frontiers in policy and law [4].

3. Academic Training Programs

The educational objectives for the INS are to establish a robust set of collaborative projects in nuclear security across the members that foster and sustain new educational and training offerings in nuclear security across multiple academic units at UT and among the regional partners. In Academic Year 2011-2012, the INS has sponsored the development of multiple new curricular offerings within the UT's Department of Nuclear Engineering and Political Science departments. In particular, the INS sponsored a new graduate course on Physical Security for Nuclear Operations and UT's Department of Political Science is now providing an INS co-sponsored course on Arms Control and Treaty Negotiation, co-taught by Ambassador Thomas Graham. During the summer session in 2012, the INS has co-sponsored a new undergraduate and graduate course in radiochemistry that is jointly taught between UT's Departments of Chemistry and Nuclear Engineering. In Fall 2012, the INS sponsored a freshman honors seminar on arms control entitled "Global Zero: Pathways, Roadblocks, and Hard Problems," which examined the options and challenges in arms control and reduction talks.

UT and the INS are currently working toward a closely integrated offering that combines two education and training pathways – a three-semester-credit-hour (3 SCH) traditional academic course offered in an intense, compressed schedule; and a complementary certificate program taken concurrently through the INS that will provide unmatched enrichment and experiential opportunities for nuclear professionals via the INS regional partners.

Classroom activities for a portion of the professional development classes have already taken place in the UT Howard H. Baker Jr. Center for Public Policy. A signature landmark facility on the UT campus, the Baker Center has provided a setting of suitable gravitas for student experiences in this program. Furthermore, the Baker Center is committed to honoring Senator Baker's legacy of civility and public service, which provides an atmosphere conducive to amplifying the State Department's mission of solving complex international issues (such as nuclear security) through diplomacy and engagement.

The program objectives parallel current successes in the aforementioned classes in Nuclear Engineering and Political Science. These programs, curriculum, and training materials (for domestic and international participants):

- Enable participating nuclear professionals from around the world to understand and appreciate their roles in an effective nuclear security system,
- Provide valuable professional development and nuclear security context for international technical experts, enabling them to assume leadership on nuclear security issues at their respective institutions, and
- Provide both traditional academic credit and an appropriately accredited professional certification.

3.1 Academic Component

The academic course component provides a sound basis for nuclear professionals to understand and appreciate their role in a global, regional, and local system for nuclear security. These course materials cover the principles of nuclear security in the international context, expose students to the various regulatory and international treaty considerations that are important, and prepare students for the challenge of identifying, adapting, embracing, and sustaining strong systems of nuclear security in their day-to-day work. These courses:

- Integrate international participation with the global technical community by attracting students from around the world,
- Advance the adoption of strong principles of nuclear security through direct educational interaction with current and future decision makers in priority countries,
- Familiarize students with other international bodies that seek to enhance nuclear security (such as World Institute for Nuclear Security (WINS), International Atomic Energy Agency (IAEA), World Nuclear University, etc.), and
- Leverage UT and INS partner experts and existing curriculum.

The academic course component draws from some of the existing coursework in the existing UT Nuclear Security Science and Analysis certificate program [5], the global security track in the Master's in Public Policy and Administration in the Department of Political Science, the graduate course on science and technology policy in the Physics Department, and experiential learning from our regional partners. These courses and related modules, which already address many of the IAEA recommendations for educational programs in nuclear nonproliferation and security, are currently in the "traditional" semester format and are being adapted to the compressed delivery format.

We are also working with staff at our regional partners (ORNL, ORAU, and Y-12) to assess our overall curriculum against the needs, requirements, and any recommended content from all US Government (USG) agencies and related nuclear security concerns in the private sector that are potential career placement opportunities for our graduates. Many of these agencies have not developed specific educational requirements for their mission objectives, so this assessment is more complex than the assessment already completed against IAEA recommendations. Where recommended content exists from agencies such as the Department of Energy or the Nuclear Regulatory Commission, we will incorporate the appropriate materials into the curriculum.

The academic class portion of the program provides 3 semester credit hours of academic credit from the Graduate School of the University of Tennessee upon successful completion of the course. This credit may be transferred (at the discretion of the receiving institution, of course) or applied to graduate study at UT if the recipient elects to pursue further graduate study with UT.

3.2 Certificate Component

Through the certificate component of our program, we provide the participating students with extensive experiential learning opportunities through our partners.

In some cases, we can take advantage of important existing opportunities with our partners – for example, ORNL operates their Safeguards Laboratory as an IAEA inspector training facility. Utilizing this facility, our participants can get hands-on experience conducting measurements on real nuclear materials and learn more about the overall IAEA process for monitoring nuclear facilities in their home countries. Likewise, Y-12 provides physical security training to a number of foreign nationals as part of the Global Threat Reduction Initiative, and these training capabilities could potentially serve as a basis for a class exercise or demonstration.

We also partner with the Tennessee Valley Authority (TVA), which operates several nuclear power stations that are relevant tour sites. Watts Bar and Sequoyah Nuclear Power Stations are operating nuclear power stations within less than two hours' driving distance from UT. Bellefonte Nuclear Power Station is approximately 3 hours' driving distance. The Watts Barr Unit 2 reactor facility was deferred during initial construction and is now being reactivated, and hence is a beneficial opportunity to view a nuclear power plant under construction.

Active new builds for new nuclear power stations provide useful examples of integrating best practices in nuclear security throughout the planning and construction “front end” of building a peaceful uses of nuclear energy capability. For nations that are undertaking their first builds (or considering it), this is an invaluable opportunity to see how the nuclear “3S” (safety, security, and safeguards) culture is incorporated into the very beginning of construction.

In addition to the experiential sites listed above, there are also a number of smaller private sector concerns (instrument manufacturers, analytical laboratories, waste management facilities, transportation companies, etc.) that are engaged in nuclear operations in the vicinity of UT. These facilities, when available, also provide useful tour sites and perspectives on the breadth of the nuclear enterprise.

At the conclusion of this portion of the program, successful participants receive a certificate from the INS. Additionally, for those participants whose professions recognize or require Continuing Education Units (CEUs), UT awards an appropriate number of CEUs. This is especially beneficial to participants who are US-licensed Professional Engineers (or the equivalent thereof).

4. Summary

UT's interests and activities in nuclear security education and research have created a unique set of qualifications and capabilities that are particularly beneficial to developing the next generation of nuclear security experts. UT has demonstrated its ability to develop transformative curricula in nuclear security education through highly qualified faculty with expertise in nuclear security. UT also fosters a strong culture of partnership and collaboration with key nuclear industries in the region that are particularly beneficial to these academic programs.

The INS was established in recognition of the fact that the ability to sustain efforts in nuclear security is eroding as the population of skilled personnel in this field declines, yet the national/global need for expertise and new capabilities in this area is growing. Our regional partners, ORNL, Y-12, and ORAU are in a unique position for solving crucial problems in global nuclear security. Collectively, the members of the INS bring together close organizational ties, geographic co-location, and access to working nuclear facilities – including reactors, accelerators, hot cells, and special nuclear materials, all engaged in nationally and globally relevant work.

The INS educational objective is to establish a robust set of collaborative projects in nuclear security that create needed educational and training offerings across multiple academic units at UT and among the INS members, building on the collective expertise and capabilities of the Institute. This leverages the success of the existing graduate certificate program in nuclear security in the Department of Nuclear Engineering, which already heavily engages ORNL and Y-12 in the University's graduate education efforts.

5. References

- [1] H. L. Hall, J. N. Sumner, A. Icenhour, J. Stainback, C. Clark, C. Robinson, E. Abelquist, and A. Garrison, in *Proceedings of the Annual Meeting of the Institute for Nuclear Materials Management* (Institute for Nuclear Materials Management, 2012).
- [2] H. L. Hall, H. L. Dodds, J. P. Hayward, L. H. Heilbronn, J. W. Hines, H. Liao, G. I. Maldonado, L. F. Miller, R. E. Pevey, A. E. Ruggles, L. W. Townsend, and B. R. Uphadhyaya, in *Proceedings of the Pacific Northwest International Conference on Global Nuclear Security—the Decade Ahead* (Institute of Nuclear Materials Management, 2010).
- [3] N. Wogman, L. Bond, A. Waltar, and R. Leber, *Journal of Radioanalytical and Nuclear Chemistry* **263**, 137 (2005).
- [4] D. Prosnitz, *Science* **310**, 978 (2005).
- [5] H. Hall, in *Proceedings of the Annual Meeting of the Institute for Nuclear Materials Management* (Institute for Nuclear Materials Management, 2012).

EXPERIENCES OF APPLICATION OF BEHAVIOURAL SCIENCES METHODOLOGIES TO THE OBTAINING OPERATING LICENSE PROCESS

J.L. MARTINEZ-SORIA, F.J. RUIZ-MARTINEZ, L. VAZQUEZ-RODRIGUEZ
Nuclear Training, Tecnatom

ABSTRACT

The aim of this study is to analyse the possibilities of knowledge and intervention aspects of the subjects' behaviour, taking into account its influence, increasingly recognized, in the safe operation of the NPP. Tecnatom has undertaken the implementation of Behavioural Sciences methodologies whilst obtaining an Operating License in two different areas: 1. Exploratory analysis about the influence of aptitudes and personality traits on academic achievement during training to obtain an Operating License; 2. Systematic and progressive training, for one person, aimed at reducing and eliminating motor, cognitive and physiological anxiety responses in an oral exam situation, after a previous diagnosis of the problem. The outcomes obtained can be applied proactively and preventively to facilitate proper recruitment processes and emotion management, respectively.

1. Overview

The experiences presented focus on the training processes associated with obtaining an Operating License, and thus reinforce the need for the application of Behavioural Sciences methodologies to improve operational safety of Nuclear Power Plants (NPP).

In the first section, we present an exploratory study that aims to identify those intellectual and personality variables that predict optimal academic performance during training for the Operating License. In the second section, we present the results of a systematic training in stress management for better coping anxiogenic situations and appropriate emotion management.

2. Study 1

2.1. Introduction

The personnel selection in the nuclear sector is a field of study of undoubted interest. The Human Factor pre-eminence as a determinant of the plant safety conditions has been manifested largely. Furthermore, the individual has an important role in strengthening or weakening the safety culture (INSAG, 1991; Haber, 1991)¹². For these reasons, it seems logical that a proper recruitment process will increase the safety margins in the organization and, conversely, an inadequate recruitment reduces these margins.

In this context, the personnel selection of Control Room Operators stands above the rest due to the inherent characteristics of the job. However, the selection of Control Room Operators must also identify applicants who successfully complete the previous training to job. Thus, recruitment maintains a double criterion: first, to assess the skills associated with worker profile, and secondly, to assess the skills associated with student profile.

This study focuses on identifying what skills and personality traits facilitate academic performance of future Control Room Operators, and evaluates whether the results are aligned with the competencies required for the job. To do this, we carry out a cross-sectional analysis in which crosses the data collected at the time of recruitment with the scores obtained during the training.

2.2. Objectives

1. To identify those skills / attitudes / competencies that promote academic achievement in obtaining licenses and outline a high performance student profile.
2. To explore the alignment between student profile and job profile required for future Control Room Operators.

2.3. Method

Participants

The study includes data from 70 subjects who passed the recruitment process and initiated the formation of Operating License, 62 males (88.6%) and 8 women (11.4%). These different promotions ended formative period between 2003 and 2012. The sample has been split into two cohorts (39 and 31) because it is not possible to homogenize all variables for different promotions. However, the final evaluation has been made globally.

Measures

General Mental Ability Tests: Raven's Progressive Matrices, Differential Aptitude Tests (DAT-5), Memory Test, Toulouse Pieron (Attention and Perception Test).

Personality Tests: 16 Personal Factors (16 PF-5), Constructive Thinking Inventory (CTI), Personality and Preferences Inventory (PAPI).

Specific Tests: Oral and Written Communication, Values and Personal Disposition to Safety Questionnaire (VPDSQ).

Procedure

This study uses data collected, using tests shown above, in each recruitment process and compares it with the scores obtained during the Operating License training. The number of factors contrasted is 66 (37 for the first cohort, 29 for the second cohort), amongst which include intellectual abilities and personality variables.

Data Analysis

We conduct an analysis of Pearson product-moment correlations between scores on each of the training phases and the factors evaluated in the recruitment process; we implement Student's t-test to compare differences between the Successful group (ends training) and the Unsuccessful group (not training ends), and finally, we perform an Analysis of Variance (ANOVA) to explore differences between the high performance group, the middle performance group and the lower performance group during training.

2.4. Results

Pearson product-moment correlation

The correlations between the different variables evaluated and scores achieved during training (see Table 1) can be grouped in two main groups. The first one is related to intellectual skills, particularly with crystallized intelligence (verbal ability and memory) and its influence is observed throughout the training process; the second group is related to psychological stress, where moderately elevated levels achieve best results in the oral assessment.

Table 1: Pearson product-moment correlation

		Phase 0	Phase I	Phase II	Phase III (Oral)	Thematic Areas	Total Average
Memory	Correl.	,331(*)	,386(*)	0,189	0,298	0,182	,334(*)
	Sig.	0,042	0,017	0,261	0,078	0,289	0,040
	N	38	38	37	36	36	38
Verbal Ability - 1	Correl.	0,305	0,320	0,358	,424(*)	0,193	0,309
	Sig.	0,095	0,079	0,052	0,022	0,317	0,091
	N	31	31	30	29	29	31
Verbal Ability - 2	Correl.	0,174	0,128	0,194	0,341	,607(**)	0,350
	Sig.	0,376	0,515	0,323	0,082	0,001	0,068
	N	28	28	28	27	27	28
Emotional Stability - 1	Correl.	-0,243	-0,320	-0,283	-0,172	-0,260	-0,309
	Sig.	0,141	0,050	0,089	0,316	0,126	0,059
	N	38	38	37	36	36	38
Emotional Stability - 2	Correl.	-0,327	-0,062	-0,225	-,515(**)	-0,270	-0,326
	Sig.	0,096	0,759	0,260	0,007	0,183	0,097
	N	27	27	27	26	26	27
Tension	Correl.	0,219	0,230	0,149	,338(*)	0,203	0,269
	Sig.	0,186	0,164	0,377	0,044	0,235	0,103
	N	38	38	37	36	36	38
Anxiety	Correl.	0,257	0,212	0,189	,427(**)	0,244	0,292
	Sig.	0,120	0,202	0,263	0,009	0,151	0,076
	N	38	38	37	36	36	38

*. Statistical significance < 0,05 (bilateral).

** . Statistical significance < 0,01 (bilateral).

Student's t-test

The result obtained in the Student's t-test shows significant differences only in one factor: Social Boldness (see Table 2 and 3). This factor is directly related to extraversion-introversion traits. As can be imagined, the bolder students socially and uninhibited are more likely to fail in training versus those students more shy and sensitive to the threat.

Table 2. Student's t-test. Statistics.

	Training Result	N	Average	Stand. Desv.	Average Standard Error
Social Boldness	Successful	33	5,73	1,825	,318
	Unsuccessful	6	7,33	,816	,333

Table 3. Student's t-test. Independent samples test.

	t	df	Sig. (bilateral)	Aver. Difference	Differ. Stand. Error
Social Boldness	-2,100	37	,043	-1,606	,765

ANOVA

Regarding the ANOVA, we get differences in memory and anxiety factors (see Table 4). In both cases the differences are between the High Performance and Low Performance group (see Figure 1 and 2). These results indicate that those students with high memory and a moderate level of psychological stress will get better results in the formation.

Table 4. ANOVA

		Sum of Squares	df	RMS	F	Sig.
Memory	Inter-groups	42,026	2	21,013	5,409	,009
	Intra-groups	132,082	34	3,885		
	Total	174,108	36			
Anxiety	Inter-groups	12,805	2	6,402	3,677	,036
	Intra-groups	59,195	34	1,741		
	Total	72,000	36			

Figure 1. ANOVA. Memory.

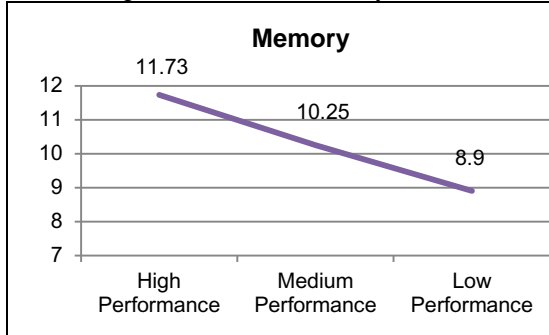
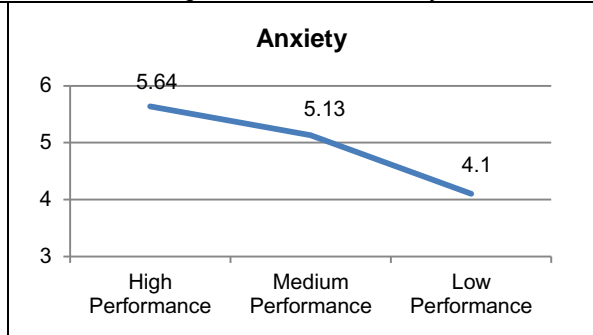


Figure 2. ANOVA. Anxiety.



2.5. Discussion

The results allow us to outline a successful student profile. This profile is characterized by high memory and verbal ability, moderate levels of psychological stress and task orientation. At this point, it is important to reflect on the alignment of these features with the Control Room Operator profile. For instance, while the student uses crystallized intelligence to overcome the training period, the Control Room Operator should employ fluid intelligence in solving complex problems. Also, it is important to maintain moderate levels of psychological stress; however, that brings the person near the borders of anxiety and could become disabling (Yerkes, 1908)³. Precisely, the following study addresses to this topic. And finally, the people orientation is, at least, equally important that the task orientation, as has been demonstrated in several studies about constructive culture (Cooke, 1988)⁴. For this reason, it should be promoted during the training period to avoid excessive concentration on the task.

3. Study 2

3.1. Introduction

The following study is related to the subject of psychological stress aforementioned. It concerns an intervention on a student who showed high levels of anxiety during oral evaluations of the Operating License training. This person has high intellectual abilities, highlighting in memory, and is characterized by introverted personality traits, with a clear focus on the task. In addition, levels of psychological stress at the time of recruitment were normal. His academic performance was adequate, overcoming properly written evaluations. However, in the oral evaluations he showed thought locked and nervous symptoms that kept him off from doing assessments adequately. In this situation, it was decided to make a diagnosis of symptoms and proceed with a systematic and progressive training, aimed to reduce and eliminate motor, cognitive and physiological anxiety responses in an oral exam situation.

3.2. Objectives

1. Reduce intensity and frequency of cognitive and physiological anxiety responses.
2. Learn skills to cope with anxiety in oral evaluations.
3. Increase self-esteem.

3.3. Method

Diagnosis

Diagnosis is performed by the State-Trait Anxiety Inventory (Spielberg, 1983)⁵ and several personal interviews with staff training and the trainee. The diagnosis result was high State

Anxiety (situational), keeping normal rates in Trait Anxiety (see Table 5). Specifically, the person manifested *Specific Phobia of Situational Type* (APA, 2002)⁶. This type of phobia is linked to lack of coping resources and intense stress experiences. Its consequences are impeding the processes of attention and concentration temporarily, and reducing social competence and self-esteem.

Table 5. STAI Results.

State-Trait Anxiety Inventory (STAI)		
	State Anxiety	Trait Anxiety
Direct Score (Percentile)	29 (80)	11 (13)

Training Techniques

- **Systematic desensitization (Wolpe, 1958)⁷**: Systematic desensitization is a type of behavioural therapy used to help effectively overcome phobias and other anxiety disorders. To begin the process of systematic desensitization, one must first be taught relaxation skills in order to extinguish fear and anxiety responses to specific phobias. Once the individual has been taught these skills, he or she must use them to react towards and overcome situations in an established hierarchy of fears.
- **Rational Emotive Behaviour Therapy (Ellis, 1977)⁸**: REBT is a therapeutic system to help people see the ways in which they have learned how they often needlessly upset themselves, teach them how to un-upset themselves and then how to empower themselves to lead more fulfilling performances.

Procedure

First, we carried out the diagnosis phase. Once we had identified the problem, we selected the techniques to implement the training. The training lasted for five months and there were 5 face-to-face sessions with the specialist plus a set of individual tasks, together with permanent contact by telephone and e-mail. The tasks included focused on physiological, motor and cognitive anxiety responses.

3.4. Results

After training, the student shows a significant improvement. He faces oral assessments obtaining very satisfactory results. In physical, behavioural and cognitive level, the student is able to control his responses to the stressful situation appropriately. In the graphs, we can see the differences reached after training in the State Anxiety factor (see Figure 3); further, it is possible to check how the student keeps Trait Anxiety levels (Figure 4).

Figure 3. State Anxiety.

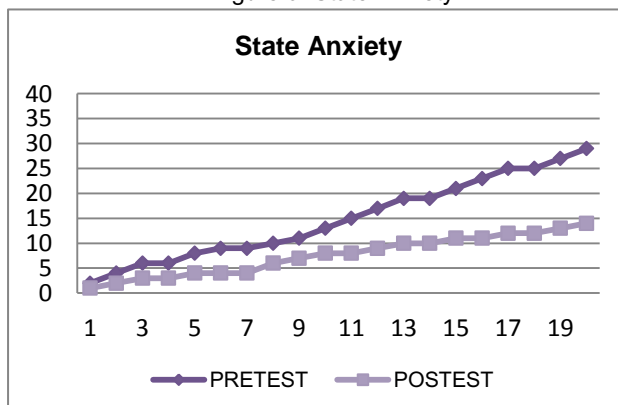
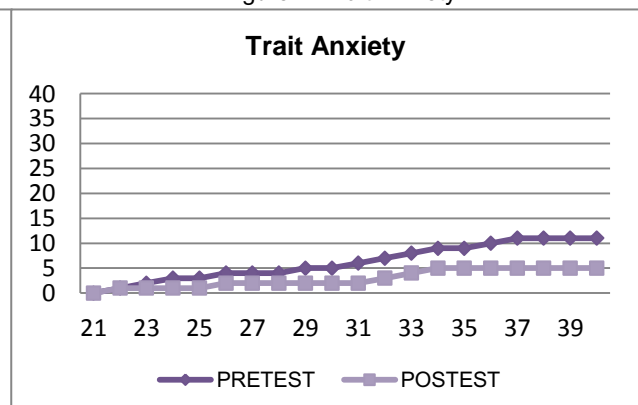


Figure 4. Trait Anxiety.



To contrast statistically the difference observed in State Anxiety, we perform the Wilcoxon signed-rank test. The result is $p < 0.05$ (see Table 6), confirming the effect of the training.

Table 6. State Anxiety Pretest-Posttest

	State Anxiety Pretest - Posttest
Z	-2,829
Sig. (bilateral)	,005

3.5. Discussion

The training has been proven effective, as already found in previous studies (Wine, 1980)¹⁰. It is important to be successful conduct an early detection and act quickly. Also, it is a key the interdisciplinary collaboration between professionals from behavioural sciences, the teachers and the support staff group.

The implementation of Prevention and Intervention Programs in training achieves to control and reduce student anxiety before exams, and improves academic performance. Furthermore, it provides students with coping skills and stress management techniques to respond appropriately in stressful situations in their future work as Control Room Operator.

4. Conclusion

Applying Behavioural Sciences in Control Room Operators training has shown its effectiveness. First, it has allowed us to achieve more accuracy in the profile definition of incoming students. Thus, it is possible to obtain higher returns in the recruitment process and training periods. Likewise, the requirements of the training process can be rated high demand by students and trigger a process of stress, however, preventive and systematic training in coping skills and stress management will support the performance, both in the training period and in their future work.

5. References

- ¹ International Nuclear Safety Advisory Group, Safety Series No. 75-INSAG- 4 (1991). *Safety Culture*. International Atomic Energy Agency, Vienna, Austria.
- ² Haber, S.B., O'Brien, J.N., Metlay, D.S., and Crouch, D.A. (1991). *Influences of Organizational Factors on Performance Reliability*. NUREG/CR-5538, U.S. Nuclear Regulatory Commission, Washington, D.C.
- ³ Yerkes, R.M., Dodson, J.D. (1908). *The relation of strength of stimulus to rapidity of habit-formation*. *Journal of Comparative Neurology and Psychology* 18: 459–482.
- ⁴ Cooke, R. A., Rousseau, D. M. (1988). *Behavioural norms and expectations: A quantitative approach to the assessment of organizational culture*. *Group & Organization Studies*, 13, 245-273.
- ⁵ Spielberger, C.D., Gorsuch, R.L., Lushene, P.R., Vagg, P.R., Jacobs, G.A (1983). *Manual for the State-Trait Anxiety Inventory*. Consulting Psychologists Press, Inc.
- ⁶ American Psychiatric Association. (2000). DSM-IV-TR. *Diagnostic and Statistical Manual of Mental Disorders*. Masson.
- ⁷ Wolpe, J. (1958). *Psychotherapy by Reciprocal Inhibition*. California: Stanford University Press, 53-62.

⁸ Ellis, A., Grieger, R. (1977). *Handbook of rational emotive therapy*. New York: Springer.

⁹ Wine, J.D. (1980). *Cognitive-Attentional Theory of Test Anxiety*. In I.G. Sarason (ed.) *Test Anxiety: Theory, Research and Applications*. Hillsdale: Erlbaum.

ADVANCING NATIONAL AND JOINT NUCLEAR RESEARCH IN THE EUROPEAN UNION: THE NEWLANCER PROJECT

L. CIZELJ

*Jožef Stefan Institute, Reactor Engineering
Division
Jamova 39, SI-1000 Ljubljana, Slovenia*

D. DIACONU

*Institute for Nuclear Research Pitesti
Campului 1, RO-115400 Mioveni, Romania*

P. GHITESCU

*University "Politehnica" of Bucharest, Faculty of
Power Engineering
Splaiul Independentei 313, RO-060042
Bucharest, Romania*

I. IVANOV

*Technical University of Sofia, Electrical Power
Department
Boulevard Kliment Ohridski 8, BG-1000 Sofia,
Bulgaria*

I. TISELJ

*University of Ljubljana, Faculty of Mathematics
and Physics
Jadranska 19, SI-1000 Ljubljana, Slovenia*

N. ŽELEZNIK

*ARAO
Parmova 53, SI-1000 Ljubljana, Slovenia*

ABSTRACT

The NEWLANCER project examines the opportunities and challenges of the sustainable nuclear research and higher education in the European Union with special focus on the comparative performance of institutions from the old and new member states. The NEWLANCER project is funded by the European Commission within the 7th Framework programme (EURATOM). A brief presentation of the aims, organisation and achievements of the NEWLANCER project is given. These is followed by the preliminary results of the in-depth analysis of the participation of the institutions from the old and new member states in the 6th and 7th EURATOM Framework programmes (FP6, FP7). Some preliminary conclusions including proposals for future activities to advance both national and joint research in all member states of the EU will be given.

1 INTRODUCTION

European project NEWLANCER (NEW Member States Linking for an AdvANced Cohesion in EURATOM Research) [1] started in November 2011. It proposes to identify and implement effective and efficient actual solutions leading to enlarged involvement of new member states (NMS) of European Union (EU) in future EURATOM Framework Programmes by strengthening and catalysing the full R&D potential at national level, by increasing cohesion between new member states institutions, and by improving their cooperation with old member states (OMS) research centres.

The specific sub-objectives of the NEWLANCER project are [1]:

- Analysis of skills and current participation of NMS in EURATOM Projects aiming to review and assess NMS research capabilities and participation in EURATOM research and development (R&D) programmes (key issues, gaps, good practices and barriers, challenges, etc. with increased attention to the risk, safety and environmental aspects).
- Network for advanced cohesion in NMS nuclear research aiming to create a multi-level regional network having as mission to enhance cohesion and interact with national and European levels in order to strengthen future participation in European research.
- Good Practices and Recommendations aiming to collect and analyse relevant cases on New and Old MS participation in EURATOM Programmes and draw up good practices

and recommendations addressed to a large end-users spectrum: scientists, research managers, national authorities, European structures (for example technology platforms SNE-TP and IGD-TP) – interested in better use of entire research potential.

- Visibility and Connectivity aiming to ensure broad visibility of NMS research potential in Europe, to promote actual activities shared between networking partners, to publicize the project outcomes, and to create links with European structures with a major role in the configuration of nuclear research programmes.

The NEWLANCER project is carried out by 15 partners from 9 EU member states (6 new and 3 old). The diverse partnership includes research institutes, universities, governmental organization and consulting bodies (Fig. 1). Special focus of the NEWLANCER partners is given to generation IV reactors, materials, nuclear safety, radioactive waste management and disposal, radioprotection and education and training.

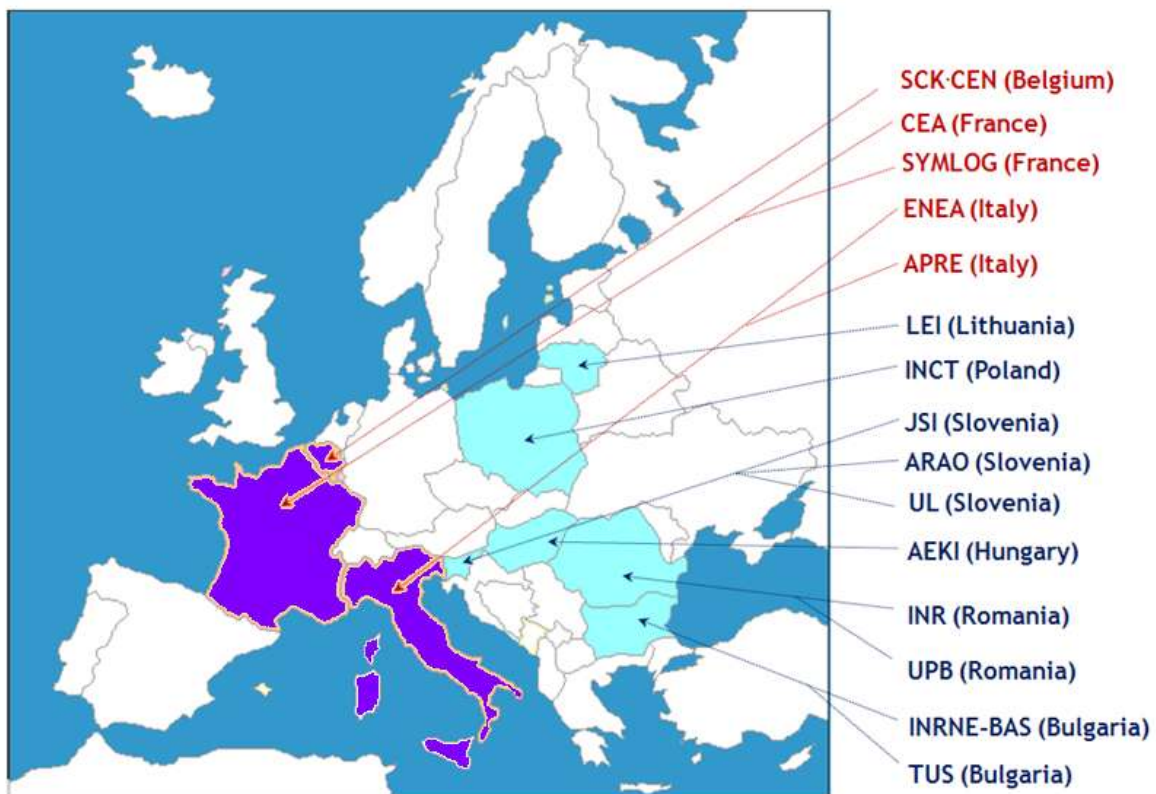


Fig. 1 Institutions and countries involved in NEWLANCER

To achieve the objectives of the NEWLANCER project the work is organized in coordinated regional networks, which consist of national expert groups in different fields of interest. In this way clusters of organizations dealing with similar topics are formed at regional level and are supported by old MS institutions.

In parallel, the analyses are being performed to determine the reasons for current low participation of NMS in EURATOM research projects (see Fig. 2) and to propose activities possibly leading to improvements in the future. Some preliminary insights from these analyses [2] are outlined in this paper.

All analyses presented in this paper assume that new members states (NMS) include the following EU members: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovak Republic and Slovenia. Old members states (OMS) include: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom.

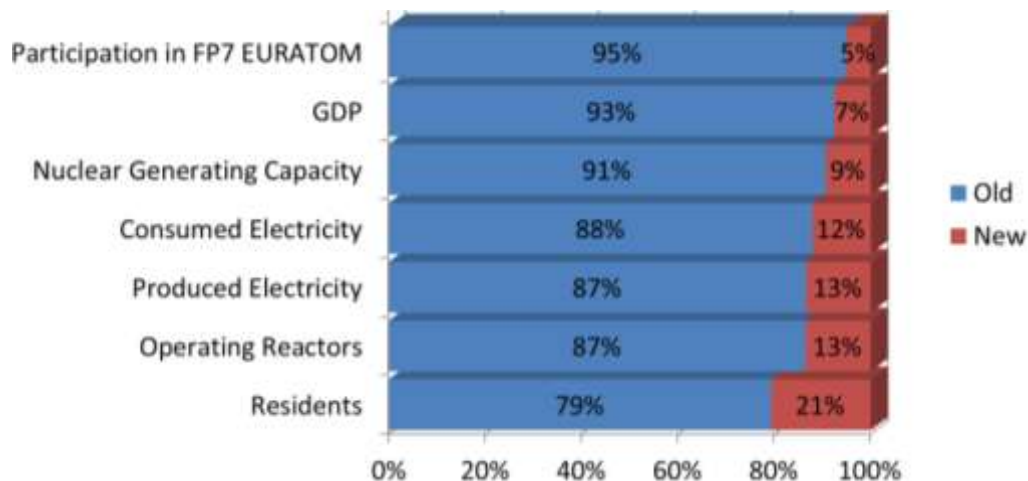


Fig. 2 Relative performance of old and new EU member states on selected statistical indicators

2 ANALYSES OF CURRENT EURATOM PARTICIPATION

A detailed analysis investigating and comparing qualitative and quantitative aspects of NEWLANCER NMS and OMS current participation in EURATOM programme has been performed [2]. One of the major aims was to obtain a balanced qualitative and quantitative assessment in a depth sufficient to identify the major reasons that determined the present involvement of the OMS and NMS in the EURATOM research and training programmes.

The quantitative analysis is based on the official data on the founded projects as obtained from the Directorate General (DG) Research for the EURATOM FP6 and FP7. The analysis focused entirely on the EURATOM participation. The quantitative analysis included the funded and rejected proposals.

The qualitative analyses relied on two information sources. First, a review of national strategies with relevance to the nuclear energy have been collected and analysed. Second, a questionnaire has been developed to collect the data of relevance to the operation, management and funding of the NEWLANCER partners.

Some details on the available data and methods used in the assessment are given together with the preliminary results below.

3 RESULTS

3.1 Review of national nuclear strategies

The review was limited to the national strategies of the NEWLANCER partners. The brief general conclusions include:

- The National Nuclear Strategies and Nuclear R&D programs in the NMS are in different rate available and developed – more in Hungary and Romania as independent document, and only as parts of other general country documents for energy policies, electrical systems, educational programs, etc. in Bulgaria, Slovenia, Lithuania and Poland. The National Nuclear Strategies and Nuclear R&D programs in the OMS are more representative for the nuclear activities, intentions and perspectives for further development, especially for France and Italy, partly also to due to their similarity with the European strategy defined by the SNE-TP.
- There is a need for a process of vertical harmonisation of the national nuclear strategies first with the European strategy defined by the SNE-TP and also greater horizontal harmonisation between separate NMS and also OMS.

- There are good preconditions and opportunities for joint actions for more successful participation of NMS in EURATOM R&D programs, especially for the topics “Nuclear Safety” and “Radioactive Waste and Spent Fuel Management”.

3.2 Quantitative data by EC

The quantitative assessment of current participation of new (NMS) and old member states (OMS) in the EURATOM research and training programmes is investigated through the analysis of a rather wide set of attributes.

The data has been collected in MS Excel files and aggregated as needed for this purpose. Linear trend curves based on the minimized sum of squared errors are used in some of the subsequent graphs. They are used as very rough indicators of trends in sometimes highly scattered data. It is noted however that the trend curves may change radically if some of the data points would be removed.

The requested and received EURATOM grants, aggregated by the OMS, NMS, Associated and Third countries, are depicted in Fig. 3 (FP6) and Fig. 6 (FP7). Participants from the new member states (NMS) which joined the EU after 2004 were beneficiaries of only about 5% of the total EURATOM FP6 and FP7 budget. Similar or larger part of the budget was spent on third countries and international cooperation. Slight decrease of the share of NMS may be seen in FP7 as compared to the FP6.

Breakdown of received EURATOM grants aggregated by country is illustrated in Fig. 4 (FP6) and Fig. 7 (FP7). The largest share among the NMS has been granted to institutions from the Czech Republic. Among the OMS, the largest shares of grants have been received by France, Germany, Belgium and Great Britain. The shares of individual countries generally decreased in FP7.

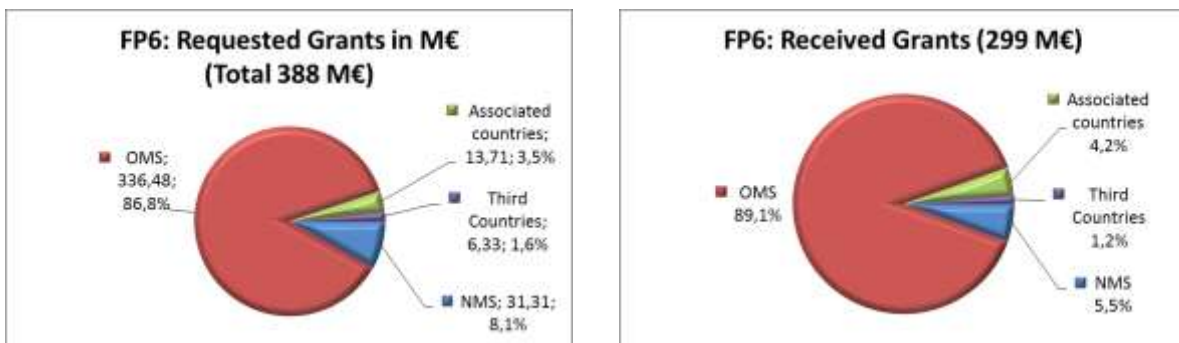


Fig. 3 Shares of requested and received FP6 EURATOM grants by groups of countries

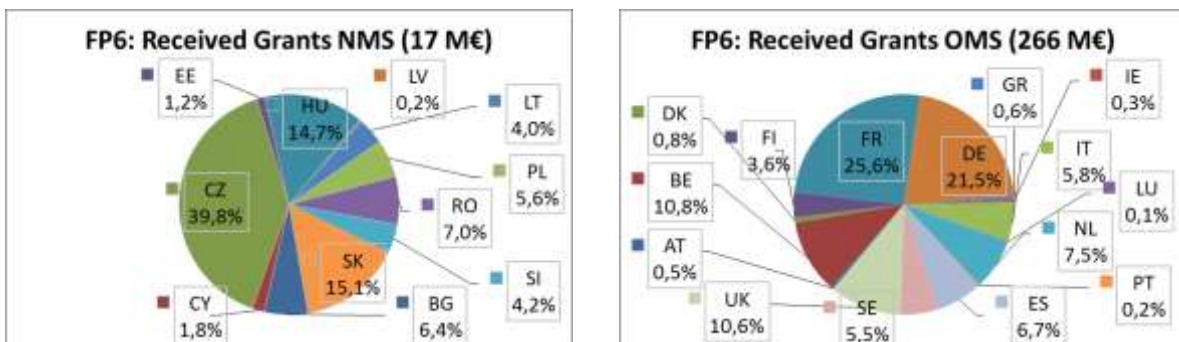


Fig. 4 Shares of received FP6 EURATOM grants by NMS and OMS

Success rates (received/requested grants) of OMS and NMS countries are depicted in Fig. 5 (FP6) and Fig. 8 (FP7). Success rates are clearly correlated with the size of the grants

received. It is clearly seen that much larger grants were requested/received by the OMS countries, who also had consistently larger success rates in FP6.

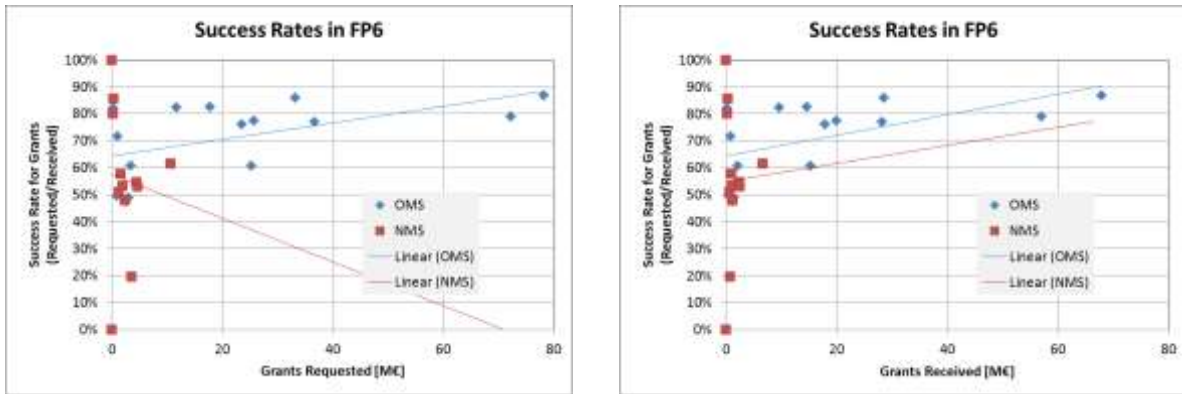


Fig. 5 Success rates of NMS and OMS in FP6 EURATOM calls as functions of grants requested (left) and grants received (right). Note: Linear trends are extrapolated far beyond the data for illustrative purposes. Grants are aggregated by country.

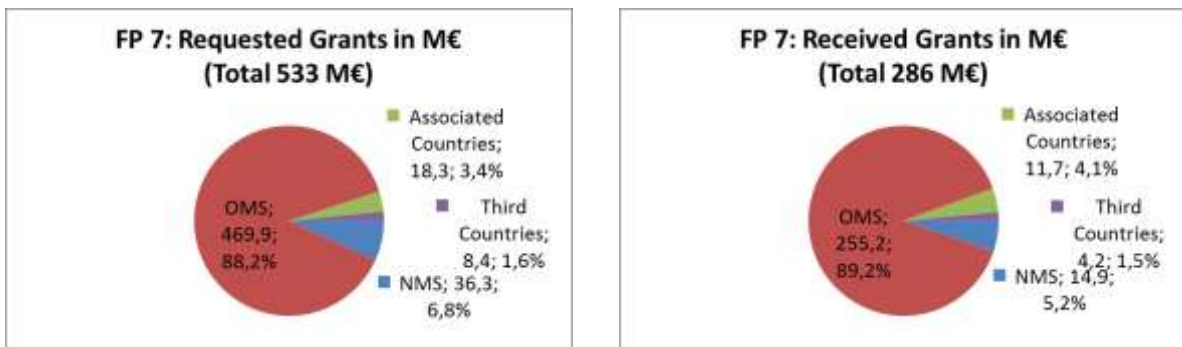


Fig. 6 Shares of requested and received FP7 EURATOM grants by groups of countries

The following attributes were also investigated in [2] and are not further detailed in this paper:

- EURATOM grants requested and received by project partner (limited to FP7 2008-2011);
- Shares of requested and received grants by country, group of country and/or project partners;
- Success rate of the country/partner, defined as the ratio between received and requested grants;
- Amount of EURATOM grants coordinated by country (or project coordinators in FP7 2008-2011);
- Success rates of the coordination by the country/partner, defined as the ratio between proposed and received grants;

Relative shares of grants between different types of members (e.g., universities, research centres etc. in the period FP7 2008-2011).

Although not shown in this paper, the selection process in both FP6 and FP7 clearly strengthened the relative position of the research organisations, preserved the relative position of the private for profit enterprises and weakened the relative position of the universities. The strengthening of research organisations and weakening of the universities is much more pronounced for the NMS. More details are available in [2].

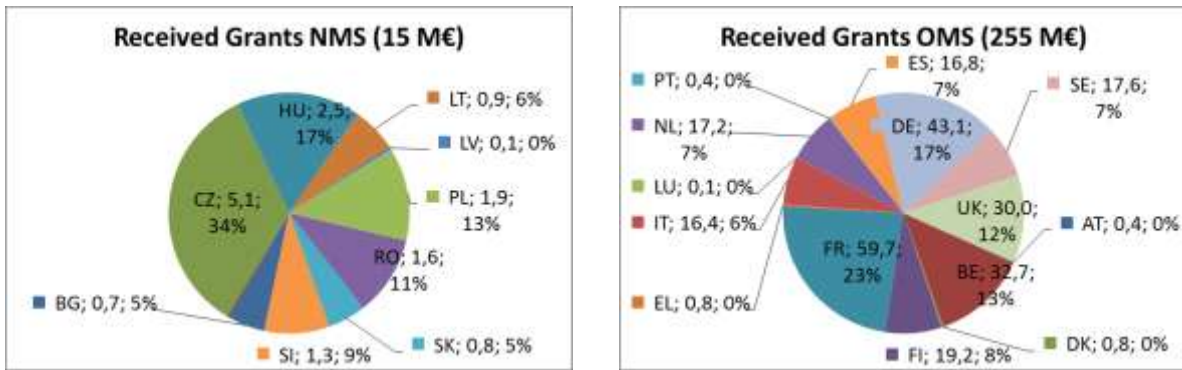


Fig. 7 Shares of received FP7 EURATOM grants by NMS and OMS

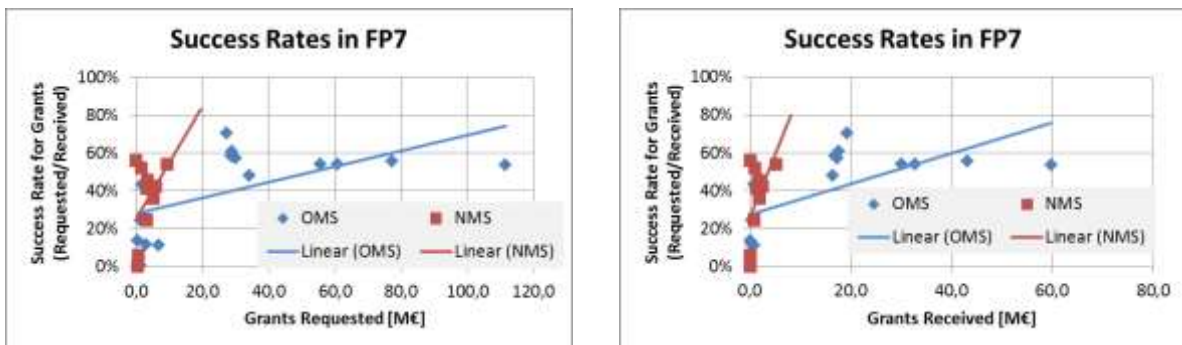


Fig. 8 Success rates of NMS and OMS in FP7 EURATOM calls as functions of grants requested (left) and grants received (right)

3.3 Questionnaire

A questionnaire has been developed to assess the main characteristics of the NEWLANCER partners. The questions were aiming at the description of the participating institutions (e.g., budget, number of researchers, and number of publications), their strategic research management (e.g., the degree of institutional autonomy in defining research topics) funding, main research topics and performance within EURATOM research programs.

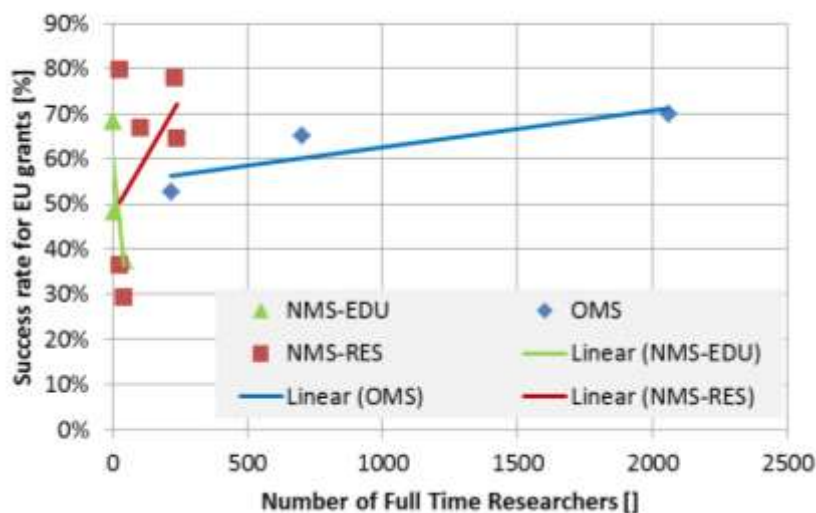


Fig. 9 Success rates of NEWLANCER partners with respect to the number of full time researchers

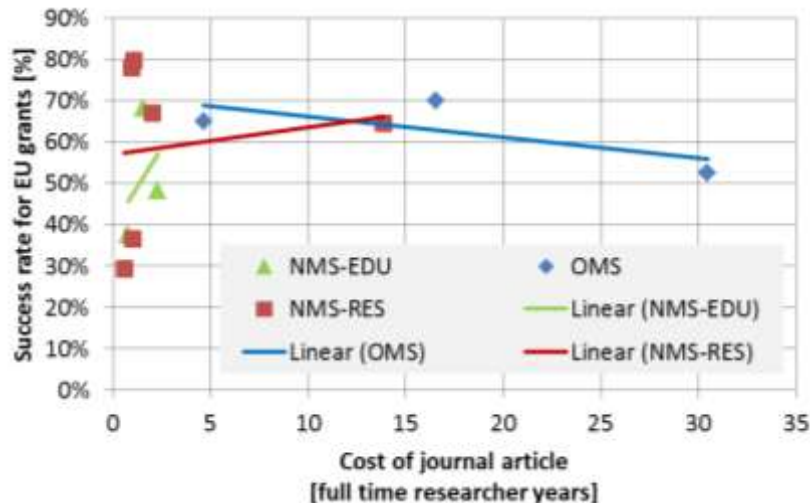


Fig. 10 Success rates of NEWLANCER partners as EURATOM project partners with respect to the cost of journal article

To cope with rather large diversity of research institutions both in OMS and NMS, two answers were expected for each question: one indicating the estimated current status and the second the belief about the optimal status for this particular institution. The difference between the current and optimal has been then used as the basis of comparison.

Fig. 9 depicts the success rate of the OMS and NMS institutions as a function of the size of the institutions, measured in the terms of full time researchers. The OMS organisations can be much larger than those from NMS. Please note that the NMS-EDU denotes universities and NMS-RES research organisations from NMS. Larger institutions seem to have larger success rates, with NMS universities possibly being an exception to this rule.

Fig. 10 correlates the success rates of the institutions with the average cost of a journal article, measured in the researcher years. Please note that the budget available for a researcher year may vary up to a factor 10 between the NEWLANCER partner institutions. Fig. 10 clearly shows that the success rate does not depend significantly on the resources invested in journal papers.

3.4 Main findings

The research organizations from OMS have assumed a leading role and seem to be mainly interested in organizing, directing and of course also performing the large scale research projects with impact directed to the future of nuclear energy.

Organizations from OMS developed rather optimal strategic research management and funding and are better adapted for coexisting in EURATOM and national programs. The size and tradition of these establishments together with relatively stable societal and economic conditions in the last few decades are certainly strong factors.

Organizations from NMS seem to struggle both with the national and EURATOM research programs. It seems that strategic research management and funding of these organisations only marginally affect the success in EURATOM projects. It is possible that the current success depends mainly on the excellence and connections of individuals rather than from systematic approach of the organisations and/or nations.

The availability and applicability of NMS national strategies related to nuclear R&D and/or energy is rather diverse. There is needed process of vertical harmonisation of the National Nuclear Strategies first with the European strategy defined by the SNETP and hence in greater horizontal harmonisation between separate NMS and also OMS.

The lack of resources is a common threat to establishments from OMS and NMS. It may however be much more detrimental for the future of the research in the NMS.

Please note also that the large projects might be frustrating for researchers from small institutions and/or universities, as most of the budget is spent on meetings, administration and audits. Also, some member states, especially smaller and with lesser economic status, might be rather sensible even to small imbalances in the mobility.

A possible future mission for the EURATOM R&D may also be to develop and implement appropriate measures for a stronger support to the (smaller) member states in their obligations towards the nuclear safety, especially through excellent R&D activities. Some proposals will also be developed within NEWLANCER in the later stages of the project.

There are good preconditions and opportunities for joint actions for more successful participation of NMS in EURATOM R&D programs, especially for the topics “Nuclear Safety” and “Radioactive Waste and Spent Fuel Management”.

4 CONCLUSIONS

Participants from new member states (NMS) which joined the EU after 2004 were beneficiaries of only about 5% of the total EURATOM FP6 and FP7 budget. Similar or larger part of the budget was spent on third countries and international cooperation. It is noted that those NMS countries generally do have established nuclear programs. It is also noted that the research centres in OMS are generally much larger than research centres in NMS. The cost of the researchers in NMS may be up to 10 times smaller than in OMS.

A possible future mission for the EURATOM R&D may also be to develop and implement appropriate measures for a stronger support to the (smaller) member states in their obligations towards the nuclear safety, especially through excellent R&D activities. Some proposals will also be developed within NEWLANCER in the later stages of the project.

There are good preconditions and opportunities for joint actions for more successful participation of NMS in R&D EURATOM programs, underlined for the directions “Nuclear Safety” and “Radioactive Waste and Spent Fuel Management”, incl. with joint proposal-projects as soon as possible even in the next call of EURATOM with similar priorities.

5 REFERENCES

- [1] DoW: NEWLANCER – New MS Linking for an Advanced Cohesion in EURATOM research, grant agreement no. 295826, 20011-07-26, 7 FP, theme Fission-2011-6.02
- [2] Review of current participation of NMS and OMS in EURATOM Program and assessment of national strategies, edited by L. Cizelj, I. Ivanov, NEWLANCER, May 2012

ENC
2012

EUROPEAN NUCLEAR CONFERENCE



**POSTER:
EDUCATION & TRAINING**

NUCLEAR POWER TECHNOLOGY TRAINING PROGRAMMES IN SOUTHEAST TEXAS (USA)

RUDOLPH HENRY

*Nuclear Power Technology, Wharton County Junior College
911 Boling Highway, Wharton, Texas 77488 – USA*

REBECCA SHAWVER

*Grants Administration, Brazosport College
500 College Drive, Lake Jackson, Texas 77566 – USA*

BRUCE KIELER

*Resource Development, Wharton County Junior College
911 Boling Highway, Wharton, Texas 77488 – USA*

ABSTRACT

Nuclear power technology training programmes have been developed at several community colleges in southeast Texas (USA) to meet the manpower needs of the nuclear power industry in Texas and elsewhere in USA. The programmes offer Associate and Baccalaureate of Applied Science degrees that are based on the *Uniform Curriculum Guide for Nuclear Power Plant Personnel* of the Nuclear Energy Institute (USA). This report examines the process of establishing and expanding nuclear power technician training programmes at community colleges, including development of communitywide consensus concerning the training programmes and development of crucial linkages with nuclear industry and university partners. It also examines the efforts to secure financial support for the programmes, strategies for recruitment of young men and women into the programmes, achievement of racial and ethnic diversity in enrollments, and use of state-of-the-art instructional equipment for 'hands-on' training of the students.

1. Introduction

In March 2007 the U.S. Department of Labour (DOL) published *Identifying and Addressing Workforce Challenges in America's Energy Industry* [1], which discussed the energy industry's needs for new workers, who would be recruited and trained with new skill sets in the coming 10 years. It was also noted that the average energy industry worker in USA was over 50 years of age and that approximately 50% of them were planning to retire within five to ten years. That meant that there would be a need to replace approximately 500,000 energy employees nationwide. In addition to the DOL assessment, two other workforce survey reports pointed out the same concerns. These survey reports included *Gaps in the Energy Workforce Pipeline* [2] by the Centre for Energy Workforce Development (CEWD) and *2007 Workforce Pipeline Survey* [3] by the Nuclear Energy Institute (NEI).

The NEI workforce report noted that Texas would need three new nuclear power plant maintenance training programmes and at least one new non-licensed operator training programme. At the time of the NEI study, Texas had only five generic nuclear training programmes and one radiation protection programme. Based solely on estimates of retirements and normal attrition, NEI recommended that two of the existing generic programmes be restructured to comply with the *Nuclear Uniform Curriculum Programme Guidelines* (ACAD 08-006) for maintenance staff and that another programme be restructured to comply with the *Uniform Curriculum* for operators [4].

To meet current and scheduled employment needs of its nuclear plants (i.e., South Texas Project Nuclear Operating Company and Comanche Peak Nuclear Power Plant), the State of Texas faced the daunting task of educating new workers while upgrading incumbent worker skills to fill attrition and new vacancies. It was determined that workforce

and education systems had to improve existing training programmes and develop new programmes, competency models, and career ladders.

In response to the specific needs of the nuclear power industry in southeast Texas, the **Texas Nuclear Power Technician Training Programme Partnership** was formed in 2007-08. This partnership was a coalition of community colleges, industry partners, community-based organisations and civic groups, school districts, chambers of commerce, and economic development agencies. The purpose of the coalition was to address two critical issues, namely, (1) the lack of adequate nuclear power technology training faculty, facilities, equipment, and curricula aligned with industry standards that were needed to educate and train workers to meet industry needs and (2) the need for community colleges in southeast Texas to develop and implement uniform, accredited nuclear power technology curricula and to expand industry-specific certificate, associate, and baccalaureate degree programmes, and to do so quickly.

To fulfill industry needs, the partnering colleges required well-trained faculty to develop and teach curricula aligned with industry standards and in compliance with the NEI's *Nuclear Uniform Curriculum Programme Guidelines* (ACAD 08-006). The community colleges realised that they would need upgraded equipment to provide adequate classroom and laboratory training that would be compatible with industry standards and with the *Uniform Curriculum*. The colleges also realised they would need to develop comprehensive recruitment and retention strategies to attract and retain students in the newly developed and expanded nuclear power technology training programmes, and all this was to be done with limited funds.

Playing crucial roles in the development of nuclear training programmes at the Wharton and Brazosport colleges were the Nuclear Power Institute (NPI) at Texas A&M University and the South Texas Project Nuclear Operating Company (STPNOC), as noted in Section 5 (below).

2. Literature Review

Establishment of the nuclear training programmes in southeast Texas depended on gaining communitywide consensus about the programmes and gaining university, industry, and educational support. The Texas nuclear training efforts demonstrated a level of community-based integration and partnership, which can be viewed in terms of a community coalition. Community participation in health, safety, and community development planning (including planning for educational programmes) occurs through a variety of community-based advisory groups, but especially through community-based coalitions. These coalitions can be loosely defined as a group of individuals representing diverse organisations, factions, or constituencies within a community who agree to work together to achieve a common goal (adapted from Feighery and Rogers) [5]. Community participation in health, safety, social, and educational projects can take a variety of forms, and there can be variations in the extent of community participation. Coalitions as organisations are highly flexible and can engender strong support locally from the communities participating in this type of planning process.

Because the Texas nuclear power technology training partnership appeared to have characteristics of several types of coalitions, including those pertaining to grassroots coalitions, community-based coalitions, and action-set coalitions, the establishment of nuclear training programmes at community colleges in southeast Texas was viewed as an example of a community-based action-set coalition in action. Butterfoss [6] noted that the concepts and assumptions underlying community development, citizen participation, empowerment, community capacity, community competence, and social capital provided the groundwork for the coalition as a community-organising model and as a strategy for resolving community issues and achieving community goals (p.12). It also noted that community coalitions have 'the potential to involve multiple sectors of the community and to conduct multiple interventions that focus on both individuals and their environments' (p.16) and that community coalitions are 'a promising strategy for building capacity and

competence among member organisations and, ultimately, in the communities they serve' (p.17).

Community participation in health, safety, community development, and educational planning, especially through community-based coalitions, is also noted in numerous theoretical perspectives found in the literature of organisational behavior, including institutionalisation of organisations [7,8,9,10], organisational change [11], organisational development [12,13], and organisational alignment with the environment [14].

3. Methodology

This qualitative study of the establishment of the nuclear power technology programmes at community colleges in southeast Texas (namely, Wharton County Junior College and Brazosport College) utilised a variety of observational research methods, including attending, observing, and recording planning meetings; attending, observing, and recording specific subcommittee meetings; interviewing members of the coalition; interviewing key participants (i.e., representatives of educational institutions, nuclear power plant administrators, representatives of civic organisations, directors of local economic development boards, and interested citizens); assisting with drafting applications for financial support from agency, state, and federal sources; and examining documents related to the operation of the programmes since their inception in 2007-2008. It also included attendance at summits sponsored by the Nuclear Energy Institute and the Centre for Energy Workforce Development.

4. Nuclear Power Technology Coalition Members

The following entities, colleges, and agencies played important roles in fostering and gaining community, civic, educational, industry, regulatory, and business consensus concerning establishment of nuclear power technology training programmes at community colleges in southeast Texas.

Name of Organisation	Type of Organisation
Brazosport College, Lake Jackson, Texas	Community College Partner
Wharton County Junior College, Wharton, Texas	Community College Partner
Victoria College, Victoria, Texas	Community College Partner
Texas State Technical College, Waco, Texas	Community College Partner
Texas Higher Education Coordinating Board	State of Texas Education Partner
Texas Workforce Commission, Austin, Texas	State of Texas Workforce Partner
Texas A & M University, College Station, Texas	University Partner
South Texas Project Nuclear Operating Company	Nuclear Industry Partner
Nuclear Energy Institute, Washington, DC	Industry Association Partner
Bay City Economic Development Corporation	Economic Development Partner
Wharton Economic Development Corporation	Economic Development Partner
Bay City Chamber of Commerce & Agriculture	Business Association Partner
Wharton Chamber of Commerce & Agriculture	Business Association Partner
Brazosport Area Chamber of Commerce	Business Association Partner
Victoria Chamber of Commerce & Agriculture	Business Association Partner
Bay City Independent School District	School District Partner
Wharton Independent School District	School District Partner
Victoria Business/Education Coalition, Women's Job Corps, Golden Crescent, & Boys and Girls Club	Community Partners

5. Implementation of the Nuclear Power Technology Plan for Southeast Texas

The four colleges in the Texas partnership included Wharton County Junior College, Brazosport College, Victoria College, and Texas State Technical College. These colleges began to explore ways to obtain funding to develop and operate new or expanded nuclear power technology training programmes. They also sought funding to hire faculty,

purchase state-of-the-art nuclear instructional equipment, and develop curricula that would comply with the *Uniform Curriculum* (ACAD 08-006). Approvals for the colleges to develop new training programmes and expand current ones were quickly obtained from the Texas Higher Education Coordinating Board, which oversees academic and vocational training programmes in Texas.

Texas Agricultural and Mechanical University (i.e., Texas A & M University) provided significant assistance and guidance to the colleges as did the South Texas Project Nuclear Operating Company (the industry partner). Initially, the Texas Engineering Experiment Station and the Nuclear Power Institute at Texas A & M University provided initial funding as well as valuable guidance in implementing the training programme and in obtaining federal funding.

The Nuclear Power Institute (NPI) at Texas A&M University played a major role in providing guidance to the Wharton programme and in advocating for it at national and international meetings, both in USA and in Mongolia, Nigeria, Jordan, and the United Arab Emirates, among others. NPI made extraordinary efforts to highlight the achievements and quality of the nuclear power programme at Wharton County Junior College (WCJC) and arranged for Rudolph Henry, the Director of the Nuclear Power Technology Programme at WCJC, to participate in the General Conference of the International Atomic Energy Agency so that he could meet the leadership of IAEA and representatives of several national delegations, who wanted to know more about the Wharton programme. NPI also included the Wharton programme on the itinerary of various international nuclear energy delegations when they visited Texas. NPI is currently structuring new very far-reaching training programmes that could bring students from nuclear 'newcomer' countries to the Wharton programme to be trained in nuclear power technology. According to Dr. Kenneth Peddicord, Director of the Nuclear Power Institute, the NPI believes 'in the importance and value of the WCJC programmes and the critical role these offerings can play in human resource development for the nuclear industry on a global level.' He said that '[we] see our collaboration with WCJC to be at a strategic level.' [Personal communication with Dr. Kenneth Peddicord, Fall 2012.] With this in mind, NPI arranged for Mr. Henry to go to Washington, DC in December 2012 to make presentations concerning nuclear power training programmes to members of the U.S. Congress, Congressional Committee staff members, the Deputy Secretary of Energy, and the Assistant Secretary for Nuclear Energy.

6. Support from Industry Partners

The South Texas Project Nuclear Operating Company (STPNOC) played a major role in facilitating the effort to establish nuclear power technology training programmes at community colleges in southeast Texas. It provided crucial and timely letters of support, in-kind support, and an Educational Incentive Programme for Entry Level Employment at STPNOC. The incentive programme is a special scholarship programme to award grants, through a competitive process, to students enrolled in the nuclear technology programmes. Students selected for the Entry Level Employment programme receive additional trainings at the nuclear power plant through summer internships.

A second important partner in promoting and facilitating the establishment of nuclear power technology training programmes at community colleges in southeast Texas was the Nuclear Energy Institute (an industry association), headquartered in Washington, DC. Both the Wharton and the Brazosport programmes were developed in strict compliance with the NEI's *Nuclear Uniform Curriculum Guidelines*, which require adherence to standardised curricula for training nuclear power technicians (ACAD 08-006). These guidelines are now being utilised at all colleges in USA that offer nuclear technology programmes under the Nuclear Uniform Curriculum Programme of the Nuclear Energy Institute.

7. Funding for Nuclear Power Technology Programmes in Southeast Texas

The following table presents information on the funding that was obtained by the two leading colleges in the Texas partnership and that have the largest enrollment of

trainees. Since 2008, the Wharton and Brazosport nuclear power technology programmes have been the recipients of grants from federal, state, university, and economic development agencies. The award from the U.S. Department of Labour (2009-12) was shared by the four colleges that were originally participating in the Texas nuclear technology training coalition. However, Victoria College withdrew from the partnership in 2011 after plans for constructing a nuclear power generating plant in its service area were cancelled.

Period	Funding Source	Amount	Purpose
2008-10	Texas A&M University, Nuclear Power Institute, Texas Engineering Experiment Station, & Texas Workforce Commission	\$105,000 (WCJC)	Implementation & on-going operations of the nuclear technology training programme
2009-12	U.S. Department of Labour	\$1,800,000 (for 4 colleges)	Nuclear instructional equipment & operations
2009-11	Texas A&M University, Nuclear Power Institute, Texas Engineering Experiment Station, & American Recovery and Reinvestment Act	\$175,000 (WCJC)	Operations & expansion of the WCJC nuclear technology training programme
2009-10	U.S. Nuclear Regulatory Commission	\$150,000 (WCJC) \$120,000 (BC)	Scholarships for nuclear technology students
2009-10	State of Texas / Jobs & Education for Texans Office	\$350,000 (WCJC)	Instructional equipment for nuclear & process technology programmes
2009-10	Bay City Community Development Corporation	\$193,500 (WCJC)	Instructional equipment for nuclear & process technology programmes
2010-11	Nuclear Regulatory Commission	\$120,000 (WCJC) \$120,000 (BC)	Scholarships for nuclear technology students
2010-11	U.S. Dept. of Education	\$220,000 (WCJC)	Instructional equipment
2012-13	Nuclear Regulatory Commission	\$120,000 (WCJC) \$120,000 (BC)	Scholarships for nuclear technology students
2012-13	Nuclear Regulatory Commission	\$199,280 (WCJC)	Nuclear technology curriculum development
Pending	Nuclear Regulatory Commission	\$120,000 (WCJC) \$120,000 (BC)	Scholarships for nuclear technology students
Pending	Nuclear Regulatory Commission	\$156,500 (WCJC)	Nuclear technology curriculum development

Abbreviations: WCJC = Wharton County Junior College; BC = Brazosport College.

8. Wharton and Brazosport Nuclear Power Technology Programmes

At the conclusion of the DOL project, the Wharton and Brazosport programmes continued their partnership. Both colleges are public, two-year community colleges that are fully accredited by the Commission on Colleges of the Southern Association of Colleges and Schools (SACS). The colleges are authorised by the Texas Higher Education Coordinating Board to offer Associate of Arts and Associate of Applied Science degrees and curricula in preparation for baccalaureate programmes. Brazosport is authorised to

award a baccalaureate degree. The WCJC and Brazosport College service areas include all or part of eight counties in southeast Texas. The South Texas Project Nuclear Operating Company (STPNOC) is located near Bay City, Texas, which is in the region served by the two colleges.

Wharton County Junior College Programme. The WCJC Nuclear Power Technology Programme gained international recognition in 2011, when the International Atomic Energy Agency (IAEA) noted in its *Status and Trends in Nuclear Education*, that the WCJC programme was a 'best practice' programme among 2-year nuclear power technology training programmes [15]. The WCJC programme offers an Associate of Applied Science degree in Nuclear Power Technology. Upon completion of the two-year AAS degree, students have the prerequisite skills and training to work in the nuclear power generation industry in USA.

Nuclear Power Technology Courses. The WCJC programme offers three degree specialisation options, namely, **(1) Non-Licensed Operator, (2) Electrical Technician, and (3) Instrumentation and Control Technician.** It also offers an Enhanced Skills Certificate in Nuclear Power Technology upon completion of the Associate of Applied Science degree in Process Technology and completion of required nuclear technology courses. The WCJC programme is offered at the Texas Centre for Energy Development in Bay City, Texas, and has specific course requirements for each of the three degree specialisation options.

Course Requirements for All Specialisations (1st Year)			
Fall Semester (all students)		Spring Semester (all students)	
Course	Course Title	Course	Course Title
NUCP 1371	Math & Chemistry Fundamentals for Nuclear Power	NUCP 1370	Nuclear Fundamentals I
ELPT 1370	Intro to Power Technology	NUCP 1471	Nuclear Fundamentals II
or	or	PTAC 1432	Instrumentation I
PTAC 1302	Intro to Process Technology	CHEM 1405	Introductory Chemistry
BCIS 1305	Business Computer Applications	or	or
MATH 1314	College Algebra	CHEM 1411	Chemistry I
or	or	NUCP 1472	Nuclear Power Plant Organisation & Processes
MATH 2312	Pre-Calculus		
ENGL 1301	Composition & Rhetoric I		

(1) Non-Licensed Operator (2nd Year)			
Fall Semester		Spring Semester	
Course	Course Title	Course	Course Title
CETT 1409	DC-AC Circuits w/ Lab	NUCP 2471	Nuclear Power Plant Systems II
NUCP 2470	Nuclear Power Plant Systems I	To be selected	Humanities Elective
To be selected	Social Science Elective	To be selected	Discipline-related Elective
PTAC 2314	Quality	SPCH 1318	Interpersonal Communication
INTC 1450	Digital Measurements & Controls	BMGT 2347	Critical Thinking & Problem Solving

(2) Electrical Technician (2nd Year)			
Fall Semester		Spring Semester	
Course	Course Title	Course	Course Title
CETT 1409	DC-AC Circuits	INTC 1457	AC/DC Motor Controls
INTC 1450	Digital Measurements & Controls	To be selected	Humanities Elective
To be selected	Social Science Elective	ELMT 2441	Electromechanical Systems

PTAC 2314	Quality	SPCH 1315	Fundamentals of Speech
ELMT 2437	Electronic Troubleshooting, Service, & Repair	BMGT 2347	Critical Thinking & Problem Solving

(3) Instrumentation & Control Technician (2nd Year)			
Fall Semester		Spring Semester	
Course	Course Title	Course	Course Title
CETT 1409	DC-AC Circuits	INTC 1457	AC/DC Motor Controls
INTC 1450	Digital Measurements & Controls	To be selected	Humanities Elective
To be selected	Social Science Elective	ELMT 2452	Power Generation Instrumentation
PTAC 2314	Quality	SPCH 1315	Fundamentals of Speech
PTAC 2436	Instrumentation II	BMGT 2347	Critical Thinking & Problem Solving

WCJC Contact Information: Rudolph Henry, Director/Instructor
Nuclear Power Technology Program
Wharton County Junior College
911 Boling Highway
Wharton, Texas 77488
Telephone: 979-244-4666
Email: henryr@wcjc.edu

Brazosport Programme. The Nuclear Power Technology Programme at Brazosport College offers an Associate of Applied Science degree in **Chemical Technology (Process Operations Option) that includes a Nuclear Power Specialty with Enhanced Skills Certification**. The programme is designed to train students in the essential skills that are needed to work in the nuclear power generation industry. Courses include mathematics, chemistry, process technology, as well as nuclear fundamentals and power generation technology.

Nuclear Power Technology Courses. Brazosport College offers courses in nuclear power technology, including the following:

Nuclear Power Specialty with Enhanced Skills Certification	
Course	Course Title
NUCP 1371	Mathematics & Chemistry Fundamentals for Nuclear Power
ELPT 1370	Introduction to Power Generation Technology
NUCP 1370	Nuclear Fundamentals I
NUCP 1471	Nuclear Fundamentals II
NUCP 1472	Nuclear Power Plant Organisation and Processes
NUCP 2470	Nuclear Power Plant Systems I
NUCP 2471	Nuclear Power Plant Systems II

Brazosport contact information: Gary Hicks, Division Chair
Chemical Technology
Brazosport College
500 College Drive
Lake Jackson, Texas 77566 USA
Telephone: 1-979-230-3291
Email: Gary.Hicks@brazosport.edu

Additional Information about the Programmes. Students participating in the nuclear training programmes at WCJC and Brazosport College may be eligible to receive a National Academy for Nuclear Training Certificate upon graduation. This certificate is

administered jointly by the Institute of Nuclear Power Operations (INPO) and the National Academy of Nuclear Training (NANT) in collaboration with each college. To be eligible for this certificate, students must obtain a minimum passing grade of 80% in all of the required courses.

Both colleges provide scholarships to qualified full-time students to cover the cost of tuition, fees, and books. These scholarships are funded by the U.S. Nuclear Regulatory Commission through grants awarded to each of the colleges. STPNOC (the industry partner) provides periodic classroom-related tours of the nuclear plant and opportunities for students to work at the nuclear plant during the summer.

9. State-of-the-Art Instructional Equipment

The courses developed at these colleges are aligned with the U.S. Nuclear Energy Institute's *Nuclear Uniform Curriculum Programme Guidelines* (ACAD 08-006) for training nuclear technicians, including operations, electrical, and instrumentation and control technicians. Experiential learning exercises are designed to be almost identical to actual on-the-job industry training, job shadowing, and industry discipline.

In addition to course work in nuclear power technology fundamentals, the Wharton and Brazosport programmes include 'hands-on' laboratory exercises as reinforcement for classroom lectures. This experiential learning component includes training using state-of-the-art instructional equipment that includes the following:

- **ABB Digital Fieldbus Technology Demo Box**
- **Hampden Boiler/Turbine Generator Power Distribution Skid**
- **Intellitek Electrical Training Modules**
- **Computer-based simulators for operating Pressurised Water Reactors (PWRs) and Advanced Boiling Water Reactors (ABWRs) (under development)**

Additional curricula and training exercises will be developed in the near future that will focus on the use of computer-based nuclear power plant simulators for operating Pressurised Water Reactors (PWRs) and Advanced Boiling Water Reactors (ABWRs). These simulation exercises will reinforce lecture material by facilitating experiential learning for students by providing 'hands-on' use of actual state-of-the-art nuclear power generation equipment. Training modules will be developed that integrate computer-based nuclear power plant simulation applications into the training programme. The computer-based nuclear power plant simulations will provide an opportunity for faculty to train students to become familiar with plant startup and shutdown, plant operations, and analysis of common problems at nuclear power plants. The curriculum that will be developed for operating PWRs and ABWRs at nuclear power plants will be made available, through the Nuclear Energy Institute, to other educational institutions offering training programmes in nuclear power technology.

10. Programme Results

The Wharton and Brazosport programmes are leaders in educating and preparing young men and women to enter employment at nuclear power generating facilities in southeast Texas and elsewhere in USA. These programmes have been successful in aligning their curricula with the *Uniform Curriculum* (ACAD 08-006) and in recruiting and training students, who will become the next generation of highly skilled workers in the nuclear power generation industry in USA. The following table shows the programmes' accomplishments.

Wharton County Junior College and Brazosport College – Combined Results					
	2007-08	2008-09	2009-10	2010-11	2011-12
Enrollments in the Wharton and Brazosport Nuclear Programmes					
Total students	13	72	140	116	109
Gender					
Male	11	58	117	93	90
Female	2	14	23	23	19
Race/Ethnicity					
White	10	46	92	75	68
Hispanic	3	19	29	32	31
Black	--	1	5	8	8
Other	--	6	14	1	2
Completers of the Nuclear Technology Programmes					
Associate Degree	--	2	33	22	32
Certificate	--	4	10	6	6
Newly Employed in Power Generation Industries (partial count)					
Nuclear	--	2	57	23	7
Non-Nuclear	--	--	3	4	9

As noted in the table, above, the colleges have made efforts to foster gender, racial, and ethnic diversity in their nuclear power technology enrollments and graduations in order to reflect the diversity in the population of southeast Texas. Beginning in 2009-10, diversity in enrollments was achieved, with approximately 50% of enrollments being students from the racial and ethnic minority communities in the region.

The benefits of the initial U.S. Department of Labour (DOL) grant to the Texas nuclear power technology educational partnership as well as the support received from South Texas Project Nuclear Operating Company, Texas A&M University, the Nuclear Power Institute, and the Texas Engineering Experiment Station have been significant. These include the following:

- **Instructor Training:** The DOL grant provided provisions for faculty members to receive an average of 120 hours of training at the coalition's industry partner (i.e., South Texas Project Nuclear Operating Company), under the supervision of nuclear subject matter specialists and the Nuclear Power Institute.
- **Curriculum Development:** The DOL grant provided for three of the participating colleges to work with South Texas Project administrators to develop and modify curricula in accordance to the *Nuclear Uniform Curriculum Programme Guidelines* issued by the Nuclear Energy Institute. Additional funding for curriculum development was received from the U.S. Nuclear Regulatory Commission and the Nuclear Power Institute.
- **Laboratory Development:** The DOL grant provided support for significant upgrades of laboratory facilities used in conjunction with the curricula for the nuclear power technician training programme. This included funding for nuclear instructional equipment, workstations, simulators, and 'hands-on' training skids (i.e., 'HOT skids'), which ensure that students are being trained to use and operate the same state-of-the-art technology as found in the power generation industry in USA. Other grants also focused on upgrades to laboratory equipment and supplies, including grants from Texas A & M University, Nuclear Power Institute, Texas Workforce Commission, American Recovery and Reinvestment Act (ARRA) Programme, U.S. Nuclear Regulatory Commission, and U.S. Department of Education.

References

1. U.S. Department of Labour (Employment and Training Administration). *Identifying and Addressing Challenges in America's Energy Industry*. Washington, DC: U.S. Department of Labour, March 2007.
2. Centre for Energy Workforce Development. *Gaps in the Energy Workforce Pipeline: A 2007 Workforce Survey Report*. Washington, DC: Centre for Energy Workforce Development, 2007.
3. Nuclear Energy Institute. *2007 Workforce Pipeline Survey*. Washington, DC: Nuclear Energy Institute, 2007.
4. Nuclear Energy Institute. *Nuclear Uniform Curriculum Programme Guidelines (ACAD 08-006)*. Washington, DC: Nuclear Energy Institute, 2008.
5. Feighery, E.; Rogers, T. *Building and Maintaining Effective Coalitions*; Palo Alto, CA: Stanford Health Promotion Resource Centre, 1989.
6. Butterfoss, F.D. *Coalitions and Partnerships in Community Health*, San Francisco, CA: Josey-Bass, 2007.
7. Meyer, J.W.; Rowan, B. Institutionalised organisations: formal structure as myth and ceremony. *American Journal of Sociology* 1977; 83:340-363.
8. Scott, W.R. *Organisations: Rational, Natural and Open Systems*, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1987.
9. Suchman, M.C. Managing legitimacy: strategic and institutional approaches. *Academy of Management Review* 1995; 20(3):571-610.
10. Zucker, L.G. Institutional theories of organisations. *Annual Review of Sociology* 1987; 13:443-464.
11. Hannan, M.T.; Freeman, J. Structural inertia and organisational change. *American Sociological Review* 1984; 49(2):149-164.
12. Golembiewski, R.T. *Organisation Development: Ideas and Issues*. New Brunswick, NJ: Transaction Publishers, 1989.
13. Van de Ven, A.H.; Poole, M.S. Explaining development and change in organisations. *Academy of Management Review* 1995; 20(3):510-540.
14. Meyer, A.D.; Goes, J.B.; Brooks, G.R. *Organisational Change and Redesign*. New York: Oxford University Press, 1993.
15. International Atomic Energy Agency. *Status and Trends in Nuclear Education*. No.NG-T-6.1. Vienna, Austria: IAEA, March 2011.

EVALUATING THE LEVEL OF HUMAN RESOURCE MANAGEMENT

KRISTA PAHKIN

Centre of Expertise for Work Organizations, Finnish Institute of Occupational Health

Topeliuksenkatu 41 a A, FI-00250 Helsinki

TANJA KURONEN-MATTILA

EERIKKI MÄKI

Department of Industrial Engineering and Management, Aalto University

PL 15500, FI-00076 Aalto

ABSTRACT

The Finnish nuclear power industry faces several challenges in the areas of knowledge and competence management and the development of expertise. One way in which to respond to these challenges is to pay attention to the personnel management practices carried out in organizations. The goal of personnel management is to ensure that an organization has the human resources (HR) it needs in order to operate. In many organizations, the human resources department/unit is responsible for achieving the goal of personnel management, but the role of supervisors is growing. The Sustainable and Future Oriented Expertise (SAFEX2014) project aims to generate an evaluation method for HR management practices so that organizations can raise their practices to an adequate level. Through its literature review, interviews and workshops, the project will create an assessment method for evaluating HRM practices by the end of 2012, which will be piloted the following year.

1. Introduction

In the near future, the Finnish nuclear power industry will have to deal with many challenges in knowledge and competence management and in the development of expertise. The reasons for these challenges include the start-up and construction of new power plants, global labour markets, and the retirement peak of the 'baby boomers'. Increasing competition for skilled workers calls for active measures in order to ensure that the industry has competent employees, both now and in the future. Developing the personnel management practices carried out in organizations can provide a way in which to overcome these challenges.

The goal of personnel management is to ensure that an organization has the human resources it needs in order to operate. Personnel management includes activities that keep the knowledge and well-being of employees, as well as the management of personnel, at an adequate level. Personnel management is carried out through, for example, recruitment, initiation, training, and career planning. The literature divides personnel management into human resources management, industrial relations and leadership (1). Sometimes it is referred to as strategic human resource management (SHRM) or human resource management (HRM) (2). The main focus of this study is the management of human resources.

The human resources department or unit is often responsible for fulfilling the goals of personnel management. However, nowadays most HRM practices are implemented through immediate supervisors (3). In technically-based organizations in particular, such as nuclear power plants, supervisors often have technical or other specialist backgrounds. In the past, most nuclear power plant managers were selected mainly for their technical expertise, and less attention was paid to their people management skills. In addition, many nuclear power plant training programmes focused on the technical skills of the power plant operators, and managers were expected to learn management and leadership skills through practice and informal mentoring (4). Nowadays, people-focused skills are also demanded of nuclear power plant managers and supervisors. To be able to respond to these new demands, organizations' human resource functions should offer tools for management and supervisors to perform their people management responsibilities.

The management of HR has a particularly important role in the field of nuclear industry because of the high standards of performance and reliability expected in this field, as well as the considerable time it takes to develop such special competences (5). One of the aims of the Sustainable and Future Oriented Expertise (SAFEX2014) project was to generate new knowledge of the evaluation methods of HRM practices. As the earlier stages of the project (6, 7) had shown paying attention to personnel management, especially to the actions of the human resources department/unit and supervisors, is important. In 2011 the project started to develop methods and practices for HRM in the nuclear power industry. The SAFEX2014 project is a four-year (2011-2014) collaboration project of the Finnish Institute of Occupational Health and Aalto University. It belongs to the "Organization and Human" part of the larger SAFIR2014 research programme (8) funded by the Ministry of Employment and the Economy's Nuclear Waste Fund.

Method

In 2011, we reviewed both general HRM practices and those in the nuclear energy industry (9). In addition, 14 HR specialist or team/group leaders from three nuclear industry organizations took part in six group interviews. The aim of the interviews was to determine the practices currently applied in the nuclear industry's organizations, and how HR specialists and team/group leaders perceive and use them.

In 2012, two half-day workshops were arranged to develop the evaluation method of HRM practices. The first workshop was held in April and had nine participants (HR specialist and team/group leaders) from five nuclear power organizations. The first workshop identified the main areas of HRM practices. The second workshop was arranged in September, with almost the same participants. The main focus of the workshop was the levels of the identified HRM practices.

Results

The findings of the interviews showed that, in recent years, the organizations had increasingly devolved HR responsibilities to supervisors. To help supervisors prosper as people managers, the HR functions should provide more systematic guidance in supervisor training and other development activities, and facilitate forums for exchanging the knowledge and good practices related to supervisory work. The HR function could also take more responsibility for following up on HR processes, and for dividing responsibilities between HR and supervisors. Administrative duties in particular should be clear, functional and well communicated. (10) A clear need thus exists for an assessment method for evaluating HRM practices so that organizations can develop their practices to be more adequate and user friendly.

The workshop defined the main areas of human resources management: the management of personnel competence, the management of performance, and the management of organization culture. Each of these areas includes both strategic and operational activities. (Figure 1)

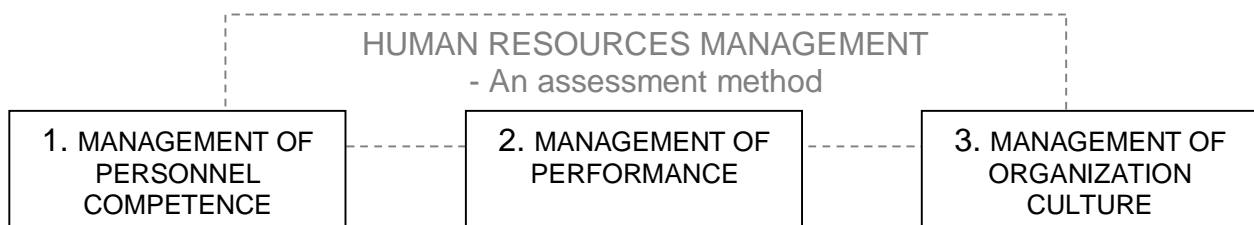


Figure 1: Overall model of human resource management method

The project's review (9) showed that many of the models related to personnel management include different stages. The goal in these models is that HRM practices should form a global approach in the organization, so that they are no longer separate, individual actions. This same principle is therefore used in the method developed in the project, since the practical advantage of these kinds of models is that they include the idea that the organization can develop from one stage to another by improving its practices. The stages were defined as: 1) Practices require development, 2) Practices are at a good level, and 3) Practices are progressive.

Stage 1: "*Practices require development*" means that the organizations have no clear guidelines or ways of action, or that the guidelines are defined very superficially. Moreover, it is common that the guidelines come from the top management, without discussion with the other actors in the organization. Stage 2: "*Practices are at a good level*" means that the organization has clear guidelines or ways of action and that the guidelines are defined sufficiently clearly. When the guidelines are defined, the viewpoints of personnel are taken into account. Stage 3: "*Practices are progressive*" means that the organization has clear guidelines or ways of action, and that the guidelines are defined clearly. One of the principles is that the guidelines are defined together with the personnel, and that they are continuously evaluated and developed.

The final model will include statements which describe both the official and unofficial guidelines and practices used in the organization. The idea is that each participant first evaluates the statements on a three-point scale and writes her/his ideas on how the practices should or could be developed. After this the results are collected and discussed. The aim of the discussion is to determine why activities were given a certain value; for example, if some of the participants thought a certain practice was something which needed developing while others classed it as progressive. Or even if everyone agrees that the practice is at a good level, is there still something that needs to be done? The goal is to define the main development areas and agreed on actions.

Conclusions

There is a clear need for a method for evaluating HRM practices in the nuclear industry sector to help organizations develop their practices. The first draft of this assessment method will be presented in the ENC 2012 conference. The method will be piloted in 2013 in three to six nuclear industry organizations in Finland. One to three studies will be carried out in every participating organization. After piloting, the method will be finalized. The aim is that in the future, organizations can use the method to evaluate their own HRM practices and identify the areas that they need to develop.

References

- 1) Viitala R, 2009: *Henkilöstöjohtaminen: Strateginen kilpailutekijä*. [Personnel management: Strategic advance.] JULKAISIJA, JULKAISUPAIKKA
- 2) Sädevirta J, 2004: *Henkilöstöjohtamisen ja sen tutkimuksen kehittyminen. Henkilöstöhallinnollisesta johtamisesta ihmisvoimavarojen strategiseen johtamiseen*. [Personnel management and the development of its reasearch] Helsinki.
http://www.mol.fi/mol/fi/99_pdf/fi/03_tutkimus_ja_kehittaminen/02_tykes/05_aineistopankki/julkaisut/raportti35.pdf
- 3) Purcell, J., & Hutchinson, S. (2007). *Front-line managers as agents in the HRM performance causal chain: theory, analysis and evidence*. Human Resource Management Journal , 17 (1), 3-20.
- 4) IAEA. (1998). *Selection, competency development and assessment of nuclear power plant managers*. Vienna: International Atomic Energy Agency.
- 5) IAEA 2009: *Managing human resources in the field of nuclear energy*. IAEA NUCLEAR ENERGY SERIES, International Atomic Energy Agency, Vienna.
- 6) Kuronen, T., Säämänen, K., Järvenpää, E. & Rintala, N. 2007. *Hiljaisen tiedon säilyttäminen ja jakaminen ydinvoimalaitoksessa* [Preserving and sharng tacit knowledge in nuclear power plants]. Project report. Laboratory of Work Psychology and Leadership Report Series No. 1/2007. Espoo: Helsinki University of Technology, Department of Industrial Engineering and Management. (in Finnish)
- 7) Pahkin K., Kuronen-Mattila T., Mäki E., Leppänen A, ja Järvenpää E. (2011): *Asiantuntijatyö turvallisuuskriittisessä ympäristössä SafeExpertnet 2007–2010*. [Expert Work in Safety Critical Environment] Työterveyslaitos, Työympäristötutkimuksen raporttisarja 57. Helsinki 2011.
- 8) The Finnish Research Programme on Nuclear Power Plant Safety 2011 - 2014.
<http://virtual.vtt.fi/virtual/safir2014/>
- 9) Kalliomäki-Levanto T, Pahkin K, Kuronen-Mattila T & Mäki E 2012: *Katsaus osaamisen ja asiantuntijuuden kehittämiseen ja ylläpitämiseen osana henkilöstöjohtamista ydinvoima-alalla*. [Developing knowledge and expertice as a part of personnel management in nuclear industry - review] Työterveyslaitos ja Aalto-yliopisto.
- 10) Poukka P, 2012: *Role of HR in supporting supervisors' people management - A study in Finnish Nuclear Power Plant context*. Master's thesis, Aalto University

SAFETY CASE ON A PAGE

S.A. FORBES, M. CARTLIDGE
Safety Services, AMEC PPE, Building 150
Harwell Oxford, Didcot, Oxfordshire, OX11 0QB – UK
and
Nuclear Safety, AWE, Aldermaston
Reading, Berkshire RG7 4PR – UK

'Safety Case on a Page' (SCOAP) has been developed for the Atomic Weapons Establishment (AWE) to enhance front-line operator awareness and understanding of the significant process hazards and safety controls present in their workplace. There has been significant demand from facility teams for SCOAPs to be produced for their areas, as they simplify the complex and analytical nature of safety cases. It is also receiving significant interest from regulators and other licensees.

SCOAP is presented as a facility- or process-specific poster displayed in the workplace (Fig. 1). It provides operators with a visual and accessible summary of the main information from the safety case, eg. engineered and procedural safety controls. Development of a SCOAP with facility staff engages the workforce and encourages them to consider how their day-to-day actions directly affect safety.

The content and layout of the SCOAP format was developed and piloted in conjunction with a front-line operations team, to ensure it was appropriate for the intended audience. It uses visual representations to effectively communicate relevant high level safety case information, including:

- Bow-tie diagrams to illustrate fault sequence progression from initiating event to consequence, along with the engineered and procedural safety controls.
- Photographs and/or diagrams to illustrate key safety related items of plant, along with a description of their safety function.
- References to source documentation, eg. the Safety Case and Safe Operating Envelope.

In addition to its primary function of promoting front-line operational safety awareness, SCOAP can also be used to convey key safety case information to a range of other stakeholders, such as:

- Maintainers undertaking work on safety related equipment.
- Designers undertaking modifications to plant.
- Safety Committees requiring an 'Executive Summary' view of a safety case.

Through its utilisation of the 'bow-tie' methodology to illustrate the major hazards, SCOAP draws upon leading research into workforce understanding of hazard management and their role within it [Ref. 1].

In addition, SCOAP also implements a number of key lessons learned identified from major accident investigations, such as:

- Presenting safety case information in a form that is **SHAPED**: '*Succinct, Home-grown, Accessible, Proportionate, Easy to understand and Document-lite (SHAPED)*' (Haddon-Cave Inquiry on the Nimrod Review).

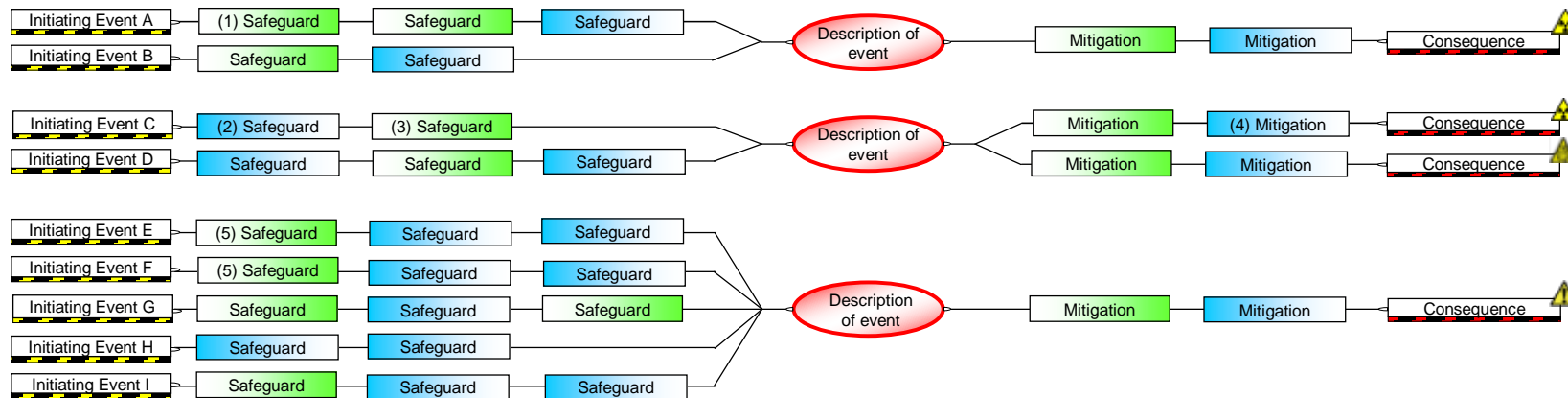
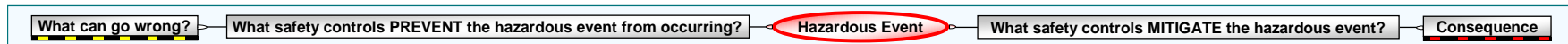
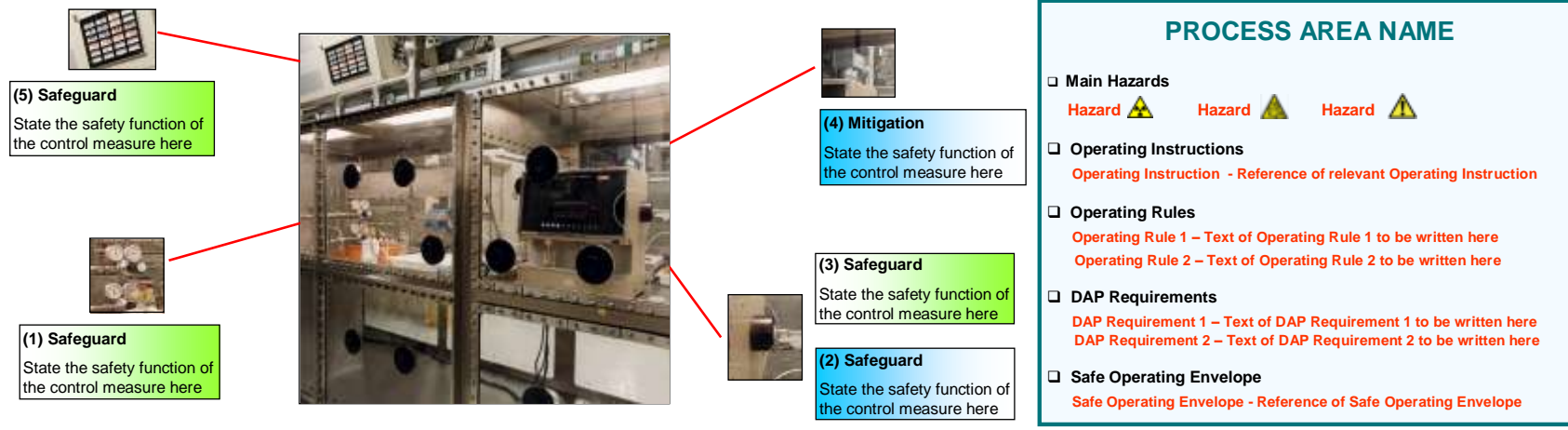
- Focusing attention on the major process hazards and controls, to supplement the consideration of occupational safety (Deepwater Horizon accident investigation).

The SCOAP does not replace the safety case or any existing safety instructions or training, but simplifies key information from the safety case in a visual format to focus attention on major process hazards.

References

Ref. 1. HSE Research Report RR637 – Optimising Hazard Management by Workforce Engagement and Supervision.

Safety Case On A Page – The significant process hazards and controls on YOUR plant



Remember 'STAR' – Stop, Think, Act, Review. If in doubt... ASK!

ENGINEERED CONTROLS

PROCEDURAL CONTROLS

SCoAP Ref:	SCoAP/xxx/xxx	Issue 1	July 2011
Safety Case Ref:	xxx/xxx/xxx/xxx	Issue x	Xxxx 20xx
Owned By:	X Xxxxx (Process Supervisor)		

Fig. 1. Safety Case on a Page Template

BELARUS CAPACITY TO CONTRIBUTE TO REGIONAL CO-OPERATION IN EDUCATION AND TRAINING ON NUCLEAR AND RADIATION SAFETY FOR EUROPE AND MIDDLE ASIA

A. TIMOSHCHENKO

*Department of Nuclear and Radiation Safety
International Sakharov Environmental University
Dolgobrodskaya, 23, 220070, Minsk, Belarus*

ABSTRACT

Belarus is the country with rapidly developing nuclear and radiation applications now. Speedy growing use of ionizing radiation in medicine and decision of Belarus government taken in 2008 to put the nuclear power in place and to establish nuclear education and training has opened new chapter in developing Belarus capacity to share by education and training resources with countries of the Russian speaking region in Europe and Middle Asia. Geographical position and policy of friendship with all the countries of the region pursued by Belarus government open the opportunity to accommodate participants even from countries that have some clashes between each other. Assuming the competence of international community and, first of all, that is provided by IAEA via different technical co-operation programmes, Belarus institutions can provide now a number of training courses and assistance in organization of education and training in nuclear, radiation, transport and waste safety. First of all, it is related to IAEA Post-Graduate Educational Course on radiation protection and safety of radiation sources. At the same time developing nuclear and radiation applications and practices in Belarus creates a big capacity to establish in co-operation with highly experienced bodies from other countries of the region new education and training programmes related to nuclear and radiation safety, e.g. in medical physics, targeted to various audiences. The aim of the report is to discuss how to build the optimal and sustainable system of education and training in nuclear and radiation safety for Russian speaking region in compliance with international standards and what core internationally recognized competences should be achieved in result of training.

1. Introduction

Developing of education and training in the field of radiation safety and related activities is having pushed forward in Belarus by growing demand of use of radiation sources especially in medical applications and by decision of the Belarus government to introduce the nuclear power. Owing the system of education and training in the field of radioecology and radiation protection developed earlier mainly to mitigate the Chernobyl accident consequences, the country is changing the paradigm of that going along the road of establishing (renovating) education and training for nuclear power. Since 2007 the State Programme on the human resources development for nuclear power is functioning. This Programme comprises 4 higher institutions (Belarus State University, Belarus National Technical University, International Sakharov Environmental University) and the number of special secondary colleges of the Ministry of Education, Joint Institute on Power Engineering and Nuclear Research of the National Academy of Sciences of Belarus, Ministry of Power Engineering, Ministry of Health. Main radiation protection issues are given to all the trainees but the specific focus is allocated within the specialty "Nuclear and radiation safety" established at the 1st stage (undergraduate higher education), the 2nd stage (master courses) and the post-graduate re-training course on "Radiation protection and safety of radiation sources". The last one is mainly conducting in co-operation with IAEA whose contribution to the course is crucial and sufficient.

2. Training in nuclear and radiation safety in Belarus – 5 years of experience

The specialty “Nuclear and radiation safety” with qualification “engineer” awarding to graduates was designed in Belarus in the beginning of 2008 and aimed to train specialists with higher education that will be able to work both in nuclear safety and radiation safety and in case of radiation safety not only at nuclear power plants but also in any other applications of ionizing radiation sources, radiation monitoring and radioactive waste management. To merge two of to somewhat extent different flows into one sink we need because there is no very broad demand for specialists purely in nuclear safety in the country and in the region. We considered that the scientific background and modeling technologies of the processes in a nuclear reactor and main elements of nuclear power plants are the same that specialists need to use in environmental radiation studies and, their training can be built at the common theoretical background. Nevertheless, the focus on issues specific to nuclear safety and security, on one hand, and on radiation safety and security of other sources, on the other hand, is anticipated now within 3 specializations up to student’s option: “Nuclear safety and control of nuclear materials”, “Radiation monitoring and control” and “Safe use of ionizing radiation sources”. The total duration of studying is 5,5 years now.

According to decision of the Ministry of education of the Republic of Belarus we must start the new 5 year programme on nuclear and radiation safety since September next year. The main difference of it from the previous one will be the absence of specializations that do not contribute very much to the final qualification but only provide to students some background for their postgraduate progress in a particular field. We will comprise all theoretical and practical subjects that form necessary main knowledge and skills in common topics for studying and separation of graduates between particular applications will happen in taking into account their interest and wishes at the stage of course works or projects that they must do within the studied disciplines.

The peculiarity of the content of some major special disciplines like, for instance, “Physics of a nucleus and ionizing radiation” is that there are several basic common topics that could be delivered in the same way, they say, cross-section concept, the concept of the mean life-time and the mean free length and some others. The other special point is that the studying of concepts precedes the accumulating measuring and action skills, basic practical skills in the ionizing radiation measuring are gained by students at the laboratory works having been made during specific integral course “Radiation detection and measurement” supplemented by 2-week entirely practical work in the laboratory. Due to that, students do not meet the problems in understanding the processes of interaction of radiation by sensitive parts of any detector.

This education and training is free of charge for the citizens of Russia (not needed), Kazakhstan and Tajikistan who has successfully passed entrance enrolment. Other citizens are also admitted by entrance enrolment but they must pay some education fee that is equal to approximately Euro 1300 per year.

At the second level of higher education, for the Master’s course we have 2 options.

- 1) The student can enter the so called ‘scientific and pedagogical’ 1 year course on Nuclear and radiation safety.
- 2) Very recently, the justification of special 2-year Master programme that oriented to train specialists for regulatory authorities, definite institutions where more deep professional training is required.

The last programme is built in accordance with IAEA recommendations work out for Master courses on nuclear and radiation technologies.

The training capacity on this specialty is 10-12 people a year and will cost about Euro 1000 for the first year and Euro 700 for the second year where 1 semester practice at some specialized institution (e.g. regulatory authority) is anticipated.

3. Post-graduate educational and training course on radiation protection and safety of radiation sources

The Post-graduate educational and training course on radiation protection and safety of radiation sources (PGEC) is made upon the Standard Syllabus worked out by IAEA and lasts 5,5 months for the day-study education. There are also options of evening and even correspondent education at the course with extended duration. At the end of the course participants defend the project work for specific area of radiation protection and according to the decision of the State commission are awarded by the diploma on re-training with qualification "Radiation protection specialist". This qualification is higher than Radiation protection officer qualification but intermediate between it and regulatory authority specialist.

There were 7 PGEC courses held since 2001 (2001: 9 weeks, 2002: 18 weeks, 2004 – 2005: 21 weeks, 2005 – 2006, 2006 – 2007, 2008, 2009 – 2010: 22 – 23 weeks). 141 of participants from 19 countries finished them successfully. There is the 8th PGEC going on now for 13 specialists from 9 countries. Collaborating Centres and Institutions count 22 organizations and enterprises which specialists and facilities are involved in the PGEC. There is one week field practice in exclusion zone in Khoyniki nearby the Chernobyl nuclear power plant.

The cost of the course excluding accommodation and meals is about Euro a 1000 per participant.

4. Towards to establishing education and training in medical physics

The decision to introduce medical physics in Belarus was taken in May, this year, and it is supposed that first undergraduate students will be admitted in September, 2013. So there is some but very little time to finish the developing Syllabus for 5 year education and training programme of the specialty "Medical physics". The draft of it anticipates the synergism of the university training in physics and major issues related to life sciences and health studies like physiology, genetics, biophysics and biochemistry, internal diseases, basic oncology, physical methods of diagnostics of diseases etc. Special radiation medical physics programme can be, probably, start only at the 4th year. The special clinics will be as the base for practice of students. At the end of studies graduates will defend the diploma work and will be awarded by the diploma with qualification "Medical physicist".

The cost of the programme is not established now.

All the education and training programmes considered above are accommodated in International Sakharov Environmental University (ISEU).

5. Short courses available

There are several short time (1-2 weeks) training courses available for professional updating in the field of radiation protection providing not only by ISEU but by some other institutions. They are:

- professional training courses for different radiation protection workers and specialists:
 - in industry (National Institute on Higher Education – NIHE, ISEU, Belarus – Russian University – BRU, and also the «Institute of re-training and professional updating» of the Ministry of Emergency of the Republic of Belarus);
 - in public health (NIHE, Belarus Medical Academy of Post-Graduate Education – BelMAPO).

Moreover, the knowledge on elements of radiation safety are included in:

- discipline «Civil protection in emergencies. Radiation safety» for all higher educational specialties in the Republic of Belarus;
- programmes of professional updating of labor safety specialists, lecturers of higher education institutes and secondary colleges (NIHE),
- agriculture specialists (Belarus Academy of Agriculture, Belarus State Agriculture Technical University);
- medical specialists including nurses (BelMAPO).

6. Elements of strategy on education and training in radiation protection and quality management system

There are several elements of the national strategy on education and training in radiation protection in Belarus. Thus there is the State programme of education and training for nuclear energy, in place since 2008, including the specialty «Nuclear and radiation safety» aimed not only for nuclear energy but also for other radiation applications.

The up-to-date concern in radiation safety compliant to the Basic Safety Standards, recommendations of the IAEA and International Commission on Radiological Protection (ICRP) is inducing into the academic programmes and syllabi.

The system of professional education (*secondary and tertiary levels*) is governed by educational standards and academic plans endorsed by the Ministry of Education (second generation).

There are only academic plans authorized by the Ministry of Education and profiled Ministries in the system of re-training and professional updating for now. The procedure of establishing educational standards and new academic plans related to them for the field of re-training and professional updating has been started recently and will be finished this year.

Quality control of the education and training is traditionally carried out by the established procedure of appraisal and accreditation (1 time in 5 years). There is the special body in the Ministry of Education for this purpose – the Department of the quality control of education and training. During a week or two weeks special commission headed by an officer of the Department together with specialists invited from other institutions and professional bodies assess the following:

- the quality of academic process (organizing flow, documentation, quality of knowledge of trainees – by written examination of students, questionnaires for students and teachers, etc.);
- the state of art in carrying out research, use of the research findings in education and training;
- the education and training infrastructure (premises, equipment, their sufficiency, conditions of use, etc.);
- effectiveness of the administration management, including organization chart, sharing responsibilities, interaction between the chart blocks and elements, logistic flows, internal quality control system, etc.

The Quality Management System (QMS) and control according to ISO 9001 is introducing since 2009 in all the higher education institutions and organizations providing re-training and professional updating. All leading universities and organizations providing training in radiation protection are certified now within the QMS.

7. Development of international co-operation and regional capacity of Belarus for education and training in radiation protection

During the regional meeting in Dushanbe in May 2012 organized by the IAEA, the following tasks for international and, particularly, regional co-operation were found to be solved:

1. To perform analysis of training needs according the presented methodology by IAEA, taking to account the existing practices and activities with sources of ionizing radiation.
2. To define the responsibilities of regulatory body, relevant ministries and institutions in field of education and training on radiation safety, including design of plans and programmes.
3. To appoint a coordinator for development of national strategy for education and training in nuclear and radiation safety with appropriate authority for collection of necessary data needed to succeed the aims.
4. In case of absence of appropriate education and training basis in the countries to develop legislative base for education and training abroad including financing.
5. To discuss the recognition of certificates and diplomas of training and retraining in nuclear and radiation safety on the legislative level.

Belarus can play a co-ordination role in the process of finding consensus in solution of these problems. Those countries that needs the consultancy and advise for establishing

their national education and training programmes in radiation protection can apply for advise to the ISEU.

8. Conclusion remarks

The national education and training programme for any country should be built on the base of permanent analysis of education and training needs. This is the starting point of building national strategy. There is a tool to make it included in the IAEA education and training appraisal procedure but this tool should be much developed to reach the purposes proclaimed. The development of this tool is the special issue of another report.

For rather small countries that not need to have the full spectrum of radiation techniques and practices there may be not practicable to cover all their needs at the national level establishing expensive educational programmes to train a few people. In this case regional training centers can play a role of education and training body, on one hand, and of advisory and the best practice dissemination unit, on the other hand.

For the majority of the CIS countries and for some Eastern Europe countries of the European Union there is an opportunity to bear on the capacity and experience of Belarus and, at the same time, to strengthen it by ideas and common education and training programmes on the base of international recommendations developed by the IAEA in favor of all the countries of the region with optimal cost-benefit relationship.

INTERNATIONAL COLLABORATION FOR ENHANCED EXPERIENCES IN NUCLEAR EDUCATION

G. D. HARVEL

*Faculty of Energy Systems and Nuclear Science
University of Ontario Institute of Technology
2000 Simcoe Street North, Oshawa, Ontario, L1H 7K4, Canada*

F. NAKAYASU

*Department of Applied Nuclear Technology
Fukui University of Technology
3-6-1 Gakuen, Fukui-Shi, Fukui, 910-8505, Japan*

ABSTRACT

Nuclear energy continues to be an important component of the energy mix. Refurbishment projects and new builds continue around the world along with the development of Gen-IV designs. In combination with a significant attrition in staff due to retirement, several Universities around the world are experiencing growth in their Nuclear Engineering programs both at the undergraduate and graduate level. Yet, it is becoming apparent that the traditional education model used in the 20th century is no longer sufficient. Graduates from Nuclear Programs need to be market ready as opposed to ready for industrial training. As such, the successful graduate needs increased flexibility and knowledge in both their local market and the international market.

The University of Ontario Institute of Technology (UOIT) in Canada and the Fukui University of Technology (FUT) in Japan signed an MOU on June 2011 for collaboration related to exchange of students, faculty, knowledge and joint development of nuclear education. The collaboration has allowed for the exploration of nuclear education experiences and pathways to improve the overall student experience and to produce a higher qualified graduate. Both UOIT and FUT have a large localized nuclear sector that plays a strong role in defining the needs of the student. The nuclear technologies employed are different in terms of implementation which results in one of the significant influences on the programs. Another major influence is the different expectations in the capabilities of the graduate student due to cultural influences.

As part of the collaboration, an international training was conducted at FUT where students from FUT, other Japanese Universities, and UOIT attended to perform the same study. The resulting training was successful in the technical objective and showed interesting results for the collaboration between students from multiple locations. All of the students improved in their overall capability and also obtained a broader perspective of the international environment. The exercise suggests that further collaboration will lead to more flexible graduates of the programs.

1. Introduction

Nuclear energy continues to be an important component of the energy mix. Refurbishment projects and new builds continue around the world along with the development of Gen-IV designs. In combination with a significant attrition in staff due to retirement, several Universities around the world are experiencing growth in their Nuclear Engineering programs both at the undergraduate and graduate level. Yet, it is becoming apparent that the traditional education model used in the 20th century is no longer sufficient. Graduates from Nuclear Programs need to be market ready as opposed to ready for industrial training. The market is also becoming more global with companies performing work for multiple clients in multiple countries. As such, the successful graduate needs increased flexibility and knowledge in both their local market and the international market.

To address this need, the University of Ontario Institute of Technology (UOIT) in Canada and the Fukui University of Technology (FUT) in Japan have each been pursuing different approaches for enhancing

educational experiences. At UOIT, three activities have been conducted. Common with FUT, there has been on-going review of curriculum and the development of new education modules by each professor in the classes they teach. This activity is part of the traditional models used at most Universities. In addition, UOIT has been following various feedback mechanisms as part of the accreditation process to improve the overall quality of the education [1]. UOIT has also been considering additional learning technologies such as distance learning [2]. An evaluation of distance learning has shown that a larger audience can be included in the education process and that stronger ties with industry are available.

The purpose of this work is to discuss an international collaboration between UOIT and FUT. Specifically, the purpose is to describe the foundations of the agreement and the training exercise conducted at FUT where UOIT and FUT students undertook joint education activities.

2. Methodology

As both UOIT and FUT recognize the need to strengthen international collaboration, the initial effort was an exchange of international visits for the purpose of establishing a framework for collaboration. These visits resulted in a Memorandum of Understanding that governs the connections between the two Universities and allows for further collaboration to proceed.

A review of both Universities indicated that there were significant similarities such that the programs in Nuclear Technology complemented each other. Each university is relative small with focussed programs. At FUT, the Department of Applied Nuclear Technology is responsible for educating students in the area of nuclear power, radiation measurement and protection, radiation applications, and nuclear plant design. At UOIT, the faculty of Energy Systems and Nuclear Science is responsible for the same areas of Nuclear Technology. In both institutions, the professors are a mix of industry experienced and academic personnel with a strong focus on industry. Both universities and programs are strongly tied to local industries and research groups with the intent to provide highly qualified personnel direct to those industries straight from a bachelor of Engineering degree. UOIT concentrates advanced labs on design topics such as integrated effects of hydraulic systems, and simulation technology for nuclear power plants. FUT has less focus on design and more focus on nuclear applications with particular expertise in the use of unsealed radioisotopes. Hence, the fundamental portions of the programs are the same with a different focus at the end of the education.

Based on the similarities and differences, FUT and UOIT pursued the following methodology to enhance educational experiences through international collaboration.

1. International Exchange visits to review Curriculum
2. Establish a Memorandum of Understanding (MOU) for Information Exchange and Student Exchange
3. Establish a training program in FUT based around the Unsealed Radioisotopes laboratory
4. Establish a training program in UOIT based around integrated effects experiments and simulation technology
5. Pursue annual exchanges of Professors and students for Enhanced Experiences
6. Compare findings after each exchange

Approximately 3 International Exchange visits were required to review the curriculum and establish the MOU. Upon satisfactory completion of the MOU, FUT was able to obtain funding to support an international visit from UOIT for enhanced experience training using the training program developed in their unsealed radioisotopes laboratory. The first training exercise was completed in March of 2012 with the attendees shown in Table 1. Both professors and students participated in the exercise and FUT was able to include students from other Japanese Universities as well.

Table 1: Category of Attendees from various Universities for Unsealed Radio-Isotopes Training

University	Category	# of Attendees
FUT	Professor	4
	Master Candidate	1
	Undergraduate	1

UOIT	Professor	1
	Doctoral candidate	2
	Master Candidate	1
University of Tokyo	Doctoral Candidate	1
Tohoku University	Master Candidate	3

Students were required to complete the training and prepare a report on their findings for submission to the FUT Professors for evaluation. These results are used by the FUT and UOIT professors to further enhance the international experience.

3. MOU

FUT and UOIT prepared two Memorandum of Understanding (MOU) to support International Collaboration. The first MOU was at the University level and acts as the principal agreement to allow other, more specific, agreements to be formed. The second MOU is between the Department of Applied Nuclear Technology and The Faculty of Energy Systems and Nuclear Science. Both MOUs are for a period of 5 years. The principles that guide this collaboration and partnership between UOIT and FUT are mutual respect for academic integrity, commitment to student success, and the broadening of international academic networks to support excellence in teaching and research.

The higher level MOU agreed to the following key areas of collaboration:

1. Exchange of students on a reciprocal basis
2. Exchange of faculty members
3. Exchange of publications, research materials, newsletters, etc.
4. Joint projects related to research, teaching, faculty development and service

Each university agreed to welcome visiting faculty members and research fellows from the other institution. Such visits are subject to the consent of the relevant unit at the host institution and the conditions of work cited in writing prior to the visit. Where possible, each university will arrange for library privileges, e-mail access, and office space. Neither institution is obliged to provide financial support for visiting scholars.

With the above foundation, it was now possible to pursue a Department level specific MOU for collaboration. The specific elements of the Department level MOU are as follows:

1. Joint Research in the Application of Super-Critical Fluids to Fast Breeder Type Reactors
2. Exchange information on MONJYU and GEN-IV Reactors
3. Support Visiting Researcher/Student for Joint Study/Laboratory Training
4. Exchange of Conference and Journal publications related to study area

4. FUT Training Program Exchange

FUT has an open source laboratory where they can perform experiments with radioactive liquids for educational purposes. UOIT does not have such a licensed laboratory and hence can only discuss such phenomena theoretically. Other institutions in Canada do have this capability but the facilities are reserved for research or industrial applications only, not education. As such, Canadians who need to work with non-sealed radiation sources usually undergo training at the workforce. While this approach is safe, the user does not obtain an appreciation of such techniques in advance.

The training was designed to meet all of the safety requirements of the Japanese regulatory system. As such, the training included safety awareness training, pre-experiment lectures, and walkthroughs of the actual experiments to be performed before the students were permitted to complete the work. The students were then allowed to perform the experiments under supervision while observing all of the safety and regulatory rules of the experiments. After the experiments, the students were required to prepare a written report on their findings and discuss them with the Professors. The experiment was performed in such a way that the Japanese and Canadian students were required to work together.

The following steps were followed for the international exchange:

1. Travel to FUT and interact with Japanese Society during the travel
2. Meet with FUT Professors and students and develop a working relationship

3. Conduct Regulatory required training on the same use of radiation and working in a radiation environment
4. Perform experiments using the unsealed radio-isotopes laboratory
5. Discuss the results of the experiments with the Professors and students
6. Discuss other topics of interest to the International Nuclear Community
7. Prepare a written report on the findings of the visit

The two student groups were significantly different. Both male and female students were involved in the training exercise. There were significant cultural differences as well as language barriers. Two methods were used to improve the working relationships of the students to reduce the effect of cultural differences and language barriers.

The first method was to tour the FUT facilities as a group with all of the Professors. Figure 1 shows Professor Sunagawa explaining FUT experimental equipment to the students. The students were all treated equally and time was taken to encourage discussion amongst the two groups. This method resulted in a modest improvement in contact between the students and certainly broadened their minds with respect to the cultural differences.

The second method was a joint welcome dinner. This method allowed for the students to interact in a more social setting without concerns of the technical work. Two observations are important here. First, it was imperative that some form of the first method occurred first before the dinner to allow some interaction to occur. This allowed the students to become comfortable with each other before dinner. The second observation was the importance of the Professors to interact with both sets of students. This action equalized the interaction and allowed the students to be more open.



Fig. 1: Professor Sunagawa explaining the fundamental workings of Laboratory Equipment to all of the students

Before the specific training could be conducted, regulatory training was required. All students jointly participated in an exercise of lectures and discussions related to radiation safety. The material covered was common to both Canada and Japan and was delivered to the Japanese regulatory requirements. This process ensured the students followed proper safety procedures. One feedback from this type of training is the need to augment the training with some form of exercises to broaden the exercise such as requiring calculations to be performed by the students or a discussion of the similarities and differences between the two nations training materials.

Once the regulatory and safety training was completed, a series of lectures were conducted to explain the experimental methods that would be studied. Two experimental methods for isotope separation were conducted in the unsealed radioisotopes laboratory. One method used knowledge of isotope behaviour for organic solvents and the other method used knowledge of resins and pH control for various isotopes.

Solvent extraction is the process of removing a solute from a liquid mixture with a solvent. The main purpose is to separate the solute(s) based on its different solubilities in two immiscible solvents, usually water and an organic solvent. The solvent dissolves the sorb chemicals and is drained, whereby the chemicals are separated into an aqueous and organic phase as can be seen in Fig. 2. The types of solvents used for extraction depends on the chemicals being extracted.

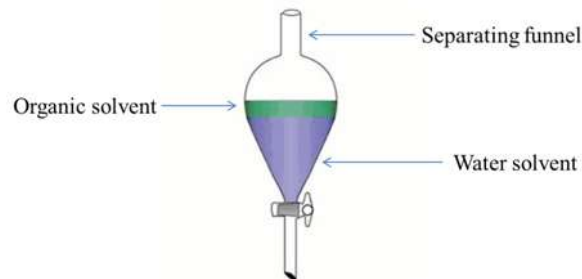


Fig. 2: Separating funnel with the organic and water solvents in the solvent extraction method

This technique has many applications, including water purification, oil and chemical refining, pharmaceuticals, ore processing, nuclear fuel reprocessing as shown in Figure 3.

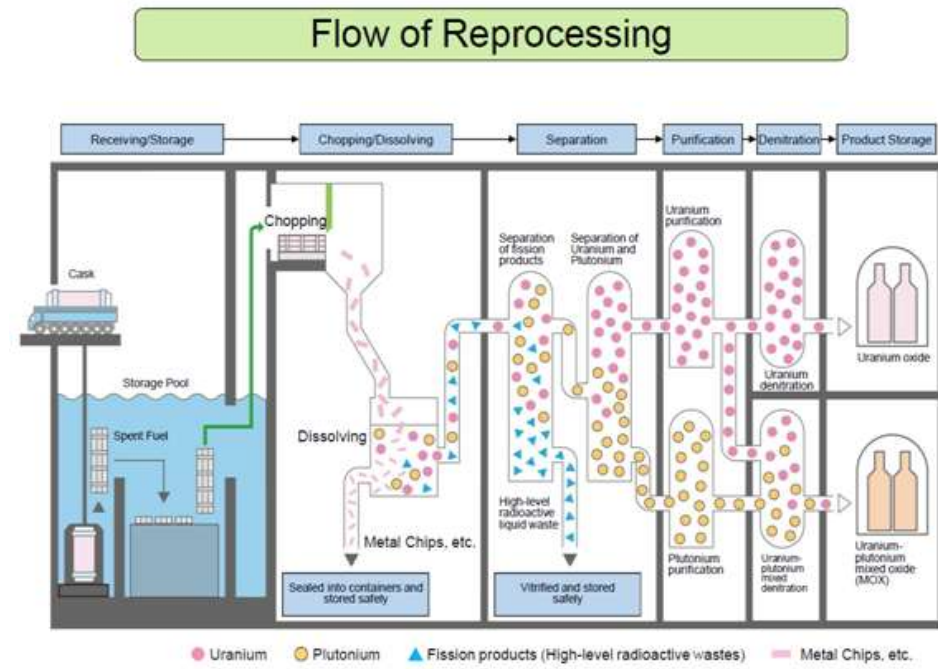


Fig. 3: Reprocessing of Spent Fuel Using the Solvent Exchange Method

The second method, Ion exchange, is an adsorption phenomenon where the mechanism of adsorption is electrostatic. Electrostatic forces hold ions to charged functional groups on the surface of the ion exchange resin. The adsorbed ions replace ions that are on the resin surface on a 1:1 charge basis.

The students utilized both separation techniques to separate radioactive species of Cesium and Barium as shown in Figure 4(a) and 4(b). The students from outside FUT were able to pick up new skills related to the technology. While the experiments and analysis were successful, the students also learned a few other items related to the study. The need to stay together and work together required the students to enter and exit the facility at the same time and to share in the work. Hence, lessons were learned related to access control of a large group (relative to the size of the laboratory) and also to sharing activities inside the lab. Figure 4(b) shows an exercise in washing the solvent extraction with a HCl solution. As this was one activity in a series, there was the need to develop hand-offs from one experimental step to the next. It was critical that the students communicate between themselves clearly and also practice the hand-off before we began working with the radio-isotopes.



Fig. 4: (a) Experimental Apparatus of a resin column for ion exchange methods, (b) Performing the washing phase with HCl of the solvent extraction in a fume hood

In addition to the main study, time was set aside to discuss recent events of international interest primarily focussing on available data related to the release of radioactivity from Fukushima Nuclear Power Plants. At this point in the history of the incident, much of the information presented to media was still conflicting, incompletely analyzed or not yet available in Canada. The exchange of information allowed the Japanese and Canadian students to interact on this topic from both the internal and international perspective. The topic was approached first by the Japanese professors describing the incident and the data available for them for analysis. Typical data available is shown in Figure 5. The data was discussed as a group from a technical perspective. The quality of the data and the general findings were summarized and explained thus allowing both sets of students to obtain a common technical basis for discussion.

Immediately after the facts were presented, the discussion continued towards interpretation of the results and the responses of various countries around the world. The response in Japan and Canada were markedly different. Obviously the incident had a strong impact upon Japan resulting in the shutdown of the nuclear fleet pending a review of the capabilities of each plant to withstand a future similar event. In Canada, the Nuclear Power Plants continued operating as normal and instead the regulatory and utilities concentrated on lessons learned and potential design changes. The students were encouraged to discuss the differences in the responses as part of the international collaboration.

The results of the student discussion identified some of the key differences in the two perspectives. In Canada, the region where nuclear power plants exist are in seismically stable regions relative to Japan. Hence, it was difficult for the students to be able to visualize the same type of event in Canada simply because the probability of earthquake related damage is low. Other events such as weather (ice/snow), tornados, and floods were discussed from the Canadian perspective and both Japanese and Canadian students obtained an improved understanding of the technical differences between the two events. The

other main difference was the socio-economic effect upon Japan. While the Canadian students could understand the loss of life, since Canada has not recently undergone any large scale disaster scenario, it was not obvious to the Canadian students of the impact until they had reached Japan. The exchange between the two sets of students improved the understanding of both parties.

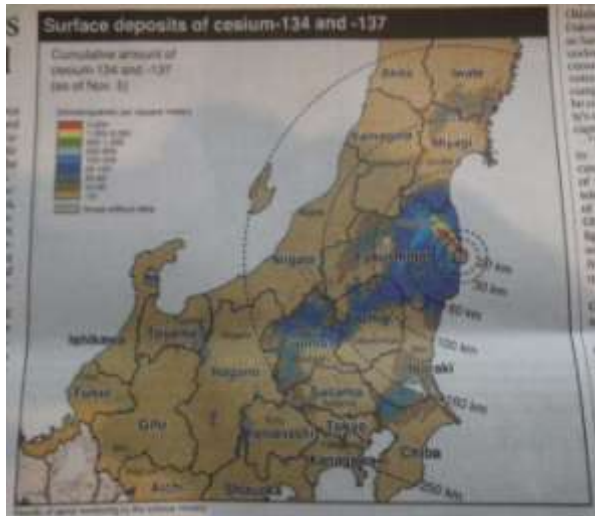


Fig. 5: Discussion of Impact of Fukushima Event by review of local perspective. Review of surface deposits of Cesium.

With the completion of the FUT training program, UOIT is currently preparing for a return visit to Canada by FUT professors and students. The exchange has been successful for a small group.

5. Concluding Remarks

To date, the collaboration has demonstrated that the exchange of information, professors, and students has led to an improvement in education and experiences at both institutions. The following concluding remarks can be made:

1. FUT and UOIT students have both gained an appreciation for different approaches towards the same problem and improved their hands-on training capability.
2. While differences in language did slow down the transfer of information, the need to work with a different culture and those whose original language was not English resulted in an increased effort to understand each other.
3. FUT and UOIT have both benefited from external ideas to strengthen their educational curriculum.
4. FUT was able to market the benefits of this exchange to other Universities in Japan.
5. The program was successful for a small group. Once the UOIT visit is complete, a review will be done to determine if larger groups are possible. The main concern for a larger group is obviously financing.

7. Acknowledgements

The authors wish to thank all of the students from Canada and Japan that participated in the training exercise and Professor Sunagawa and Professor Yoshioka for their valuable support and discussions.

8. References

1. G. Harvel and G. Berezna, "Use of Feedback for Improving Nuclear Engineering Curriculum", 17th Pacific Basin Nuclear Conference, Cancun Mexico, October 24, 2010.
2. G. Harvel and W. Hardman, "A Comparison of Different Communication Tools for Distance Learning Education", *Journal of Energy and Power Engineering*, 4(1): January 2010.

ONTARIO EXPERIENCE IN EDUCATION AND TRAINING: A UTILITY-UNIVERSITY PARTNERSHIP

G. BEREZNAI, J. FROATS and G. HARVEL

*Faculty of Energy Systems and Nuclear Science
University of Ontario Institute of Technology
2000 Simcoe Street North, Oshawa, Ontario, L1H 7K4, Canada*

ABSTRACT

The majority of engineers working in the nuclear industry receive their university education in one of the traditional engineering fields (such as mechanical, electrical, chemical and civil) and gain specific knowledge in the nuclear design, commissioning, operation and maintenance fields via in-house training courses and post-graduate education. There is a significant overlap between the specialist training provided by the industry and what is often available via post-graduate university courses. Established practices, lack of flexibility and/or the availability of specific expertise, and/or the lack of accessibility to the university courses by people working in the industry are some of the reasons why the two systems often continue independently of one another, despite potential benefits to all parties if shared course development and delivery were implemented. In Ontario, a new university was established in 2002 with the specific mandate to prepare “job-ready” graduates for several industries, including nuclear power. The university’s location in close proximity to the head office and ten operating nuclear units of Ontario Power Generation provided the opportunity to establish a partnership, and to provide cost-effective yet high quality learning opportunities for students seeking employment, or already working, in the nuclear industry.

1. Introduction

Canada’s nuclear power program, including the early development of reactors using natural uranium fuel and heavy water for both moderator and coolant, had a strong link to nuclear scientists and engineers in the UK. They made important contributions to the development of the critical pile ZEEP, and to the design, construction and operation of the NRX and NRU reactors [1]. The transfer of knowledge between UK, other European, American, various international and Canadian scientists and researchers established a pattern of industry-based training of the subsequent CANDU power reactor development program. Although Canadian universities, such as the University of Toronto and McMaster University offered courses in nuclear physics and engineering towards degree programs, these were seen as specialist education that was complementary to the industry training programs, and it was the latter that provided the bulk of the essential knowledge and skills to the designers, operators and maintainers of the CANDU fleet. It was not until the late 1990s, when a large percentage of the workers, hired by Ontario Hydro to staff the 20 nuclear-electric generating units the company operated in Ontario, were reaching retirement age, that the need arose to re-evaluate the relative roles of college and university education versus industry training.

2. Degree Programs in Nuclear Engineering and Science

Essential elements to establish university degree programs in a particular specialty are the necessary level of student interest, the availability of professors knowledgeable in the field of the study, and the existence or capability to create the physical infrastructure necessary to provide for teaching and learning, including classrooms and laboratories. Coinciding with the change of demographics that precipitated the need for a significant level of new hiring into Ontario’s nuclear industry was the relocation of the nuclear design staff of Ontario Power Generation (OPG), the successor company to Ontario Hydro in the area of electrical power generation, to Durham Region east of Toronto. OPG had become the owner and operator of

12 of Ontario's 20 nuclear-electric generating units, with Bruce Power taking over operation of the remaining eight nuclear units. Along with the human resources needs of the nuclear sector, other skill shortages, such as motor vehicle design and manufacturing, nursing, legal studies, the teaching of mathematics and science, were also identified as suffering from insufficient graduates being produced by the existing universities in the province. The Ontario Government, which holds responsibility of the province's education system, and is, at the same time, the sole shareholder of Ontario Power Generation, decided that a new university should be established, and located in Durham Region. One of the seven Faculties of this new entity, the University of Ontario Institute of Technology (UOIT), was to be in the area of nuclear engineering and science [2].

The new undergraduate degree programs in Nuclear Engineering and in Radiation Science were developed with significant input from the nuclear industry, including Ontario Power Generation and Bruce Power. Design, operating and maintenance engineering, nuclear waste management, health physics, plant chemistry, regulatory requirements and the overall concerns for safe and reliable operation of all key aspects of the nuclear fuel cycle were all to be given emphasis in the programs. The initial intake when the university opened its doors to students was 930, of which 110 were in the two nuclear programs. By 2012 UOIT has grown to 8,500 students, studying in programs that include not only undergraduate but also masters and doctorate degrees and graduate diplomas. In the nuclear programs, there are currently 450 undergraduate and 65 graduate students with a total of 290 alumni. The growth in graduands is shown in Figure 1 and at least 85% of the graduands are currently working in the Canadian Nuclear Industry as a direct result of the Utility-University partnership.

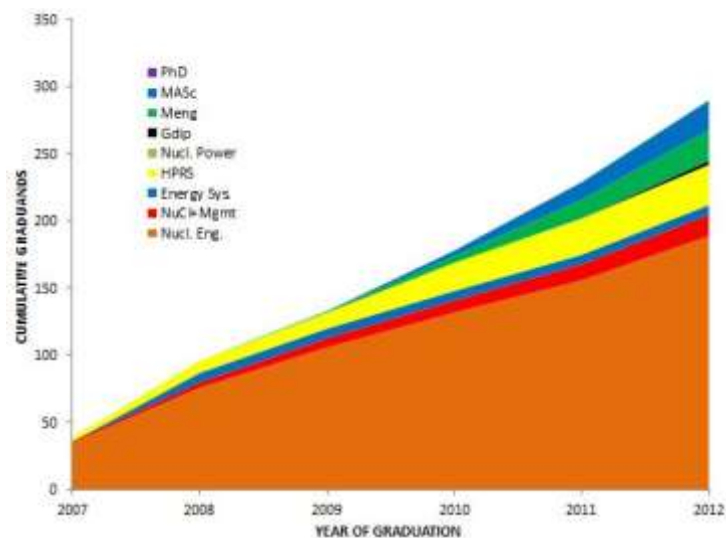


Fig.1: Growth in graduands from the Nuclear Related programs at UOIT

3. Utility-University Partnership

Having had a significant involvement in the design and development of the nuclear undergraduate degree programs at UOIT, OPG's management recognized the benefits of forming a strong partnership with the University, and decided to contribute \$10M to the construction of the Engineering and Applied Science Building on the UOIT campus, which was named in honour of Ontario Power Generation when it opened in 2007. The main results of the first five years of this partnership included UOIT creating degree and diploma programs for graduate engineers and scientists working in the nuclear industry to prepare them for career advancement including Master of Engineering, Master of Applied Science and Doctor of Philosophy degrees in Nuclear Engineering, make provisions for delivering such programs in facilities close to OPG's workplaces to facilitate greater employee participation, develop prior learning assessment criteria for providing OPG employees with

university course credits for OPG training and work experience, provide opportunities for their respective staff for exchange positions to facilitate continued professional development such as sabbaticals, adjunct professorships and instructors, and that UOIT should work to establish a Centre of Excellence in Energy Research [3].

To a significant extent these objectives were achieved during the five year term of the first partnership agreement. In particular, with significant funding in equal portions by the Provincial and Federal Governments, a 10,000 m² building to house UOIT's Energy Systems and Nuclear Science Research Centre with classrooms, research and teaching laboratories, student study spaces, and offices for faculty and staff was constructed and placed into service in 2011 [4]. Ontario Power Generation helped to equip the laboratories and extended the scope of the partnership into a second phase with a further investment of \$2M. Some of the key outcomes of the partnership include the development of graduate diplomas to help people working in the nuclear industry to keep up to date and enhance their knowledge as needed to follow the various opportunities of a 30 to 40 year working career, as well as to deliver training that is specific to working at Ontario Power Generation and is within the scope of university-level knowledge and skills.

4. Specific Programs

4.1 Graduate Diplomas in Nuclear Technology

A suite of six diplomas were created, each with a specific area of specialization within the fields of Nuclear Power, and Radiological and Health Physics [5]. The diploma programs were designed to meet the needs of personnel working in the nuclear industry to upgrade their knowledge and skills, to position themselves for advancement within their industry, and to promote an orientation toward lifelong learning. Over the course of their careers, individuals may choose to complete a number of these diplomas.

The six Graduate Diplomas in Nuclear Technology are as follows:

1. Fuel, Materials and Chemistry
2. Reactor Systems
3. Operation and Maintenance
4. Safety, Licensing and Regulatory Affairs
5. Health Physics
6. Radiological Applications

To earn a diploma, students are required to complete four courses associated with one of the six areas of specialization. Each diploma has a set of defined courses relevant to the area of specialization, and there are a number of non-specialist courses common to all the diploma programs. These courses are shared with the Master of Engineering and Master of Applied Science programs offered by UOIT's Faculty of Energy Systems and Nuclear Science, and Faculty of Engineering and Applied Science. To date, three students have completed their graduate diploma with four students currently enrolled. These numbers are expected to increase significantly starting in 2013 as OPG is planning to send 30 students per year the dedicated design engineering diploma.

4.2 Advanced Operations Overview for Managers

OPG developed a unique program in 2004-05 to meet its need for the training of middle and senior level managers in the integrated operation of its nuclear plants that was previously only offered to employees being trained to be nuclear plant shift managers. This rigorous program required typically three years of classroom, simulator and on-shift training in the plant for which the employee was designated to become a shift manager. The lengthy training program, followed by various periods of managing a shift, meant that there were

insufficient candidates to fill all the jobs for which previous shift manager experience was a prerequisite. An extensive job and task analysis concluded that while the shift manager experience was highly valuable for the many middle and senior manager positions in the OPG hierarchy, it was possible for many of these jobs to acquire the desired technical knowledge and management skills by means other than via occupying the shift manager position. In particular, the science fundamentals, station equipment and systems knowledge, integrated station operations, the analysis and practice of safe unit operations could be acquired via a combination of classroom lectures, simulator exercises and field observations.

The program to meet these needs was developed by a team of specialists who had been shift managers and subsequently worked as middle and senior managers at OPG. They selected from the shift manager training program the content that they subsequently used as technical managers. These same specialists also delivered the resulting training program, called Advanced Operations Overview for Managers(AOOM for short) annually between 2005 and 2008. It wasn't until 2011 that the program was needed to be offered again, and it was realized that under the terms of the OPG-UOIT partnership, there was an opportunity to offer the program at the university. In both 2011 and 2012 UOIT successfully delivered the program, and additional programs are now scheduled for 2013 and 2014. Key to delivering the AOOM program was setting up classrooms at UOIT that could use the "virtual" or GUI-based versions of the full-scope training simulators for which OPG has developed the software, and permitted its use by UOIT. A typical layout uses multiple screens and allows for distance learning capability as well.

4.3 Graduate Diploma in Nuclear Design Engineering

The program, requested by Ontario Power Generation, was to provide an educational opportunity for practicing engineers to further their education in the nuclear design area. OPG indicated it was an important initiative to support capability in the design area as well as to enhance quality in design products and services. It was at first thought that this new area could be accommodate within the existing set of six Graduate Diplomas in Nuclear Technology, or added as a seventh, but the emphasis on design engineering indicated that a new type of diploma was the preferred approach. In the case of the existing diploma suite there is a wide choice of subjects from which a student can select what best meets his/her specific career circumstances, while the request from OPG was for every graduate of the program to have completed the same set of courses with the prescribed learning outcomes. The new diploma is to ensure that graduates have the desired level of understanding and awareness of:

- reactor safety fundamentals and concepts
- the management of risks in nuclear plant design
- how nuclear power plant systems operate and how the systems interact to enable the safe production of electrical energy
- quality management processes as they apply to nuclear design
- relevant codes and standards
- human performance management for design work
- nuclear design processes.

The four courses that make up the Graduate Diploma for Nuclear Design Engineering are as follows:

1. The Nuclear Plant Systems and Operations course provides an understanding of the key design and operating features of the main process and control systems and the integrated operation of a nuclear-electric generating unit.
2. The Nuclear Plant Safety Design course provides an understanding of the concepts and analytical safety basics of nuclear reactor design, and the design of safety and safety support systems.

3. The Design of Nuclear Plant Systems course provides an understanding of the design basis and fundamental design features of nuclear plant process and control systems.
4. The Nuclear Design Processes and Techniques course provides an understanding of nuclear engineering processes and the application of these processes to get high quality results in nuclear design.

5. Concluding Remarks

The continuing rise in the knowledge and skill levels required of energy workers in general and nuclear utility employees in particular, has led to a reevaluation of the relative roles of education and training in the provision of a well-qualified workforce. The desire of nuclear-electric utilities to concentrate on their core functions and to transfer training to post-secondary institutions that can more cost-effectively deliver training that does not require access to plant equipment and systems, has provided an opportunity for win-win partnerships between colleges, universities and the nuclear industry. The close proximity of the campus of the University of Ontario Institute of Technology to the nuclear head office and power plants of Ontario Power Generation provided further opportunities for the university to offer training and education to OPG employees. Programs in nuclear engineering, power plant operations, health physics and radiation science have been developed at the bachelor, masters and doctorate levels during the ten years of the University's operation. Graduate diplomas and plant specific training courses are also offered by the university under a partnership that benefits both institutions and their respective employees.

6. References

1. Nucleus: The History of Atomic Energy of Canada Limited, by Robert Bothwell, University of Toronto Press, 1988
2. G. Bereznai, "Start-up of a Nuclear Engineering Undergraduate Honours Degree Program in Canada", *14th Pacific Basis Nuclear Conference, Hawaii, USA (2004)*.
3. G. Bereznai, "Post-Secondary Education and Utility Partnership in Ontario", *Proceedings of the Conference on Nuclear Training and Education, Jacksonville, Florida, USA, (2011)*.
4. G. Bereznai, S. Perera, "Academic Design of Canada's Energy Systems and Nuclear Science Research Centre", *Proceedings of the European Nuclear Conference ENC2010, Barcelona, Spain, (2010)*.
5. G. Bereznai, "Graduate Diplomas in Nuclear Technology", *Proceedings of the 30th Canadian Nuclear Society Annual Conference, Calgary, Alberta, (2009)*.

LESSONS LEARNED FROM FUKUSHIMA DAICHI – DEVELOPMENT OF SEVERE ACCIDENT TRAINING EXERCISES

JUDITH K. HOHORST
CHRIS M. ALLISON
BRIAN ALLISON
*Innovative Systems Software
1284 South Woodruff Avenue
Idaho Falls, Idaho 83404*

UWE LUETTRINGHAUS
ALFRED TORRI
*Risk Management Associates
1421 Hymettus Avenue
Encinitas, California, 92024*

Immediately after the start of the accident at Fukushima Daichii a series of RELAP/SCDAPSIM calculations were performed to assess the potential for damage to the core and vessel in Units 1-3. Because of the large uncertainties in the accident conditions, sensitivity studies were performed looking at different core uncover scenarios including (a) a range of core uncover times from 0 to 70 hours after reactor scram, (b) high and low pressure scenarios, and (c) different water addition scenarios. These initial calculations of the Fukushima Daichii accident, along with the management strategies used during the accident emphasized the need for more expertise in the field of severe accident analysis and management. Model improvements to RELAP/SCDAPSIM developed by ISS personnel and partner universities have been incorporated into the computer code and new severe accident based training exercises and desktop simulator problems to be used with RELSIM, have been developed for use in training workshops and university curriculums.

Because of the complex thermal hydraulic boundary conditions, it was also found that the use of the integrated RELSIM-RELAP/SCDAPSIM(RRS) simulator package was quite helpful in presenting and understanding the results of the calculations. RRS, developed for use as a real time desktop simulator, uses an advanced interactive simulator Graphical User Interface, RELSIM being developed by Risk Management Associates, in combination with RS, a detailed system thermal hydraulic code being developed by Innovative Systems Software and other members of the international SCDAP Development and Training Program.

This paper will give a brief description of the RELSIM-RELAP/SCDAPSIM package, briefly describe the Laguna Verde plant model used for the initial calculations, show representative results from the initial calculations, describe the effect of the new models on calculated results, and discuss how the advance display options can be used in workshop training exercises, and university simulator training exercises for severe accident analysis and management.

1. Introduction

Immediately after the accident at Fukushima Daiichi, Innovative Systems Software, and other members of the international SCDAP Development and Training Program (SDTP)[1,2] started an assessment of the possible core/vessel damage states of the Fukushima Daiichi Units 1-3. The assessment included a series of detailed calculations using RELAP/SCDAPSIM[3] and RELSIM-RELAP/SCDAPSIM[4]. The calculations used a detailed model of the Laguna Verde BWR vessel and related reactor cooling systems. The Laguna Verde models were provided by the National Commission for Nuclear Safety and Safeguards(CNSNS), the Mexican Nuclear Regulatory Authority.

Because of the large uncertainties in the accident conditions, sensitivity studies were performed looking at the different core uncover scenarios including (a) a range of core uncover times from 0 to 70 hours after reactor scram, (b) high and low pressure scenarios, and (c) different scenarios of water addition. Initial assessments were prepared for the IAEA emergency response team in late March 2011 and our Japanese colleagues in May 2011. As described in more detail in Reference 5, the initial calculations indicated that extensive fuel melting likely occurred in Units 1 and 3, within the first 10 hours for Unit 1 and between 40 to 51 hours for Unit 3. Fuel melting was also predicted for Unit 2 but the estimates of the extent of melting varied widely due to the uncertainties introduced by the overlapping combination of the addition of salt water to the vessel and the intentional depressurization of the vessel by the opening of Safety Relief Valves (SRVs). Vessel failure was considered likely in Unit 1, somewhat less likely in Unit 3, and undetermined in Unit 2.

RELSIM-RELAP/SCDAPSIM is now used in both the real time and playback mode to help with the understanding of the different accident scenarios. Because some of the Fukushima-like scenarios extend over a period of days, it was initially used in the play back mode to help in the assessment of the complex conditions since most of the calculations were performed by RELAP/SCDAPSIM. Recently, the integrated package, RELSIM-RELAP/SCDAPSIM, has been increasingly used in the normal interactive mode for training on the response of the plant after the start of core uncover. As described in Section 1, the RELSIM playback option allows the user to use the powerful RELSIM graphical displays with pre-existing RELAP/SCDAPSIM restart plot files. The detailed RELAP/SCDAPSIM model of the Laguna Verde BWR vessel and related reactor cooling systems is described in Section 2 with more details provided in Reference 5. A brief description of the accident scenarios used in the sensitivity studies as well as those scenarios that may be most like those for Units 1-3 of Fukushima Daiichi, highlights of representative results, and snapshots from the RELSIM-RELAP/SCDAPSIM displays are provided in Section 3. Discussion and conclusions are presented in Section 4

2. RELSIM-RELAP/SCDAPSIM

RELSIM-RELAP/SCDAPSIM is a fully integrated “real time” desktop systems thermal hydraulic simulation package being developed jointly by Risk Management Associates (RMA), Innovative Systems Software (ISS), and other members of the SDTP development and training team. RELSIM-RELAP/SCDAPSIM uses RELAP/SCDAPSIM as the simulator engine in combination with the RELSIM interactive simulator graphical user interface (GUI). RELAP/SCDAPSIM uses RELAP5 and SCDAP models [6,7], developed originally by the US Nuclear Regulatory Commission, in combination with SDTP member developed models and advanced numeric/programming techniques to provide “faster-than-real-time” simulations of typical thermal hydraulic and reactor systems. SDTP member organizations and licensed users are using it for reactor and other thermal hydraulic systems simulation and analysis. It is also used in the training of

university students and other novice reactor systems analysts to help them understand how complex thermal hydraulic and/or reactor systems perform under realistic and postulated conditions.

The integrated package uses standard RELAP/SCDAPSIM input models. As a result, a typical user can very quickly build advanced graphics screens and animate the screens to control a simulation or display the results of the calculations as they are performed. The package has full access to the RELAP/SCDAPSIM database so any calculated results in the data base can be displayed, including "control variables" or parameters created using the RELAP5 control system input. The user also has access to RELAP5 interactive commands that allow the user to control the simulation. For example, the user can turn on pumps or open valves to simulate different types of piping breaks.

RELAP/SCDAPSIM is designed to describe the overall reactor coolant system (RCS) thermal hydraulic response and core behaviour under normal operating conditions or under design basis or severe accident conditions. The RELAP5 models calculate the overall RCS thermal hydraulic response, control system behaviour, reactor kinetics, and the behaviour of special reactor system components such as valves and pumps. The SCDAP models calculate the behaviour of the core and vessel structures under normal and accident conditions. The SCDAP portion of the code includes user-selectable reactor component models for LWR fuel rods, Ag-In-Cd and B₄C control rods, BWR control blade/channel boxes, electrically heated fuel rod simulators, and general core and vessel structures. The SCDAP portion of the code also includes models to treat the later stages of a severe accident including debris and molten pool formation, debris/vessel interactions, and the structural failure (creep rupture) of vessel structures. The latter models are automatically invoked by the code as the damage in the core and vessel progresses.

The desktop simulator version of RELSIM-RELAP/SCDAPSIM typically includes three RELSIM components, SIM, TVP, and ScreenBuilder. The SIM (Simulation and Interactive Modeling) component allows the user to run RELAP/SCDAPSIM interactively using advanced GUIs. The TVP (Transient Visualization and Post-Processing) component allows the user to play back previous RELAP/SCDAPSIM simulations using those same advanced GUIs. The third component, ScreenBuilder, is used by the user to build the graphic displays or screens used to either run the code interactively or play back previous simulations.

SIM is an interactive graphical user interface. It allows the user to interactively set up accident sequences and to change the status of system components (i.e. trip a pump or open a valve). The accident progression or code calculation results can be viewed on a single or multiple monitors as (shown in Figure 1). The user can then run or pause the simulation using buttons provided at the top right of the screen. Although the speed of the simulation will depend on the complexity of the input model and transient, typical full reactor plant models will run significantly faster than real time on current Windows PCs.

TVP is a stand-alone replay system for pre-calculated accident sequences. TVP replays either the SIM recorded replay file or the RELAP restart plot file. The TVP interface can use the same graphics screens used in the original SIM simulation run or different screens developed specifically for the play back of the results. The user can select from a variety of graphics screens during the replay. All replay functions are available by mouse action on the TVP run manager bar, including fast forward, fast backward, jump forward, jump back, one step forward, one step back and a preset replay speed. With this option, long simulations that may have represented hours of real time, can be quickly reviewed and played back.

A wide variety of different types of graphics screens can be built to display the calculated results and control the simulation using ScreenBuilder. The user can also build a variety of time history plot screens or data tables to display the simulation results as the simulation proceeds. The time history plots can be

edited with automatically generated or user defined axes descriptions, labels, markers, legends, etc. The resulting time history plots can also be exported electronically as report ready graphs. The plot screens can be rearranged and curves and plots can be added/deleted/rearranged during the simulation.

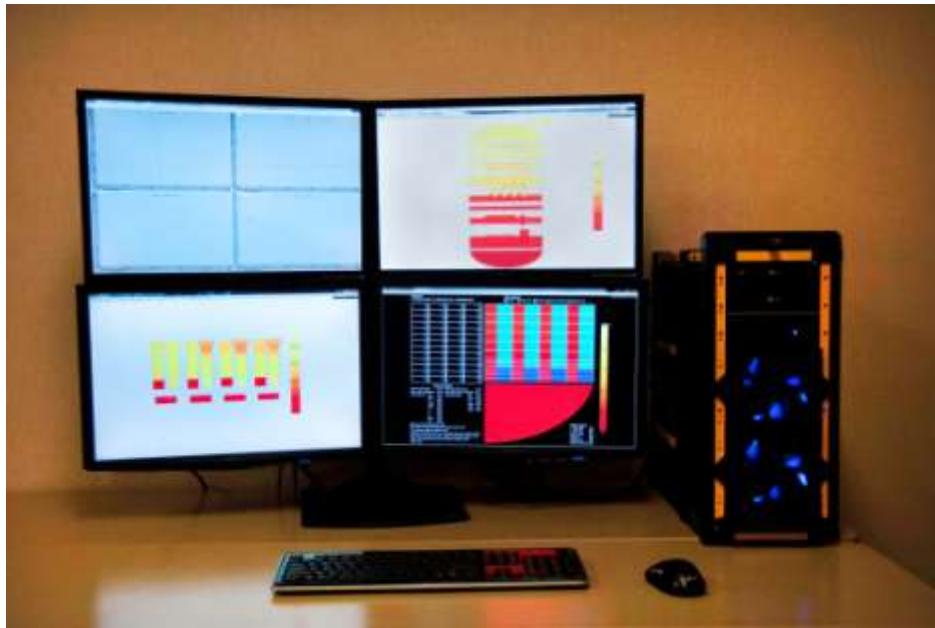


Figure 1 - Example of simulation with multiple displays on a Windows PC.

Although the option has not yet been used for the Fukushima assessment activities, the RELSIM-RELAP/SCDAPSIM desktop simulator package can also be expanded to a full training environment running on multiple networked computers. This Multi-station Training System provides an environment with a full control server station running the RELAP/SCDAPSIM simulation, a full control instructor station, an interactive control room station and one or more technical support/observer stations, including one or more off-site stations linked via the internet or cellular connection. The server and instructor stations have full control, the control room station can take corrective actions in the screens and all other stations are observer only. All stations can have individual screens and plots appropriate for their use, i.e. control room panels and screens for the control room station, SPDS screens for the TSC station, etc. The stations are in separate locations linked via the plant network or via a dedicated loop network. This permits testing of both the accident sequence response as well as the communication between the teams.

3. LAGUNA VERDE INPUT MODEL

The core is described using four groups of representative BWR assemblies and associated control blade/channel boxes at different power levels and burn-up histories. Four vertical flow channels describe the flow within each of the four groups of BWR fuel assemblies (inside the fuel channels). An additional four vertical flow channels describe the flow in the bypass regions outside the channel boxes and

surrounding the control blades. Each representative assembly in each group includes a representative fuel rod bundle, Zircaloy channel box, and B₄C control blade element, Figure 2. The fuel rods in each assembly are described by a representative SCDAP fuel rod component. The channel box and control blade segment in each assembly is described by a representative SCDAP BWR channel box/control blade component. The radial and axial power peaking for the four representative fuel rod groups are provided in Figures 3 and 4. The fuel rods in groups 1 and 2 (labelled components 1 and 2 on the figure) have average burn-up levels of 4.34×10^5 MWs/kg. Fuel rods in groups 3 and 4 have average burn-up levels of 3.74×10^5 MWs/kg and 1.88×10^5 MWs/kg, respectively.

The overall thermal hydraulic nodalization for the RELAP/SCDAPSIM model is presented in Figure 5. The plant model, developed by CNSNS, has a high level of detail. It represents the important features of the core, vessel, associated emergency cooling systems, and containment. The nodalization includes the reactor pressure vessel (RPV), the water (safety) injection components of the emergency core cooling system, and main steam line(s).

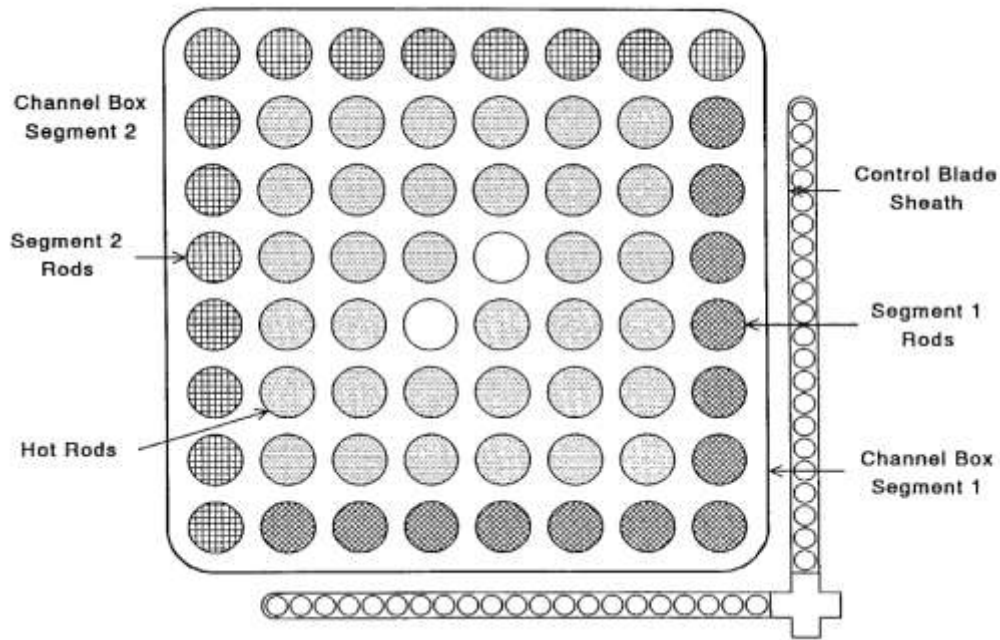


Figure 2 – Representative RELSIM-RELAP/SCDAPSIM BWR assembly for Laguna Verde.

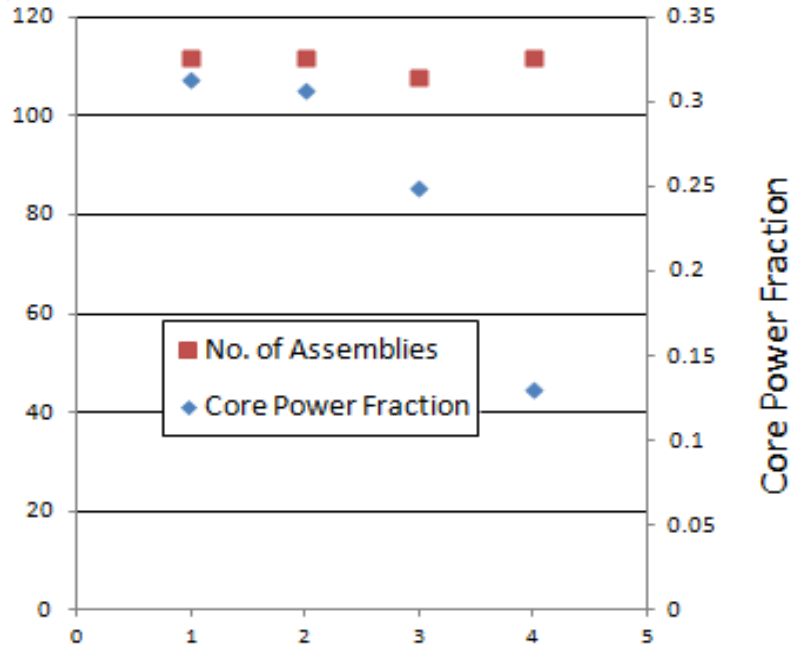


Figure 3 – Core power fraction and number of assemblies in the four representative assemblies used in the Laguna Verde input model.

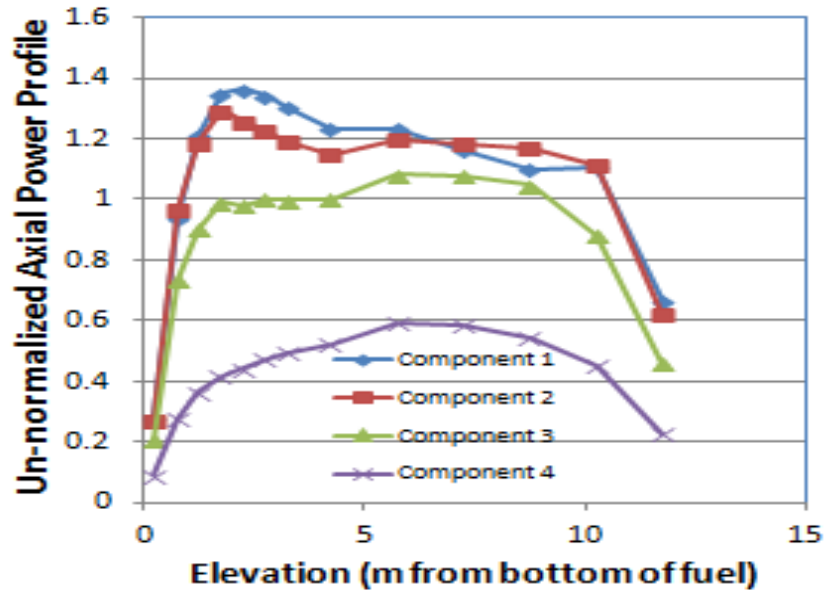
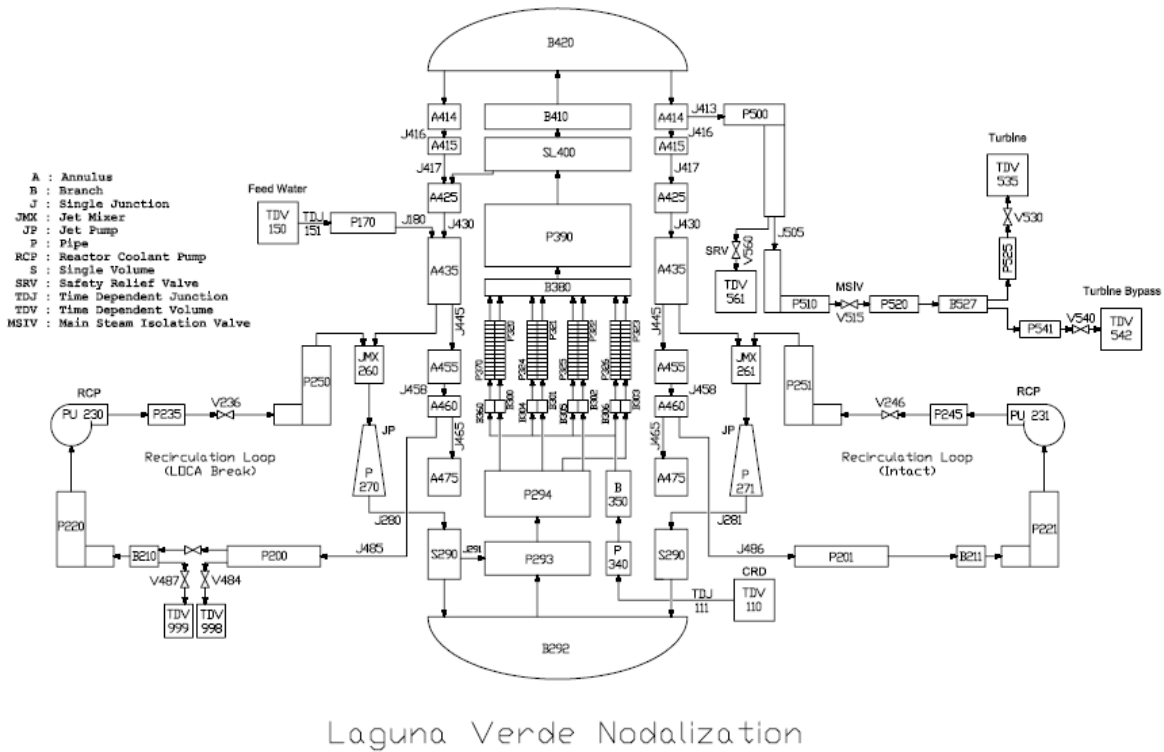


Figure 4 – Un-normalized axial power profiles in the four representative assemblies used in the Laguna Verde input model.



(c) konakdar, ecc

Figure 5 – Laguna Verde thermal hydraulic nodalization.

4. DISCUSSION OF RESULTS

The initial calculations immediately after the accident were performed by CNSNS using RELAP/SCDAPSIM for station blackout conditions with different scenarios after loss of emergency cooling including boiloff at high pressure and low pressure (opening of two safety relief valves (SRVs) after loss of emergency cooling). Additional calculations were then performed by ISS on March 21 to provide bounding results for the IAEA emergency response team. Since at this time it was not known what accident management strategies were possible or being performed, a series of calculations were initiated assuming that limited core cooling was maintained (equilibrium collapsed water levels either at ~50% of the core (high pressure scenario) or near the bottom of in the core (depressurized scenario)) for a range of times starting from 4 hours to 20 hours after reactor scram. For example, Figure 6 shows the maximum assembly temperatures, water levels, and RPV pressures for two scenarios where emergency water injection was terminated at 4.2 hours after reactor scram with and without the opening of two SRVs. In this figure the water level is measured from the bottom of the lower head where ~9 m corresponds to the top of the core and ~4 m corresponds to the bottom of the core.

After March 25, additional calculations were initiated looking at wider variety of different accident scenarios. These calculations included station blackout transients with the loss of emergency cooling ranging from 0 to 70 hrs. after reactor scram. Variations on these scenarios included high pressure and depressurization scenarios with different amounts and timing of water addition after part or most of the core was uncovered. For example, Figure 7 shows the maximum assembly temperatures and collapsed water levels for high-pressure scenarios with loss of emergency cooling at 0, 4, 40, and 70 hours after

reactor scram. The relative times are the actual times offset in time so the start of core heat up is overlaid.

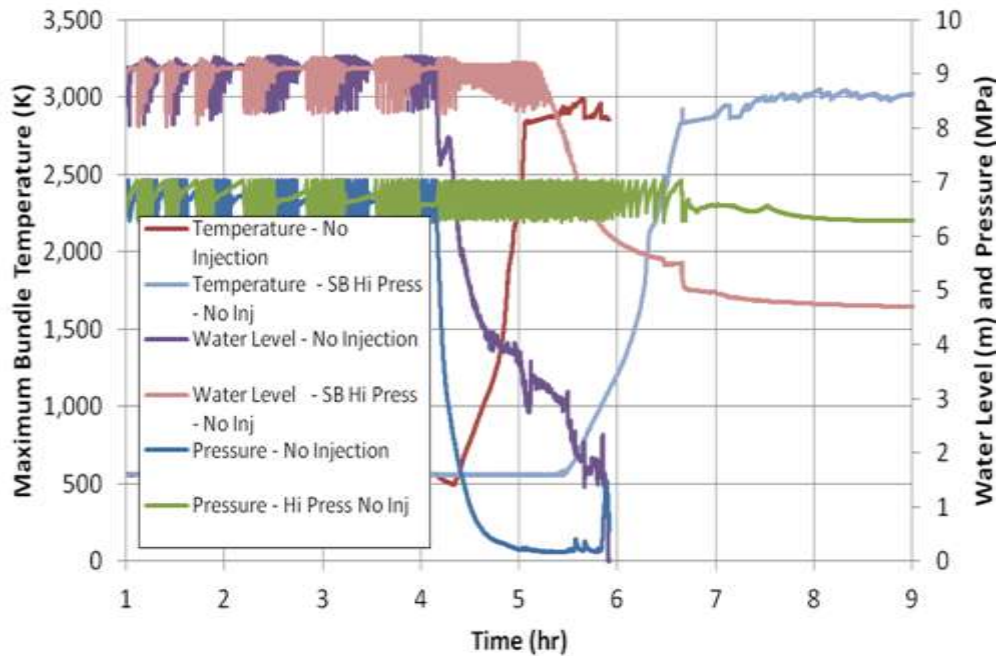


Figure 6 - Maximum bundle temperature, water level, and reactor vessel pressure for scenarios with and without depressurization (all emergency water injection was terminated at 4.2 hours after reactor scram).

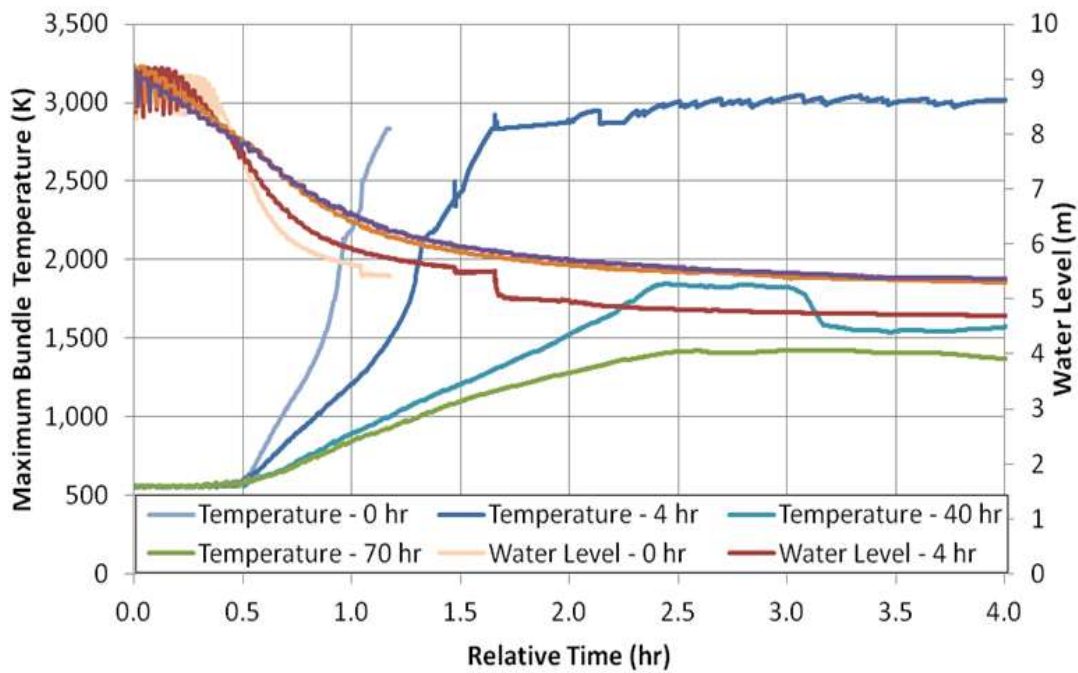


Figure 7 - Maximum bundle temperature and water level for high pressure scenarios for scenarios where all of the emergency water injection was terminated at a time varying from 0 hours to 70 hours after scram.

The calculations for a wide range of station blackout scenarios showed the core uncover, fuel melting, and relocation of the fuel and other molten materials into the lower plenum can occur rather quickly once emergency cooling is no longer available. For the scenarios with the loss of emergency cooling occurring within 2 or 3 days after reactor scram followed by the opening of the SRVs and depressurization, fuel melting can be reached within 2 hours of the loss of core cooling. For the same scenarios but keeping the SRVs closed (high pressure scenarios), fuel melting can be delayed for some hours (approximately 2 hours for a scenario with loss of cooling about 4 hours after scram). This delay is more pronounced for scenarios with a loss of cooling after 2 or 3 days.

Although the timing of the loss of emergency cooling impacts the timing of core damage, the pattern of the radial and axial extent of the damage in the core does not change significantly. However, the radial and axial extent of core damage is impacted rather strongly by (a) the variation in power in the core both axially and radially (see Figures 3 and 4), (b) the changes in vessel pressure associated with the opening (or lack of opening) of the SRVs, and (c) addition of water after core uncover. Figure 8 shows the influence of the power distribution in the core. It shows a noticeable double hump in the temperatures for the higher power assemblies, corresponding to the double peak in the axial power peak in the high to intermediate-to-high powered assemblies. This figure is for a snap shot in time after failure of the control blades and channel boxes (temperatures near 1500K) and after the start of the melting of the un-oxidized cladding material (temperatures near 2000 K) in the hottest regions of the core for the depressurization scenario.

As shown in Figure 9, the influence of double power peak in the higher power assemblies is not so visible in a comparable high-pressure scenario. In this scenario, the bottom of the core remains covered with water as the upper portion of the core heats up, reaching fuel melting temperatures over much of the upper core. However, as shown on both Figures 8 and 9, the influence of the strong radial variation from

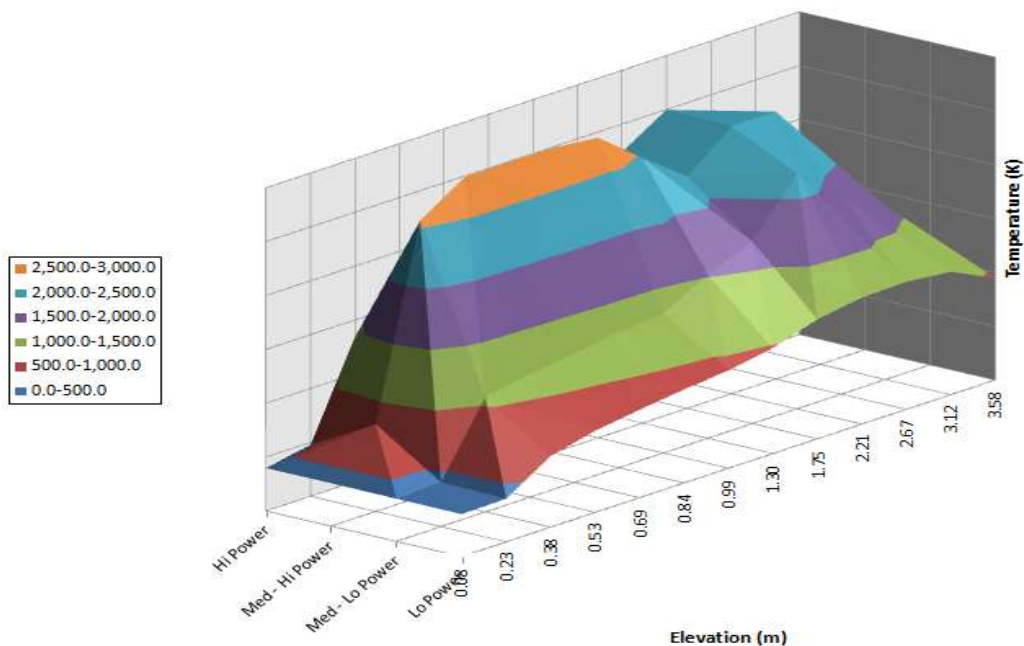


Figure 8 - Core temperatures at 5.1 hours for a scenario with depressurization (all emergency water injection excluding the CRDs was terminated at 4.2 hours after reactor scram).

the high to lower power assemblies is still evident in both the high pressure and low pressure scenarios. Figure 10 shows the influence of water injection for a scenario where the vessel is depressurized and water was injected when much of the core was still at temperatures below 2000 K. The comparison at 5.0 hours after scram clearly shows that even though the peak core temperatures in the scenario with water injection was less than in the scenario without water injection, the extent of control blade and channel box melting and relocation (temperatures greater than 1500 K) is much larger in the case with water injection.

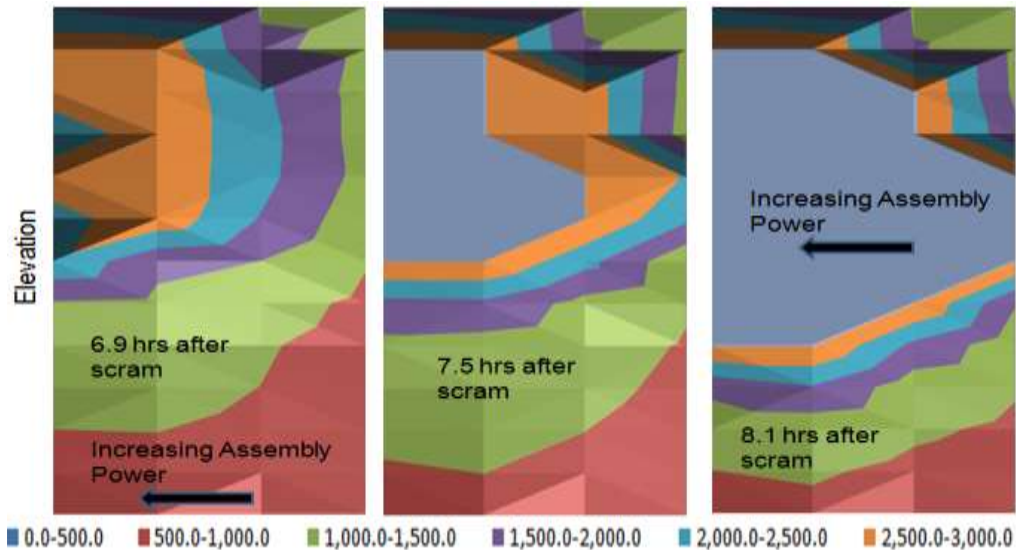


Figure 9 – Core temperature distributions for a scenario without depressurization (all emergency water injection was terminated at 4.2 hours after reactor scram).

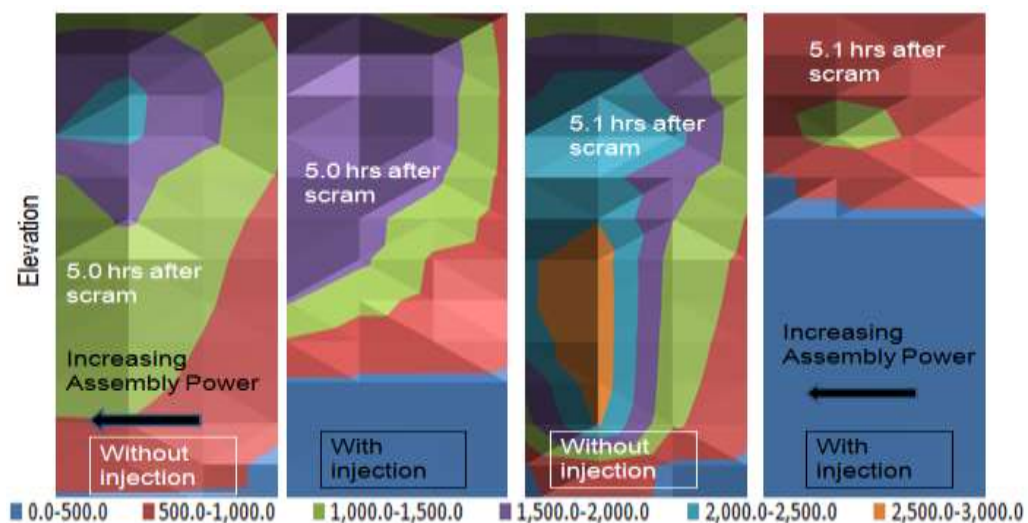


Figure 10 – Core temperature distributions for scenarios with depressurization with and without water injection after core uncover (all emergency water injection was terminated at 4.2 hours after reactor scram).

Figures 1 and 11-12 show some of the RELSIM-RELAP/SCDAPSIM displays that were developed within the first few days of the accident. Figure 1 shows the desktop simulator with four active monitors and displays. Figures 11 and 12 show the time history plots for a station blackout scenario where emergency core cooling was terminated within 20 minutes after reactor scram. As shown on the displays of reactor vessel pressure, the pressure remained high since the SRVs were not manually opened in this scenario. Ceramic, {U-Zr}-O₂, melting temperatures were reached within 80 minutes of scram and a ceramic molten pool was predicted to be formed at this time. The debris in the lower plenum during this period was the metallic mixture from the liquefaction and relocation of the control blades and Zircaloy channel boxes materials into the lower plenum. Failure of the ceramic molten pool crust and relocation of a portion of the ceramic melt occurred later after these snapshots were taken.

Figures 13-16 show snapshots of the other graphics displays showing the fluid conditions in the vessel, vessel internals, and core region during the initial part of the transient. Figures 13 and 14 show snapshot images from a RELSIM graphic display of the fluid liquid temperatures and vapor void fractions in the vessel before the start of core uncover. Figures 15 and 16 show the vapor void fractions in the vessel internals and in the core region later in the transient after much of the core had been uncovered.

Figures 17-18 show snapshots from the SCDAP core component and lower plenum displays. The core displays can show the changes in core geometry as well as parameters computed by the SCDAP core component models. The lower plenum displays show the state of the debris computed by the SCDAP 2D lower plenum models.

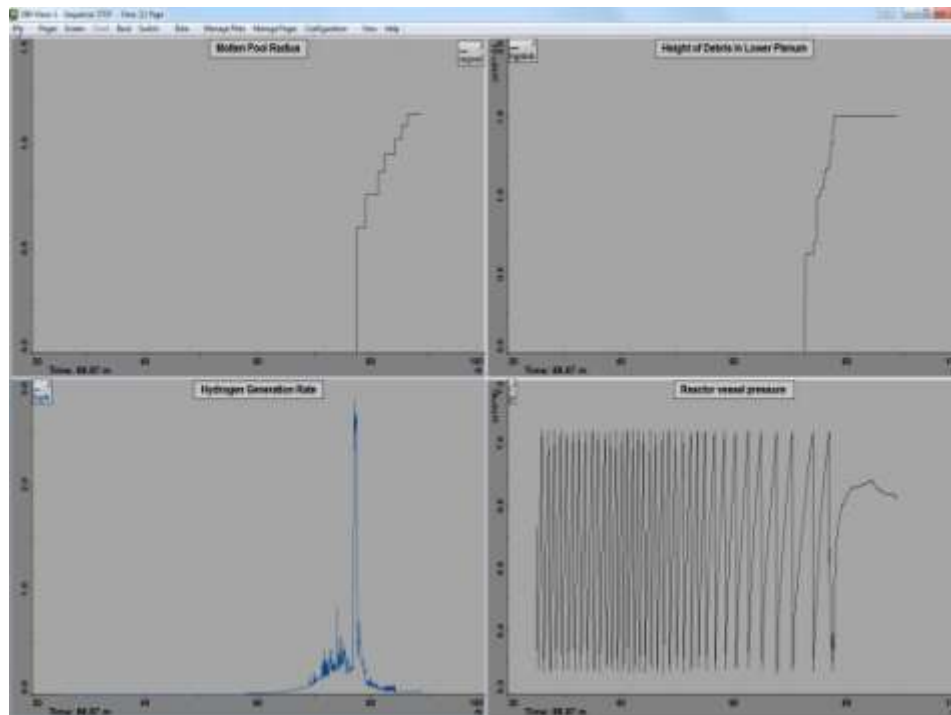


Figure 11 – Molten pool radius, height of debris in lower plenum, hydrogen generation rate, and reactor vessel pressure late in a station blackout without depressurization.

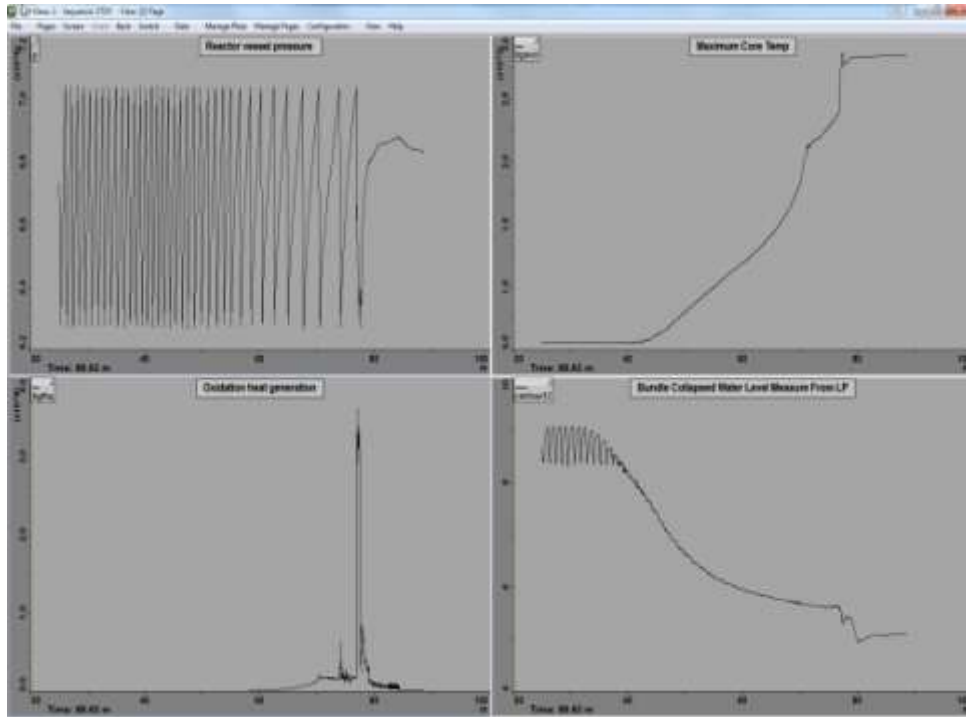


Figure 12 –Reactor vessel pressure, maximum core temperature, oxidation heat generation, and bundle collapsed water level late in a station blackout without depressurization.

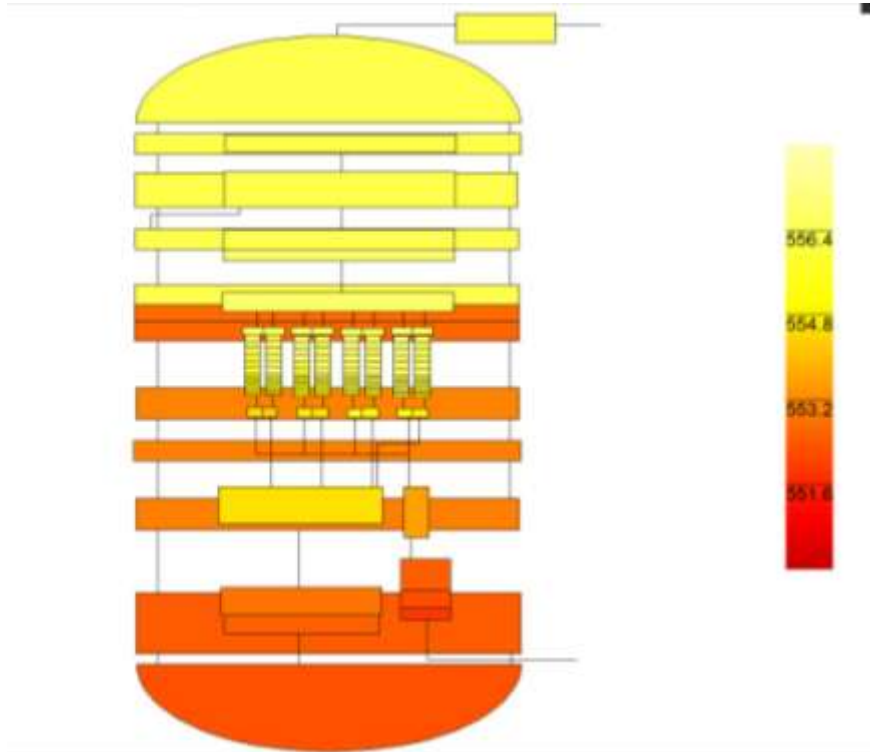


Figure 13 – Snapshot of liquid fluid temperature in the vessel view.

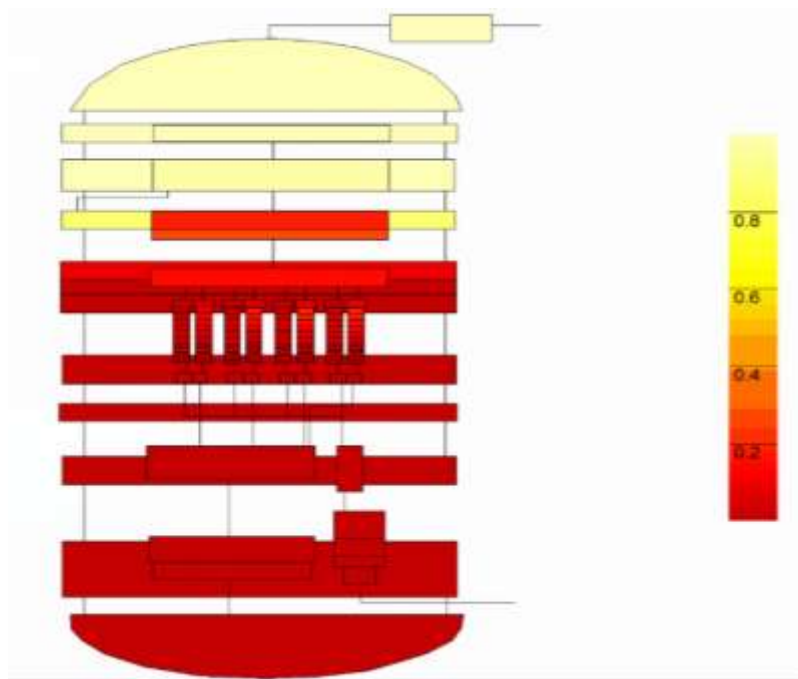


Figure 14 – Snapshot of vapor void fraction fluid temperature in the vessel view.

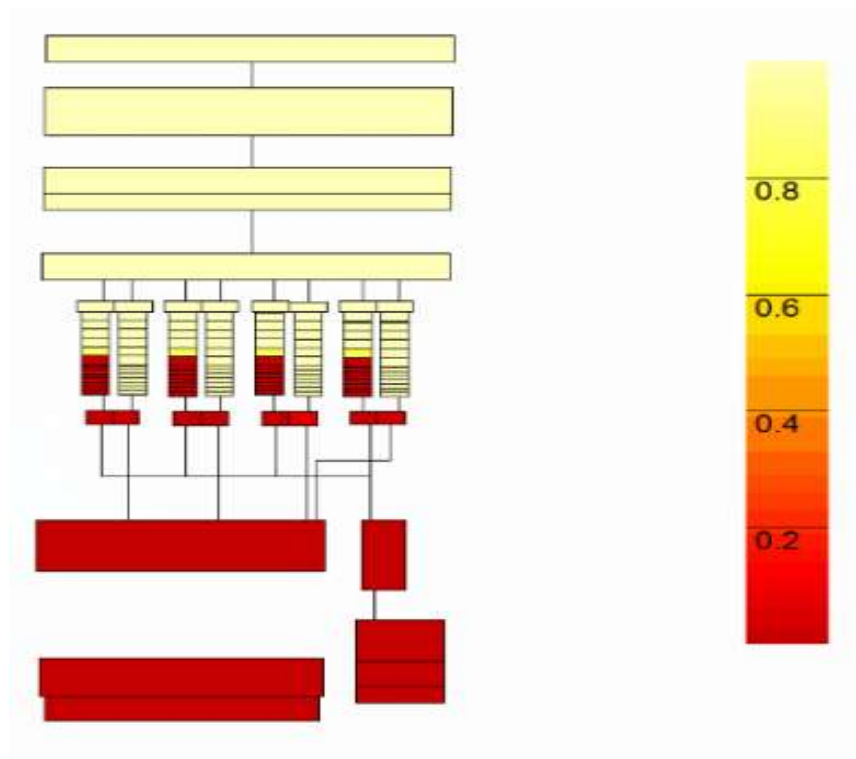


Figure 15 – Snapshot of vapor void fraction fluid temperature in the vessel internals view.



Figure 16 – Snapshot of vapor void fraction fluid temperature in the core view.

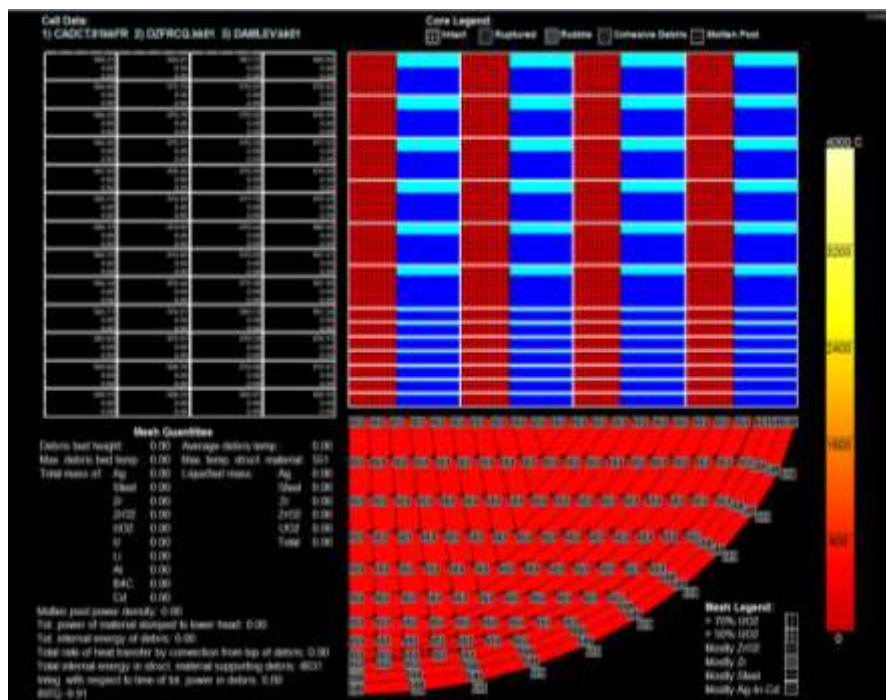


Figure 17 – Snapshot of SCDAP vessel view.

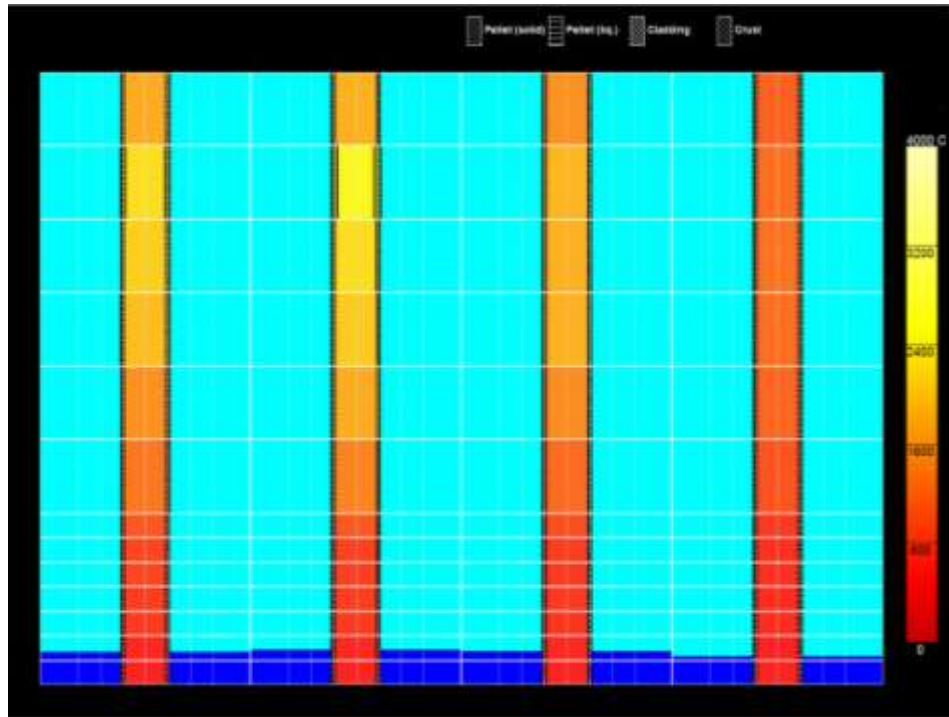


Figure 18 – Snapshot of SCDAP core component view.

5. CONCLUSIONS

Although the calculations were based on the Laguna Verde plant rather than the Fukushima Daiichi Units, it was still concluded initially that extensive fuel melting occurred in Units 1-3 within the first 10 hours for Unit 1 and between 40 to 51 hours for Unit 3. Fuel melting was also predicted for Unit 2 but the estimates of the extent of melting varied widely due to the uncertainties introduced by the combination of the addition of salt water to the vessel in combination with a depressurization of the system. Vessel failure was considered likely in Unit 1, somewhat less likely in Unit 3, and undetermined in Unit 2. It was also concluded that the initially reported water levels, particularly for Unit 1 could not be correct given the stated times of loss of emergency cooling and the observations of hydrogen explosions and radiation levels detected. A more recent summary report on the accident [9] has confirmed the information on the loss of emergency cooling and has indicated that the water level measurements may have been inaccurate.

RELSIM-RELAP/SCDAPSIM also played a significant role in the initial and subsequent analyses. During the first few days after the accident, a series of displays were built for the Laguna Verde input model while stand-alone RELAP/SCDAPSIM calculations were being performed. Initially RELSIM-RELAP/SCDAPSIM was used almost exclusively in the play back mode to look for (a) possible flaws in the input models and to insure that the scenarios were being implemented properly and (b) look at the overall behavior in the plant such as fluid conditions in the vessel and core. Since the results could be played back at high speeds, it was much faster to look at the RELSIM-RELAP/SCDAPSIM displays than looking at a series of time history plots and output files.

One of the initial uses of these displays was to look for potential problems in the input model. Figures 15 and 16 are good examples. In the early calculations, even though the intention was to terminate all emergency cooling flows, the flow injected through the control rod drive (CRD) system was inadvertently left on. This flow is injected into the bottom of the control blade channels resulting in reduced vapor void fraction in the four control blade bypass channels. In Figure 13, the bottom volume of the CRD cooling system within the vessels shows the cooler liquid temperature where the water enters the system.

The ability to generate movies of the results for the different scenarios also proved to be very useful when the results were being presented to our Japanese colleagues soon after the accident. Most recently the package is being used for training purposes running different scenarios in the simulator and playback model. Although the input models and calculations are relatively complex, the simulation model runs the Laguna Verde station blackout input models significantly faster than real time so the longer transients can be simulated at an accelerated rate.

How do these different scenarios compare to the actual Fukushima Daichii scenarios for Units 1-3 [8,9]? In Unit 1, what was known initially after the accident was that, approximately 6 hours after reactor scram and loss of emergency core cooling, radiation was detected in the turbine building. There was no indication that the operators had opened safety relief valves to depressurize the vessel. However, limited data for reactor vessel pressure and water level at this time indicated that the reactor vessel had partially depressurized to a level of 0.8 MPa while the indicated water level was still showing as above the top of the fuel. At approximately 24 hours after scram, there was a hydrogen explosion. For unit 2, the loss of emergency cooling occurred approximately 70 after scram with an attempt to start injecting seawater soon thereafter. It was noted in initial reports that operators were able to open the SRVs and intentionally depressurize the vessel. This occurred ~6 hours after the loss of emergency cooling. Limited water level and reactor vessel pressure data for Unit 2 indicate that the core may have been fully exposed for ~4 hours and that the sea water injection did not significantly impact the drop in water level. The opening of the SRVs was successful in reducing the vessel pressure to a level of ~0.8 MPa within a few hours of the opening of the valves. For Unit 3, the emergency core cooling was lost approximately 38 hours after reactor scram. Attempts to inject seawater were noted at ~51 hours after scram. A hydrogen explosion was noted at ~71 hours after scram. Limited data on the water level and reactor vessel pressure indicated that part, or all, of the core may have been uncovered for a period of ~7 hours. The reactor pressure in Unit 3 had dropped to a level below 0.4 MPa within a few hours after loss of emergency cooling even though there was apparently no operator action to open the SRVs.

REFERENCES

1. C. M Allison and J.K Hohorst, "SDTP—Developing Technology for the Nuclear Industry", 13th International Conference on Nuclear Engineering, ICONE13-50979, Beijing, China, May 16–20, 2005.
2. www.relap.com
3. C. M Allison and J.K Hohorst, "Role of RELAP/SCDAPSIM in Nuclear Safety", Science and Technology of Nuclear Installations Volume 2010 (January 2010).
4. C. M. Allison, B. S. Allison, U. Luettringhaus, J. K. Hohorst, "Application of RELSIM-RELAP/SCDAPSIM for University Training and Simulator Development, Proceedings of the 18th International Conference on Nuclear Engineering, Xi'an China, May 17-21, 2010.
5. C. M. Allison, B. S. Allison, J. K. Hohorst, D. Konjarek, T. Bajs, R. Pericas, F. Reventos, R. Lopez, "Preliminary Assessment of the Possible BWR Core/Vessel Damage States for Fukushima Daiichi Station Blackout Scenarios Using RELAP/SCDAPSIM", Paper submitted to Science and Technology of Nuclear Installations (January 2012).

6. RELAP5 Code Development Team, "RELAP5/MOD 3.3 Code Manual, Vol. 1-8", NUREG/CR-5535/Rev1 (December, 2001).
7. SCDAP/RELAP5 Development Team, "SCDAP/RELAP5/MOD3.2 Code Manual, Vol. 1-5", NUREG/CR-6150, INEL-96/0422, (July, 1998).
8. "The 2011 off the Pacific coast of Tohoku Pacific Earthquake and the Seismic damage to the NPPs, Nuclear and Industrial Agency (NISA) and Japan Nuclear Energy Safety Organization (JNES), April 4, 2011.
9. "Special Report on the Nuclear Accident at the Fukushima Daiichi Nuclear Power Plant", INPO Special Report, INP 11-005, November 2011.

ADVANCES IN THE DELIVERY OF NUCLEAR POWER PLANT SIMULATION BASED LEARNING

J.R.SMITH

Western Services Corporation, 7196 Crestwood Blvd., Frederick, MD 21703, USA

ABSTRACT

This paper describe technical advances in the delivery of complex nuclear power plant training previously available only through full scope simulators used for licensed plant operator training. Web based delivery of a wide range of nuclear fundamentals, plant systems familiarization and reactor thermal hydraulic performance is now a reality and the use of simulation as a mentoring aide for students in a multidisciplinary environment and access to object oriented simulation modeling tools provides immediate feedback that enhances consolidation of the knowledge acquired. Modern simulation technology is an important and effective tool in supporting knowledge capture and transfer to the next generation of nuclear engineers and plant operators.

1. Introduction

Western Services Corporation (WSC) is a simulation technology company that delivers nuclear power plant training simulators to plant owners and manufacturers in the USA, China, Korea, UAE and Europe using its 3KEYSOFTWARE® object oriented Microsoft Windows based simulation platforms. There is increasing interest being expressed in the use of simulation for enhancing the learning experience beyond the traditional use for certification of nuclear power plant operators particularly for the next generation of nuclear engineers and operators who have had wide exposure to state of the art devices and software applications and have less tolerance for conventional classroom learning.

WSC has developed a number of applications that deliver learning through web based applications for students and trainees both in a university and an industry environment. This paper describes the development and range of uses for these applications.

2. 3KEYSTUDENT™ (1)

2.1 What is 3KEYSTUDENT?

As younger workers begin careers in the power industry, it is important to address the way training can best be delivered to this interactive, media-adept generation. Traditional instructor-led and hands-on training practices need to be enhanced to better meet the needs of the younger students. To address this gap, WSC has developed 3KEYSTUDENT, which makes state-of-the-art simulator training available to a students' PC via the Internet.

WSC's 3KEYSTUDENT provides the platform to receive simulator and lesson plan content via the web. It is developed using Microsoft Silverlight technology to allow for access through industry standard web browsers. Lesson Plan development is realized with a graphic design package that provides the necessary tools for creation of the lesson plan content (process and I&C model configurations, initial conditions, scenarios, event triggers, HMI screens, sound and/or video files). Multiple training modes range from the tell-all mentor mode, to a real time test mode.

The 3KEYSTUDENT platform is designed to deliver simple to full scope high fidelity simulation lessons through the Web. Lessons can range from simple component or system lessons to full start-up/shutdown of a generic or a custom built specific plant simulator. There is no limitation to the number of lessons that can be developed and the platform is expandable to deliver lessons from one to hundreds of students concurrently. Lessons can be interrupted for any reason and resumed at a later time. The platform provides a safe and protected environment with the simulation software running on Servers located anywhere in the World at a secure facility with download limited to graphics and simulator control functions. The platform can provide multi-screen capability to allow for better visualization through multiple Web browsers connected to the same simulator.

2.2 System Architecture

The main components of the system architecture are shown in Figure 2.2 below.

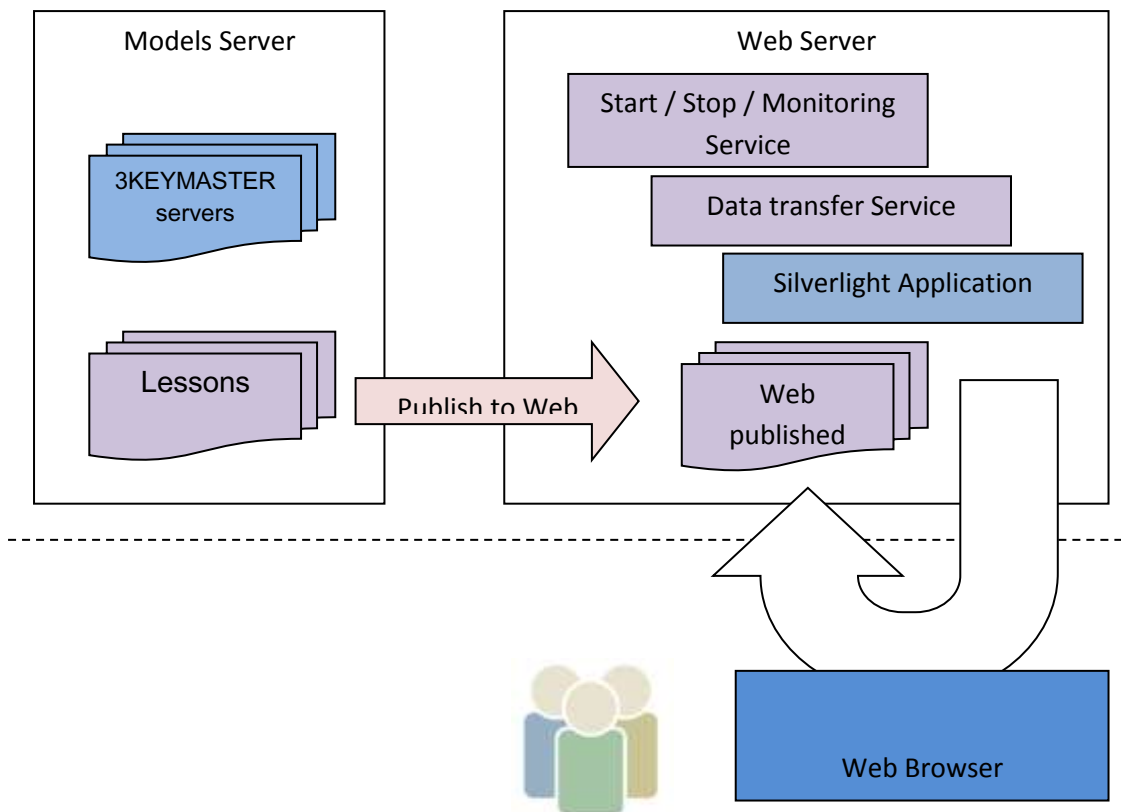


Figure 2.2.1 3KEYSTUDENT Silverlight Web Environment

The Software requirements for the Student User are:

- Microsoft Windows 7 / Windows Server 2008
- Microsoft Internet Information Server ver. 7 or later
- Microsoft .Net ver. 4.0 or later
- Microsoft Visual C++ 2008 Redistributable Package

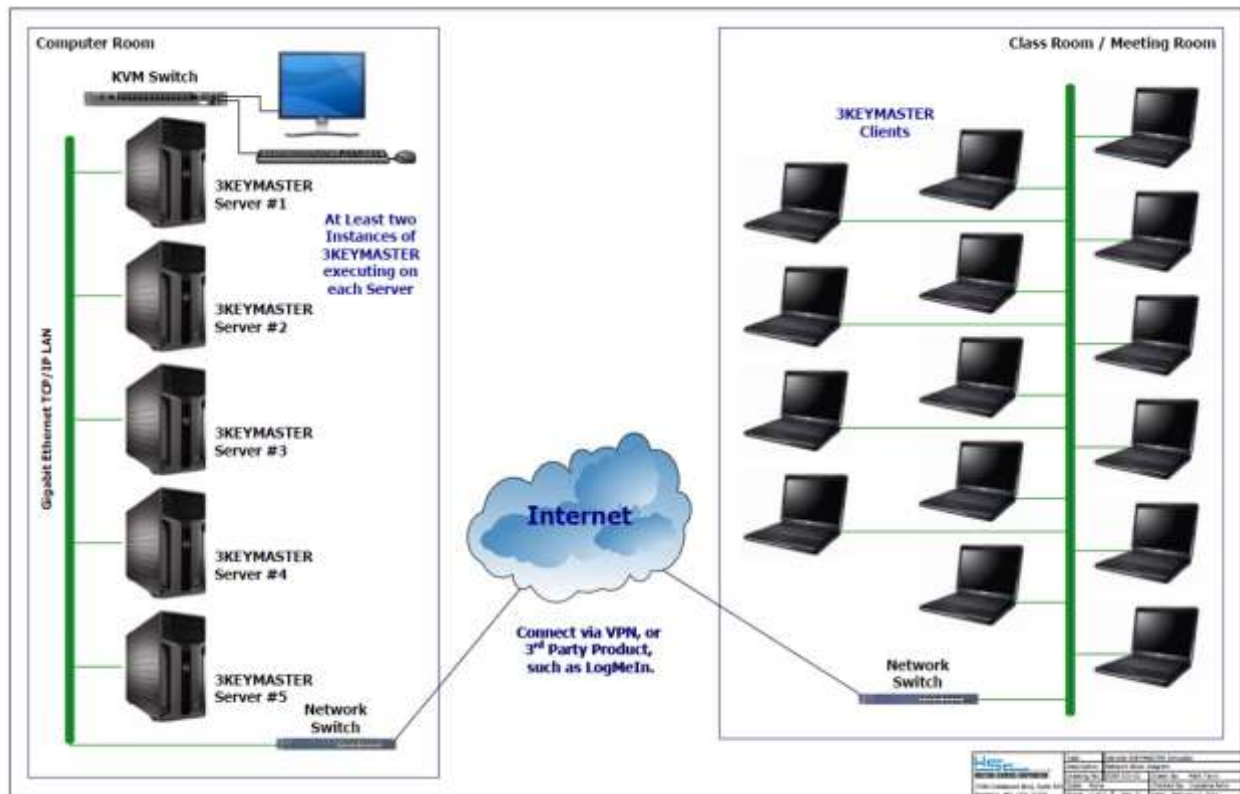


Figure 2.2.2 3KEYSTUDENT Server Client Configuration

Fig 2.2.2 shows a typical Server Client Configuration that is designed to operate over either a Local or Wide Area Network.

Disk memory requirements for the server are relatively modest at 500MB for the operating system and 500MB for each instance of the Simulator model. Student PC or laptop hardware requirements are similarly modest:

- Processor: Intel® Core i3, 2.0 GHz or comparable performance
- Memory: 2 GB or more
- Displays: from 1 with resolution as low as 1024x768, up to 4, with resolution as high as 1920x1080

2.3 3KEYSTUDENT Learning Environment

3KEYSTUDENT provides a full featured Intelligent Tutoring System (Fig 2.3.1) to provide instructions and procedures visually and verbally with multiple modes of operation based from show all - “mentor mode” to examination - “test mode”. It provides the Web based Student and Instructor single or shared access to 100s of downloadable graphical interface screens for plant controls from anywhere in the World.

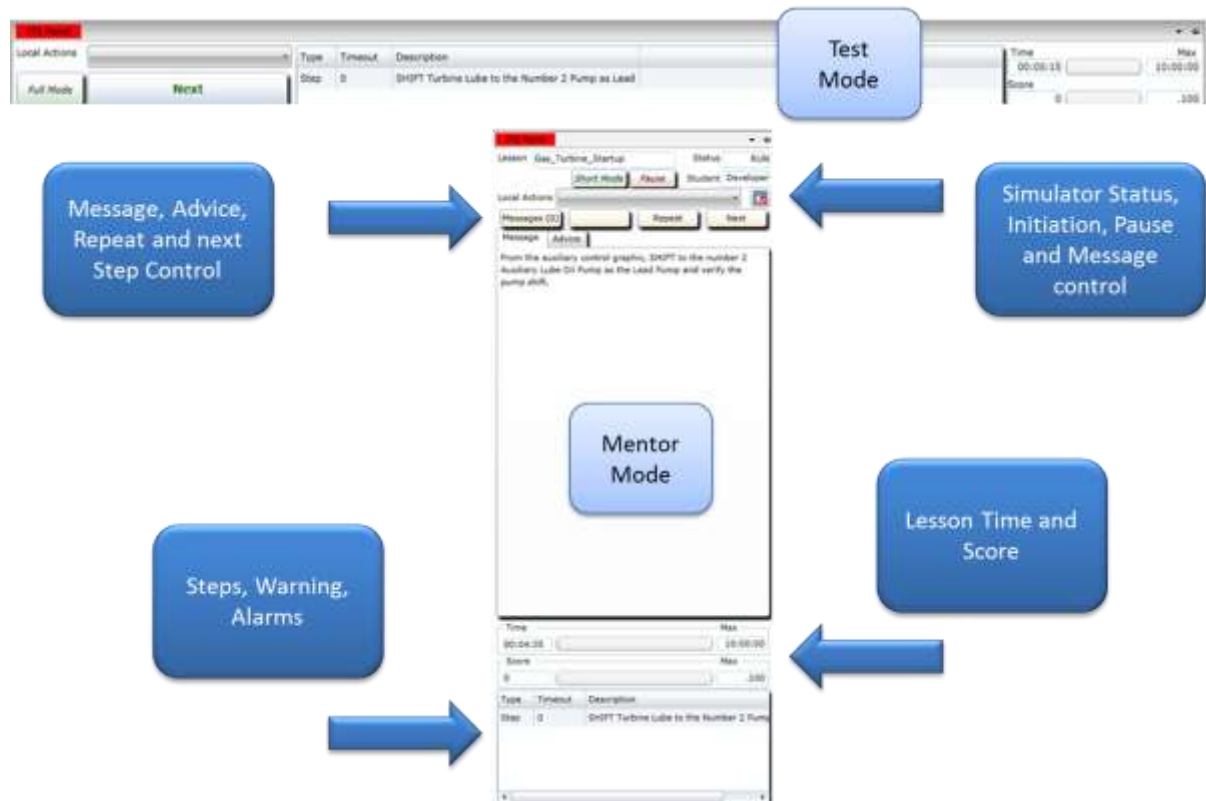


Fig 2.3.1 3KEYSTUDENT Intelligent Tutoring System (ITS) Interface

In mentor mode, 3KEYSTUDENT provides hints with graphical highlights to assist the student to understand the lesson material. The models provides a realistic nuclear power plant control system and alarm system with multiple sounds based on priority and type of alarm as well as full trending capability allowing a user to trend any process parameter for transient analysis.

3KEYSTUDENT provides time and score functionality to integrate with standard Learning Management Systems and is SCORM Compliant.

Each Lesson Plan consists of steps that define the actions required to complete a given training scenario. Each step incorporates several bits of information as outlined below:

- Step Name and Description
- Vocalized Messages
- Advice that jumps the user to the screen necessary for the execution of step
- Conditions that, when true, allow the Lesson to proceed to the next step
- Scoring of each step or selected steps
- Templates for layouts
- Audio and Video files

During execution of the Lesson Plan, the student may seek Advice, to be guided to a specific display based on the current step. For the simulator instructors, recording features are provided to improve the efficiency of generating lessons.

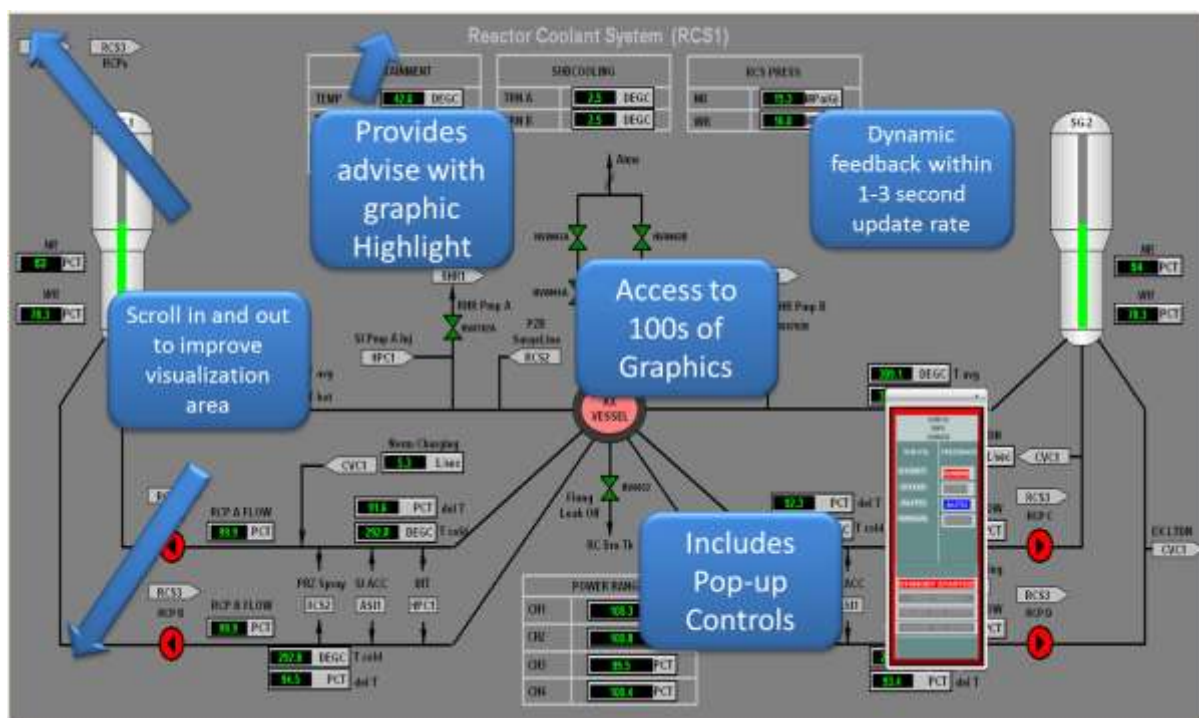


Fig 2.3.2 Typical 3KEYSTUDENT™ HMI Screen

Figure 2.3.2 shows an example of an HMI screen used to access the simulation, in this case the Reactor Coolant System. The 3KEYSTUDENT simulator contains hundreds of such graphics describing the entire reactor and its ancillaries and control systems including emulated digital control system displays. The simulator response over the web is typically 1-3 seconds so real time performance of the plant is replicated. It is important to note that the actual reactor models remain on the secure remote server and are not accessible by the student, thus protecting the security and integrity of the reactor models.

3. Conclusion

Simulation technology coupled with internet technology can now deliver high fidelity learning to the next generation of nuclear power engineers and operators in a manner that is aligned with the gaming generation expectations and learning processes.

4. References

1. 3KEYSTUDENT™ is a Western Services Corporation proprietary technology registered under 3KEYSOFTWARE®. Further information can be found at www.ws-corp.com or by contacting the author at smithj@ws-corp.com.

THE SAFETY CULTURE QUESTIONNAIRE (SCQ): THEORETICAL MODEL AND EMPIRICAL VALIDATION

B. LÓPEZ DE CASTRO, F.J. GRACIA, I. TOMÁS, J.M. PEIRÓ

*Research Institute on Personnel Psychology, Organizational Development, and Quality of Working Life (IDOCAL), University of Valencia
Avda. Blasco Ibáñez, 21 – 46010 Valencia, Spain*

ABSTRACT

The Safety Culture Questionnaire (SCQ) aims to assess the degree to which safety is an enacted value in nuclear power plants (NPPs). The SCQ is supported by a model of safety culture comprising three dimensions: daily behaviors and activities supporting safety, HR practices driving safety, and important safety-related decisions. These dimensions are intimately linked, and each of them is predominantly related to one of the three main hierarchical levels of an organization (i.e. operating core, middle line and top management). To validate the SCQ and the safety culture model it is based on, the SCQ was administered to the employees of a Spanish nuclear power plant (N=533). Evidence supporting the reliability and validity of the SCQ scores was found. We believe that this study is relevant because it presents a new approach to safety culture and a questionnaire that is able to capture the practical importance of safety in NPPs.

1. Starting point and purpose

The purpose of this paper is to present the Safety Culture Questionnaire (SCQ), which aims to overcome two of the main weaknesses of existing questionnaires on safety culture: the difficulty of going beyond the surface levels of culture and the lack of supporting theoretical frameworks for safety culture. On the one hand, the SCQ was designed to assess the degree to which safety is an enacted value of nuclear facilities. On the other hand, the SCQ is supported by a three-dimensional model of safety culture: daily behaviors and activities supporting safety, HR practices driving safety, important safety-related decisions. This study provides the opportunity to empirically validate the SCQ and the dimensionality of the safety culture model on which it is based. The authors hope the SCQ can help the nuclear industry in the difficult but unavoidable quest to assess culture.

2. Capturing something else: the enacted values

An organization's culture consists of a characteristic set of elements that guide its members' behaviors towards the attainment of specific organizational goals (e.g. productivity, safety, innovation, customer satisfaction, etc.) These cultural elements are hierarchically ordered from deeper and intangible to more surface and visible levels [1], [2], [3], [4], [5], [6], [7]. Schein's three level classification [7] provides a widely-accepted framework to understand these cultural elements: (a) the artifacts are the most tangible and overt manifestations of culture and include everything that can be seen, heard and felt when one enters an organization for the first time (e.g. physical environment, language, myths, stories, observable rituals, emotional displays and in general any kind of visible product of organizational members); (b) the second level includes espoused values, norms, philosophies and organizational rules that reflect what a group ideally wants to be, and this level can be expressed, for example, in public declarations during meetings or ceremonies, written documents describing the organization and its strategy, or leaders' messages; (c) the basic beliefs and assumptions that are shared by the members of the organization. These implicit assumptions are deeply rooted in the history of the organization because they have been shown to be useful for organizational survival and development.

Using Schein's model as a reference framework, a NPP has a safety culture when its cultural elements (i.e. basic assumptions and values held by its workers and visible artifacts) result in

safety management and performance behaviors aimed to guarantee nuclear safety. Therefore, each of these levels provides valuable and complementary information that makes it possible to understand the particular safety culture of a NPP. However, the study of basic assumptions is not common due to the methodological difficulties and costs involved, and the study of artifacts does not provide much information about the real culture of the organization without a deeper cultural analysis. The majority of attempts to assess safety culture have used questionnaires [8] directed toward the level of espoused values [9]. But in this case, the problem is that the values espoused by managers and leaders do not always coincide with the enacted values guiding their priorities and behaviors [10], [11], [12]. Thus, it is not clear to what extent espoused values determine employees' behaviors [13]. After all, it is those values that are supported, prioritized and rewarded in the day-to-day organizational functioning inform members about what actions are expected of them.

Given these circumstances, we took the challenge of creating the SCQ, a questionnaire designed to assess the degree to which safety is an enacted value within NPPs. In order to obtain this information, the authors relied on the introduction to the questionnaire (see section 5). The introduction or heading was seen as an opportunity to make participants reflect on the value of safety beyond the typical "of course, safety is very important for us". It should encourage the surveyed person to think about the practical importance of safety in the day-to-day running of the plant, setting aside its theoretical value (what is said and how things should be). Only when participants report on the way things really get done on a day-to-day basis, rather than the official policies and managerial philosophy, can we come to know the organizational values that are in use [14]. But what aspects of a NPP can provide information about the real value of safety? This question is addressed in the model of safety culture presented next.

3. A new approach to safety culture

When safety in a NPP is a central, practical and priority issue and, consequently, an enacted value, it means the NPP has a strong safety culture. However, how can we know this? Where do we need to look? The IAEA emphasizes the importance of safety as a clearly recognized value [15]. A strong safety culture is pervasive and, therefore, must be seen in "everything" the company does and in the way it behaves. This "everything" can be covered by three fundamental aspects of the operation and management of any organization: the daily behaviors, routines and activities of all organizational members; the human resources management practices; and the important and strategic decisions that must be made for organizational survival and success. Therefore, when safety is an enacted value and a culture for safety is in place, each of these aspects must have the preservation of nuclear safety as the ultimate goal. In this context, safety culture can be understood as being composed of three dimensions: daily behaviors and activities supporting safety, HR practices driving safety, and important safety-related decisions.

- Daily behaviors and activities supporting safety: Safety is the primary determinant of the actions of all organizational members in the day-to-day of the NPP. The extent to which safety is important for a NPP is reflected in its workers' routines and internalized behaviors and in the way these are carried out. The relationships among the different hierarchical levels of the plant, and between the NPP and the different external agents, such as regulatory bodies and contractors, are of paramount importance for the safety performance of the NPP. To keep, enhance and reinforce safety awareness, the central role of safety must be routinely addressed in public communications (e.g. meetings, internal publications, bulletins, etc.) and consistently supported through supervisory recognition.
- HR practices driving safety: The safety culture of a NPP manifests itself in the extent to which it uses a HR system in which all practices and policies are coherently articulated to guarantee high levels of safety and safety performance. To do so, the organization must be able to bring in new workers who agree on and share safety values (e.g. by means of recruitment and selection practices), continuously develop their employees, especially in

safety matters (e.g. through training and performance appraisals), and encourage and motivate them so that they always want to work safely (e.g. through formal reward systems such as goal setting, promotions or salary).

- Important safety-related decisions: The safety culture of a NPP is shown by the role that safety plays in the important and strategic decisions made. Is safety still the number one priority when money comes into play? Or are NPPs taking risky cost-cutting measures to cope with competitive pressures and competing demands (e.g. safety vs. productivity)? NPPs must have a business plan that reflects the strategic business importance of safety [16], carefully integrating nuclear safety goals and objectives with operational and financial performance. In practice, the importance of safety is reflected in the extent to which safety is favored over productivity when they are in direct conflict (e.g. delays in refueling outages), in the allocation of the plant's finite resources, such as processes (e.g. decision-making and change management processes) and procedures, and in any decision related to the operation of the plant.

These dimensions are predominantly related to the three main hierarchical levels of an organization in terms of Mintzberg [17]: operating core, middle line and strategic apex (see figure 1). The day-to-day and ultimate performance of a NPP is shown mainly through the daily behaviors and activities of the operating core of the different departments, and to a lesser extent in the behaviors of the middle line (i.e. supervisors) and the strategic apex (i.e. senior management). Although HR practices and policies are designed and imposed by senior management and the HR department, they are generally implemented by the middle line. And the important decisions of an organization, although they affect the work of all staff members, are principally made by senior management.

Finally, we note that although different, these dimensions are intimately linked. Safety culture is defined and shaped by top-down and bottom-up flows among its three dimensions. This way, the important decisions determine, among others, the HR practices, and these, in turn, influence the behaviors and daily activities of all employees. On the other hand, the members' routines and behaviors provide information about the most adequate and safety-oriented way to manage employees at any given moment, which, in turn, has an impact on the important decisions made in the NPP.



Fig 1. Safety culture pyramidal model

4. The SCQ: origin and description

The development of the SCQ was based on: (a) a literature review of theoretical frameworks of organizational culture and safety culture; (b) a critical examination of safety culture questionnaires currently available in the literature; (c) our consulting experience on organizational behavior within the nuclear industry. This procedure resulted in a questionnaire containing 24 items covering different aspects of the three theoretical dimensions of safety culture presented in the previous model. Each of the items was designed to obtain information about the degree to which nuclear safety is important to the organization. Five-point Likert-type scales with responses ranging from 1 (not at all) to 5 (a lot) were used to record this information. The heading or introduction of the questionnaire is as follows: “*We would like to know your opinion about how important safety is to your company. We are not as interested in discovering its theoretical importance as in finding out its practical importance on a daily basis. For this purpose, we request that you answer the following questionnaire carefully*”. As explained in section 2, this heading was important for emphasizing and focusing on the enacted value of the culture.

5. Empirical validation of the SCQ

The empirical validation of a questionnaire relies on the strength of available evidence supporting the reliability and validity of its scores. Following this course of action, we aimed to empirically validate the SCQ by testing the reliability and validity of its scores. For this purpose, 533 questionnaires completed by workers from all the hierarchical levels of a Spanish NPP were used.

5.1. Reliability

Cronbach alpha values were excellent for the three sub-scales: .91 for the dimension *daily behaviors and activities supporting safety*; .89 for the dimension *HR practices driving safety*; and .89 for the dimension *important safety-related decisions*. All corrected item-scale correlations were high and fell in the optimal range [18] (between .30 and .90.): from .54 to .80 in the dimension *daily behaviors and activities supporting safety*; from .63 to .76 in the dimension *HR practices driving safety*; and from .54 to .72 in the dimension *important safety-related decisions*.

5.2. Validity

5.2.1. Evidence based on internal structure (Factorial validity)

Confirmatory factor analysis revealed that while the proposed three-factor model fit the data well, the one-factor solution provided a poor fit (see Table 1). Moreover, differences in the fits of the three- and one-factor models were relevant from a practical point of view (Δ NNFI= 0.021, Δ CFI = 0.020 and Δ RMSEA= 0.031). These results supported the three-factor model proposed in this paper. All factor loadings exhibited the correct sign and non-negative variances. The items converged well enough, with all factor loadings being statistically significant ($p < .01$) and high enough, according to the standards ($> .60$), thus supporting convergent validity. All correlations were high but did not exceed the accepted criterion of .85 proposed by Kline [19], thus supporting discriminant validity (see Table 2).

Table 1

Summary of overall model fit indices for the three-factor and one-factor structures of the proposed model of safety culture.

	SB χ^2	df	χ^2/df	RMSEA	NNFI	CFI
One-factor structure	1834.17	252	7.28	.118	.954	.958
Three-factor structure	1094.22	249	4.39	.087	.975	.978

Note. χ^2 = Satorra-Bentler scaled chi-square; df = degrees of freedom; χ^2/df = relative/normed chi-square; RMSEA = root mean square error of approximation, NNFI = non-normed fit index, CFI = comparative fit index.

Table 2

Descriptive statistics and inter-factor correlations of the three-dimensional model of safety culture

	<i>M</i>	SD	Factor 1	Factor 2	Factor 3
Factor 1	3.84	.67	-		
Factor 2	3.33	.82	.71	-	
Factor 3	4.07	.63	.84	.63	-

Note. All correlations are significant at $p < .01$ (2-tailed). Factor 1 = Daily behaviors and activities supporting safety; Factor 2 = HR practices driving safety; Factor 3 = Important safety-related decisions

5.2.2. Evidence based on external criteria (Criterion validity)

Pearson correlations between each of the three dimensions of the SCQ and the four questionnaires (with previous empirical support) measuring safety culture outcomes (i.e. safety climate, safety satisfaction, job satisfaction and risky behaviors) are presented in Table 3. All correlation coefficients were statistically significant ($p < .01$) and exhibited the correct sign.

Table 3

Correlations between the 3 factors of the SCQ and 4 external criteria

	Factor 1	Factor 2	Factor 3
Safety climate	.64	.57	.65
Safety satisfaction	.64	.53	.66
Job satisfacción	.45	.37	.41
Risky behaviors	-.33	-.27	-.38

Note. Factor 1 = Daily behaviors and activities supporting safety; Factor 2 = HR practices driving safety; Factor 3 = Important safety-related decisions. All correlations are significant at $p < .01$ (2-tailed)

6. Conclusions and practical application

Evidence was found to empirically validate the Safety Culture Questionnaire (SCQ) and support the dimensionality of its corresponding safety culture model. On the one hand, evidence supported the reliability and stability of the SCQ scores: (a) results showed a strong internal consistency (homogeneity) for the three scales of the SCQ; (b) each of the 24 items on the questionnaire contributed to the homogeneity of its corresponding scale. On the other hand, there was evidence to support the validity of the SCQ scores: (c) results suggested that the 24 items of the model were good indicators of the conceptualized three dimensions of safety culture; (d) these dimensions were shown to be highly related to a variety of constructs that are theoretically and empirically associated with safety culture.

The SCQ maintains the advantages of questionnaires (e.g. allows frequent monitoring of safety culture, detects trends, benchmark results, etc.), but it also captures a deeper level of culture, i.e. the enacted values, collecting information about three fundamental aspects of the operation, functioning and management of NPPs that have a direct impact on the safety performance of the plant: daily behaviors, HRM and decisions. The model presented allows practitioners and scientists to approach safety culture in an intuitive, clear and visual manner. Its three dimensions may serve to understand what safety culture is, what in turn, could be exhibited in training sessions, meetings, etc. This model can help to understand the importance of safety being enacted by all hierarchical levels and in every aspect of the organization, as all these aspects are related to each other. When I make an important decision, when I implement a HR practice, or in my day-to-day activities, is safety the overriding priority? In which cases is it not? This model helps to reflect on these decisional,

management and behavioral levels. Finally, both the model and the content of the SCQ may help regulators to determine policies and guidelines affecting the functioning and safety of NPPs.

References

- [1] T.E. Deal, A.A. Kennedy, 1982. *Corporate cultures: the rites and rituals of corporate life*. Addison-Wesley Pub. Co., Reading, Mass.
- [2] J.R. Detert, R.G. Schroeder, J.J. Mauriel, 2000. A framework for linking culture and improvement initiatives in organizations. *The Academy of Management Review* 25 4, 850–863.
- [3] A. Furnham, B. Gunter, 1993. Corporate culture: definition, diagnosis and change. In: Cooper, C.L., Robertson, I.T. (Eds.), *International Review of Industrial and Organisational Psychology*. John Wiley and Sons, London, pp. 233–261.
- [4] G.H. Hofstede, 1991. *Cultures and organizations: Software of the mind*. McGraw-Hill, London.
- [5] Lundberg, C.C., 1990. Surfacing organisational culture. *Journal of Managerial Psychology* 5, 19–26.
- [6] D.M. Rousseau, 1990. Assessing organizational culture: The case for multiple methods. In: Schneider, B. (Ed.), *Organizational climate and culture*, 1st edition. Jossey-Bass, San Francisco, pp.153–192.
- [7] E.H. Schein, 1985. *Organizational culture and leadership*, 1st edition. Jossey-Bass, San Francisco.
- [8] S. Antonsen, 2009. Safety culture assessment: A mission impossible? *Journal of Contingencies and Crisis Management* 17, 242–254.
- [9] F.W. Guldenmund, 2007. The use of questionnaires in safety culture research - an evaluation. *Safety Science* 45, 723–743.
- [10] C. Argyris, D.A. Schon, 1978. *Organizational Learning: A Theory of Action Perspective*. Addison-Wesley, Reading, MA.
- [11] T. Simons, 2002. Behavioral Integrity: The Perceived Alignment between Managers' Words and Deeds as a Research Focus. *Organization Science* 13, 18–35.
- [12] D.M. Zohar, D.A. Hofmann, 2012. Organizational culture and climate. In: Kozlowski, W.J. (Ed.), *The Oxford Handbook of Organizational Psychology*, Volume 1. Oxford University Press. New York.
- [13] B. Wilpert, M. Schöbel, 2007. Changes and Opportunities of assessing safety culture. *Proceedings of the OECD-CCA Workshop on Human Factors in Chemical Accidents and Incidents*, Potsdam, May 8–9, pp. 105–112.
- [14] C. Argyris, 1990. *Overcoming Organizational Defenses: Facilitating Organizational Learning*. Allyn and Bacon, Boston.

[15] IAEA, 2009. The Management System for Nuclear Installations. IAEA Safety Standards for protecting people and the environment (Safety Report Series No. GS-G-3.5). International Atomic Energy Agency, Vienna.

[16] IAEA, 2006. Application of the Management System for Facilities and Activities. IAEA Safety Standards for protecting people and the environment (Safety Report Series No. GS-G-3.1). International Atomic Energy Agency, Vienna.

[17] H. Mintzberg, 1989. *Mintzberg on Management: Inside our Strange World of Organizations*. Free Press, New York.

[18] R. Fitzpatrick, C. Davey, M.J. Buxton, D.R. Jones, 1998. Evaluating patient-based outcome measures for use in clinical trials. *Health Technology Assessment* 2, 1–69.

[19] R.B. Kline, 2005. *Principles and practice of structural equation modeling*, 2nd edition. Guilford Press, New York.

Effective Education and Training Technology, University Engagement and Curriculum Development, International Cooperation, Recruitment, and Attracting the Next Generation of Specialists

M. Dawn Eipeldauer
Oak Ridge National Laboratory
P.O. Box 2008, MS-6010, Oak Ridge, TN 37831-6010

ABSTRACT

Nuclear energy has played an important role in electricity production since the last half of the twentieth century. Today, the United States has 104 nuclear power plants providing 20% of our nation's electricity and license applications to build 19 new power plants.

The status of nuclear power generation varies from country to country. As of July 2012, 435 nuclear power plants with an electrical net capacity of 370 GW are in operation in 31 countries, and 62 plants with a capacity of 59 GW are in operation in 14 countries under construction. Qualified people are needed to operate existing plants and fuel-cycle facilities, manage radioactive waste, and prepare for future decommissioning of existing plants, even in countries not actively pursuing a nuclear program. Now, and for generations to come, these activities will require expertise in nuclear engineering and science if safety, security, and nonproliferation are to be maintained and the environment is to be protected.

Three elements crucial to developing the next generation of safeguards specialists are (1) tapping the potential of universities to attract the best students to high-quality nuclear technology programs; (2) meeting the staffing needs of the nuclear industry, now and in the future; and (3) conducting leading-edge research in nuclear topics.

The nuclear domain encompasses a broad area of science and technologies, and a strong, competent, cutting-edge nuclear education program is essential to master this domain. Specific collaborations among national laboratories, nuclear facilities, and universities in the area of nuclear nonproliferation are important to the pursuit of such a program.

ANALYSIS

Qualified people are needed to operate existing plants and fuel-cycle facilities, manage radioactive waste, and prepare for future decommissioning of existing plants, even in countries not actively pursuing a nuclear program. Now and for generations to come, these activities will require expertise in nuclear engineering and science if safety, security, and nonproliferation are to be maintained and the environment is to be protected.

Three elements crucial to developing the next generation of safeguards specialists are (1) tapping the potential of universities to attract the best students to high-quality nuclear technology programs; (2) meeting the staffing needs of the nuclear industry, now and in the future; and (3) conducting leading-edge research in nuclear topics. There are, however, a few roadblocks:

- The decreasing number and dilution of nuclear programs,
- The lack of young faculty members to replace retiring faculty members, and
- Aging research facilities that are either being closed or not being replaced.

The nuclear domain encompasses a broad area of science and technologies, and a strong, competent, cutting-edge nuclear education program is essential to master this domain. This paper describes how collaborations of subject matter experts (SMEs) in ORNL's Global Nuclear Security Technology Division (GNSTD) with SMEs at other national laboratories, nuclear facilities, and universities can help the United States be a leader in nuclear nonproliferation and build and maintain excellence in its nuclear education programs.

NUCLEAR-RELATED EDUCATION AND TRAINING AT ORNL

ORNL's GNSTD is developing a nuclear nonproliferation education program focused on the following core areas:

1. the nuclear fuel cycle,
2. societal and regional influences,
3. the international environment,
4. advanced measurement technologies, and
5. physical security.

ORNL's program is based on the nuclear fuel cycle and the application of safeguards and security measures in an operational environment. The program is multidisciplinary, reaching out to a variety of educational departments—political science, social science, and nuclear engineering—in colleges and universities in the southeastern United States. The instructional system design methodology is a tool that instructional developers use to ensure that the curriculum is related to the tasks performed in specific functional positions. Objectives are developed based on the tasks, and the content is aligned with course objectives and sequenced accordingly. The program is based on experiential learning to encourage students to understand and integrate various components associated with nuclear nonproliferation topics through hands-on practice using scenarios that approximate real-time field experience and role playing. The twenty-first century leader for nuclear nonproliferation is a nuclear security analyst and, as such, our program will create a cadre of professionals who can work across organizational and international lines. To make this a reality, students will have the opportunity to obtain off-site assignments at the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the International Atomic Energy Agency (IAEA), operations environments, and industry.

In 2005, the first Nuclear Nonproliferation Summer Seminar Series was held. Daily "brown bags" covered topics related to domestic and international safeguards and security, including the nuclear fuel cycle, enrichment and reprocessing facilities, material control and accounting, and physical security (vulnerability assessments, performance testing, design basis threats, export controls, containment/surveillance, environmental sampling, physical inventory, measurement techniques, and more). On average, class size was 17 and included students and professional staff members. Classes were led by SMEs with broad experience both in handling, processing, and storing nuclear materials in an operations environment and in international teaching. These seminar series continue to be held every summer by video teleconference and broadcast throughout the DOE complex.

In 2008 the summer series was condensed into a one-week course, "The Coming Nuclear Renaissance for the Next Generation of Safeguards Specialists." This course was held December 15–18, 2008, at the Joint Institute for Computational Sciences at ORNL. Course objectives included engaging university participants in the area of nuclear

nonproliferation by introducing them to the next-generation safeguards initiatives; discussing nonproliferation aspects of the nuclear fuel cycle and domestic and international legal requirements; and working with participants to identify curriculum and training opportunities to prepare for the next generation of safeguards experts. The course was a partnership among ORNL, the Y-12 National Security Complex, the Savannah River National Laboratory and the NRC. The total number of attendees was 74, which included 18 professors and 19 students from several different universities. The condensed course enabled universities to integrate materials into their existing nuclear nonproliferation academic curriculum or to use the course material to develop a basic nuclear nonproliferation course with aspects of both domestic and international safeguards and security. This course, which was the first of this type, was held at ORNL. It led the way for other national laboratories in the United States and within the DOE Complex to share the current safeguards, security and safety curriculum domestically and internationally.



Figure 1: Map showing universities represented at ORNL’s nonproliferation workshop.

WORKSHOPS

ORNL GNSTD uses nuclear nonproliferation courses such as “The Coming Nuclear Renaissance,” which targets university students and professors and features courses, seminars, and workshops detailing both domestic and international policies, treaties, agreements, methods, and technologies to continue to attract the next generation safeguards specialists.

A number of workshops have been executed.

- The American Nuclear Society (ANS) conference held in Atlanta, Georgia, June 14, 2009, was designed to enable students to identify safeguards and security components in a nuclear facility. Participants observed a three-dimensional simulation of a nuclear facility and the attendant safeguards and security measures. They participated in a scenario guided by facilitators that encouraged them to identify aspects and tasks of nuclear safeguards and security, such as nuclear material control and accountability and physical protection, and how those are

integrated in an operations environment. Participants were provided with situations designed to make them think about numerous aspects related to safeguarding and securing nuclear materials. The facilitators provided a guided discovery that led the participants to make decisions about various aspects of safeguards and security applicable to different situations.

- A second workshop was held November 10–13, 2009, in partnership with the student chapter of the INMM at the University of Missouri at Columbia, the Physical Protection Technical Division, the Material Control and Accounting Technical Division, and the Central Regional Chapter of the INMM. This workshop was designed to engage students and university faculty members in the development of the next generation of nuclear safeguards and nonproliferation professionals. The goal of this workshop was to provide a process that represents a best practice that can be used by the government, industry, and universities to increase the number of graduate certificate programs for safeguards and nonproliferation practitioners. The workshop provided a forum for identifying functional positions and assessing information to determine the requirements for progressing from performing at an entry level to becoming an expert in the field. The students learned about safeguards and nuclear nonproliferation from SMEs with more than 30 years' experience in the field. The workshop benefitted universities, the nuclear industry, and the government by providing a process that identifies a curriculum for proliferating certificate programs, addressing strategic issues involving communication, sharing information, and networking.
- A third workshop was held in October 2009. This workshop, a collaboration among ORNL, the Y-12 National Security Complex, and the University of Tennessee (UT), focused on safeguards, security, and safety. The goal of this workshop was to provide the various aspects of safeguards, security and safety and the integration within an operations environment.
- On August 15, 2011, a fourth workshop was held. The workshop targeted nuclear engineering students, social scientists, and a number of undergraduates who demonstrated an interest in and who conduct research around specific public policy issues related to the mission of the Howard Baker Jr. Center for Public Policy. It was planned, designed, managed, and implemented by a student working toward a master's degree in public policy. The goal of the workshops such as this one is to reach out to a multidisciplinary academic audience, connect ORNL experts with universities, and provide internship opportunities for social scientists.
- More recently (June 27–29, 2012), the International Safeguards Workshop was host to 44 student interns and several mid-level career staff. The purpose of this workshop was to discuss international policy, safeguards technologies, and methodologies and application of such technologies. A student intern from the UT Nuclear Engineering Department (NE) assisted staff in developing and implementing this workshop.

Academic Courses and University Engagement

- Since 2009, ORNL has engaged several regional universities including UT, North Carolina State University (NCSU), Georgia Institute of Technology (Georgia Tech), the University of Florida, and the University of Michigan (UM) in embedding nuclear security concepts in the nuclear engineering curriculum. As an

example of the above effort, NCSU, developed and taught NE591 Special Topics, “Nuclear Nonproliferation and Safeguards Technology and Policy” in spring of 2012, which is an introduction to topics in nuclear nonproliferation appropriate to students from both engineering and policy-oriented backgrounds. To grow the human capital pipeline and to build the bridge between academic campuses and research facilities, the NCSU program optimizes distance education to improve the availability of its curriculum. Strategic use of remote videoconferencing and distance learning extends the reach of national laboratory audience with university students, affording opportunities for safeguards education that might otherwise be impractical.

- Ambassador Thomas Graham, Jr., and UT’s Political Science Professor Brandon Prins jointly taught POL SCI 410, “Arms Control and Nonproliferation” during the spring semester of 2012 at UT. Ann Pederson, an ORNL intern beginning a master’s degree during fall of 2012 in political science/law, served as a teaching assistant for the course. (Pederson, 2012)
- UT also added ORNL staff member Dyrk Greenhalgh as an adjunct faculty member. Dyrk delivered lectures during the spring semester of 2012 for Nuclear Engineering 597, “High-Consequence Physical Security Systems and Analysis.” In the 2012fall semester, Dyrk will teach two courses for UT NE, “High-Consequence Physical Security Systems Design and Analysis, and Physical Security Vulnerability Assessment.”
- A ‘Uranium Bowl’ exercise was implemented March 6 and 7, 2012, between nuclear engineering students from NCSU and UT. Michael Shannon, a graduate research assistant (GRA), developed the exercise, which will be executed again in 2013 with other universities like TAMU, Georgia Tech, and UM. (Greenhalgh, 2012)

Core Competencies/Skills enhancement

The GNSTD is currently conducting a staffing study of the future safeguards workforce and the expertise required to project the number of safeguards professionals needed to meet the future domestic and international safeguards requirements of the US government national laboratories, and the IAEA over the next 5 to 15 years. The study will address the following criteria: size of the workforce needed, skill sets required, appropriate educational background, necessary work-experience, and communication skills.

Graduate Research Assistantships

GNSTD is developing a plan to provide professional development training for GRAs. This is a clearcut measure to strengthen our ties with the education branch of the Institute for Nuclear Security Education Pillar. The benefits of having UT close to ORNL far outweigh the cost of having a GRA. Our SMEs are able to identify students from a pool of summer interns who can continue to work throughout the school year for a minimum of 20 hours per week on research projects at an extremely low cost. This enables us to not only increase the level of knowledge for GRAs by providing first-hand experience with the subject matter of nuclear nonproliferation and nuclear security as well as developing a talent pool from these students who can market ORNL capabilities. We are providing the following enhanced skills to students: project management, database development,

curriculum development, proposal writing, and developing budgets. This takes them out of the field of theory and places them into the realm of practical business applications.

Project planning, design, management, and implementation are important business skills that are not normally a part of an academic university degree program. Our GRAs are assisting senior staff in the development of curriculum, workshops, courses, and seminars. For example, the workshop held in August 2011 at the Howard Baker Center reached out to a multidisciplinary academic audience, connected ORNL experts with universities, and provided internship opportunities for social scientists. (Eipeldauer, 2012)

Business in the twenty-first century entails fierce competition, aggressive marketing, and strategic alliances. Much time and energy is invested in training our GRAs in the business aspects of nuclear safeguards, safety, and security work. We cultivate several important skills in GRAs by involving them in work with a wide variety of people, including mentors, project investigators, DOE Headquarter sponsors, and staff members. Through proposal writing and budget development, not only are they learning to navigate business proposals and formulate ideas, but they are also learning about business language and culture. They are acquiring important skills for future employment, such as negotiation, networking, time management, communication, teambuilding, and critical thinking. These experiences put them on the cutting edge and show them first hand some factors that determine whether a business succeeds or fails. Some examples of the proposals that GRAs are developing related to curriculum development include the following.

- In 2011, an assessment was conducted on the IAEA Nuclear Security Certificate Program for Nuclear Security. A comparison of the IAEA standard to the UT NE certificate program identified a number of gaps. The ORNL curriculum developer and several GRAs are working to address these gaps by developing the following courses:
- “Introduction to Integrated Safeguards, Security and Safety” is a course that is intended to blend lectures and participative work groups. It is led by SMEs and features practical exercises at ORNL’s Safeguards Laboratory, Y-12’s repurposed Alpha-3 facility (Y-12 Calutron building 9201-3), Alarm Response Training Facility, the Nuclear Detection and Source Test Center, UT’s Baker Center for Public Policy, and the UT Department of Nuclear Engineering. To ensure successful transfer of knowledge, instructors will utilize active, scenario-based, hands-on learning that employs multiple learning styles and close interaction between participants and instructors. The knowledge received from the curricula will promote a nuclear security, safety, and safeguards culture that supports the growth of peaceful uses of nuclear energy and nonproliferation by equipping students with the ability to approach and question situations in a global context. More importantly, the knowledge gained from this education program provides critical partners with the infrastructure needed to institutionalize and sustain knowledge on a national and regional basis and can be modified to meet the needs of the audience. (Eipeldauer S. M., 2012)
- To date, there has been rapid growth of the university development of nuclear nonproliferation and safeguards criteria at UT. However, physical protection systems are a vital component of the vast field of nuclear safeguards that is grossly underrepresented. Because of this underrepresentation, UT added Dyrk

Greenhalgh, an expert in physical protection systems, as an adjunct instructor to teach the Physical Security portion of the certification program.

- Other most notable gaps include transportation security and the insider threat, both of which create a need to integrate these components with the existing physical security curriculum.
- Nuclear forensics science involves scrutinizing pre and postdetonation samples of radiological and nuclear material, debris, and any associated information in order to amass evidence with the ultimate goal of assigning provenance. Forensic scientists typically have radiochemistry backgrounds, but the pool of students with radiochemistry and related degrees in the United States is shrinking. Universities must create courses to attract students covering both the pre- and postdetonation forensics pertaining to techniques for analyzing material used in weapons of significant yield and also low-yield radiological dispersal devices. Lily Crabtree, a GRA working in the nuclear forensic field and a PhD candidate at UT, is developing a module to create a course that would attract students to her field. This course will also be included as a part of the nuclear security certificate program at UT. (L. Crabtree, 2012)

Mentoring and Internships

ORNL leads a successful internship program that enables students from a variety of universities to engage with SMEs in one of two ORNL programs. Since 2009, 15 to 30 students participated in our summer internship program sponsored by DOE's National Nuclear Security Administration (NNSA) Office of Nonproliferation and International Security (NA-24). Most of the students come through the Nuclear Engineering Science Laboratory Synthesis (NESLS) program, a cooperative research initiative geared toward students working in physics and nuclear engineering applications. Through one- to three-year summer internships, NESLS offers engineering students and faculty on-the-job educational and research opportunities at a multidisciplinary national laboratory. The Higher Education Research Experience is an even broader program, covering computer science; earth, environmental, and marine sciences; engineering; life, health, physical, and medical sciences; and mathematics. DOE also funds the Summer Undergraduate Laboratory Internship, a program targeting students in the sciences.

Educational Initiatives

Several ORNL staff members have been conducting lectures at universities around the country, including the University of California, Berkeley, Georgia Tech, NCSU, Tennessee Technological University, the University of Wisconsin (UW), UM, the Monterrey Institute of International Studies, the Ohio State University, and many others. Lecturers have focused on their work experience at the IAEA, developing curriculum for functional positions in safeguards, safety, security, materials, control and accounting, physical protection, and international safeguards, among other topics. We actively engage with and invite guest speakers from other national laboratories, the IAEA, and industry to present lectures at ORNL.

Professional Associations

Professional associations such as the INMM, Women in Nuclear (WIN), the ANS, the American Society for Training and Development, and the Human Resource Management

Society all provide opportunities for sharing information and networking while also supplying training tools.

Career Fairs

Career fairs are another opportunity that we actively engage in and a chance for our staff to visit the universities and discuss topics and internships at ORNL related to nuclear nonproliferation. ORNL has been represented at numerous career fairs at Massachusetts Institute of Technology, the Pennsylvania State University, UM, UW, Texas A&M, Michigan State University, the Missouri University of Science and Technology, NCSU, and others.

At these career fairs, students can learn about the junior professional office internships offered by Brookhaven National Laboratory as well as internships offered by NNSA, in conjunction with Pacific Northwest National Laboratory. One of the most commonly asked questions by nuclear engineering students is “What is nuclear nonproliferation?” They can learn about nuclear nonproliferation from SMEs who have worked in operations at US facilities, offsite assignments at DOE, and internationally at the IAEA. The SMEs can provide firsthand experience to the students, thus providing a unique mentorship opportunity.

CONCLUSIONS

A number of efforts by ORNL since 2005 have strengthened the ties between SMEs, professors, and students; for example,

- courses that target university students and professors, such as “The Coming Nuclear Renaissance”;
- other courses, detailing domestic and international safeguards systems;
- collaborations with universities on course materials and exercises to embed safeguards and security measures into academic curriculum;
- workshops such as the one held in Atlanta for the ANS and the University of Missouri at Columbia; and
- interaction with student chapters of organizations such as ANS, INMM, and WIN.

ORNL is proud of its accomplishments in providing attractive educational programs; supporting the development of networks among universities, industry, and research institutes; interacting often with potential students, both male and female; and encouraging collaborations with industry, research institutes, and universities to engage the next generation; and proactively marketing internship opportunities throughout the DOE complex.

UNIVERSITY OF TEXAS STUDY ABROAD PROGRAM IN CONCEPTS IN NUCLEAR SCIENCE AND ENGINEERING AT THE TECHNICAL UNIVERSITY OF DELFT, NETHERLANDS

¹S.LANDSBERGER, ¹J.T.GRAHAM, ²H. WILKINS-VERSALOVIC,
³P. BODE, ³F.D.P.GEURINK, ³A. C., LAAN, ³O.M.STEINEBACH,
³D. DE VRIES

¹⁺*University of Texas Nuclear Engineering Teaching Lab, 10,100 Burnet Road,
Building #159, Austin, Texas, 78712*

² *University of Texas at Austin, Cockrell School of Engineering University Station C2100,
Austin, TX 78712*

³*Reactor Institute of Delft, Delft Technical University,
Mekelweg 15 2629 JB Delft, Netherlands.*

ABSTRACT

Study abroad programs in US American Universities are not as popular for undergraduate students in studying science and engineering bachelor's degrees as they are for those students in liberal arts programs. While the expense is one aspect to overcome, there is a perception that studying abroad programs are not critically important to advance one's career. This in fact is opposite since globalization has made it imperative that those US industries become much more familiar with the culture of competing countries, and have specific strategies in opening new markets outside the USA. Thus students who have had experience in study abroad programs have a competitive edge in being hired in companies that maintain international business. As well the students have an opportunity to expand their own horizons. At the University of Texas Cockrell School of Engineering study abroad programs are encouraged at the college level as well as in the Provost's office at the University level. Based on a very successful 1-hour course given in the Nuclear and Radiation Engineering Program in the Mechanical Engineering Department we have offered an equivalent 3-hour course study abroad course entitled Concepts in Nuclear and Radiation Engineering in conjunction with the Technical University of Delft, Netherlands at the Reactor Institute of Delft (RID). An intensive one month program was devised where thirteen students took a variety of lectures that were augmented with four experiments at the reactor institute, a tour of URENCO, a leading company involved in uranium enrichment for nuclear power plants and with extra presentations given by RID graduate students on a wide variety of topics in nuclear medicine, advanced reactor technology and quality control measurements in nuclear metrology. An added feature was the participation of the students at the 6th International Symposium on *In Situ* Nuclear Metrology as a Tool For Radioecology (INSINUME 2012 in Brussels, Belgium. Daily homework assignments, exams and a final presentation comprised the final grade.

1. Introduction

Study abroad programs have now become an important educational endeavour for many undergraduate engineering programs. These programs have the usual benefits of providing students the familiarity of attaining educational pursuits in a foreign country, while

experiencing cultural differences. Of all the disciplines within a university engineering students are often considered the least likely to participate in such study abroad programs for a variety of reasons. However, the primary reasons are that these students usually take extra courses in the summer to have a timely graduation and pursue industrial internships or Co-Op programs directly related to their career goals. But given the onslaught of globalization many companies now require employees to travel to foreign countries to open up new markets, close deals or continue on-going service contracts. Therefore students who have some international experience prior to graduation are often very well suited to pursue employment where travel is an important feature of the company's international forte. While the Nuclear and Engineering Radiation Program at the University of Texas has been involved in a wide variety of successful research activities, there has also been a strong educational component in undergraduate research, foreign internship programs and research opportunities for Historically Black Colleges or Universities (HBCU's).

In the fall 2011 it was proposed to offer a study abroad program in Concepts of Nuclear and Radiation Engineering to be held at Radioisotope Institute of Delft (RID) at Delft University. This three-hour course was based upon the very successful one-hour course which has been given for the past decade. The intent of the updated course was to include more mathematical theory in radioactivity and introducing the students to four introductory experiments in nuclear engineering. This curriculum was augmented by several guest lecturers in nuclear medicine, reactor technology, solar energy and the RID research reactor.

2. Recruiting

A study abroad course in nuclear engineering has never been offered at the University of Texas. It was therefore necessary to firstly find a sponsoring institution which could offer both space and experimental facilities and secondly properly advertise the course in various engineering and physics departments. The Radioisotope Institute of Delft was the ideal setting to offer as a site for the study abroad program. Intense recruiting including email communications and seminar classes along with web advertising led to thirteen students to sign up for the program. Additionally several scholarships were given out to students to alleviate the financial burden. The usual study abroad safety and cultural issues were deliberated in several additional training like sessions to educate the students on the "do's and don't's" while abroad.

3. Curriculum

The curriculum was set to include basic concepts in nuclear engineering and science, experiments, guest lecturers and two field trips.

3.1 Course Book

The popular textbook entitled Radiation and Modern Life: Fulfilling Marie Curie's Dream was chosen as the course book. There are virtually no mathematical equations, just very effective explanations and illustrations of basic nuclear properties and the application of radiation in a wide variety of areas in science and technology as well as the major impact it has in the public domain. A very good explanation of the origin of naturally occurring radiation in the environment with a good synopsis of radiation effects at low and high doses is given in the second chapter. The basic concepts of radiation interactions are provided in the third

chapter, in which fundamental processes are clarified in uncomplicated terms. Radiation in agriculture, medicine, and nuclear power is well explained in the next three chapters. Each of these areas is treated with detailed examples of the positive benefits of radiation, such as higher crop production, control of insect pests, improved medical diagnostic and therapeutic techniques, and the production of nuclear electricity. Sections on radiation applications in industry, transportation, and space exploration are equally well written. Topics include process controls, materials composition, cars and trucks, space missions, manned voyages, and the radiation-related health effects of space travel. Additional sections on applied radiation include topics related to terrorism, crime and public safety, arts and sciences, and environmental protection. Excellent descriptions of work in antiterrorism efforts, archaeological investigation activities, soil erosion, and air pollution studies are given. In an additional chapter, the impact of radiation on the economy is also very well described (1).

3.2 Lecture Component

The following fifty minute lectures were given

- 1) Radiation Animation
- 2) Pioneers and Events in Nuclear and Radiochemistry
- 3) History of Nuclear Reactors
- 4) Radioactivity (3 lectures)
- 5) Effects of Electricity Generation
- 6) Radiation in the Environment
- 7) Isotopes in Everyday Life
- 8) Nuclear Medicine
- 9) Food Irradiation
- 10) Mammography
- 11) Nuclear Power
- 12) Nuclear Fuel Cycle
- 13) Naturally Occurring Radioactive Material
- 14) Radioactive Waste Management
- 15) Nuclear Security Culture
- 16) Nuclear Nonproliferation

3.3 Laboratory Component

The thirteen participants were split up into three groups of three students and one group of four students. The four experiments consisted of the following:

- 1) half-life measurement using an isotope prepared by neutron activation analysis during the experiment
- 2) contamination experiment using different detectors to differentiate between beta and gamma emission
- 3) ion exchange experiment to understand the process to separate different isotopes during the nuclear fuel cycle
- 4) extraction experiment to show how different isotopes can be separated under different chemical conditions

All the students had to answer the questions in each laboratory but there was no formal write-up on any of the experiments.

3.4 Guest Lecturers

An important part of the curriculum was to introduce students to current research. Field experience of the students by allowing them to witness the applications for their classwork and laboratory experiments. The lectures included:

- 1) overview of the research reactor then a tour of the facilities
- 2) solar energy and visit of facilities
- 3) micro-SPECT (single photon enhanced computed tomography) and visit to the facility
- 4) high energy synchrotron research
- 5) polymersomes and visit to experimental facility
- 6) pebble bed reactor
- 7) metrological concepts of measurement

3.5 Field Trips

Two field trips were taken. One trip included a visit to URENCO (Uranium Enrichment Company) Almelo, Netherlands. URENCO is one of the largest uranium enrichment facilities in the world for nuclear power plant fuel fabrication. Besides a video overview the students had a first-hand look at the production facilities and the huge engineering complex involved. The second field trip was the attendance of the 6th International Conference International Symposium on *In Situ* Nuclear Metrology as a Tool for Radioecology (INSIUME). The conference was held in Brussels, Belgium and thus it was a reasonable distance to commute by train. This conference was mainly dedicated to the movement of radioactivity in the environment and production of isotopes.

4. Grade Evaluation

The grade evaluation of the students was made up of several components:

- 1) assignments given from the course book
- 2) three examinations
- 3) laboratory experiments
- 4) group presentation of any topic from the conference

5. Course Evaluation

Evaluations for the course and instructor were done using the usual forms supplied by the University of Texas. These forms were filled out in private on the last day of class and then handed in to the teaching assistant. The specific questions as well as overall course and instructor evaluation are shown below. The University of Texas uses only the last two questions as means of evaluating the course and instructor. The first questions are given as guideline to the instructor of the strengths and weaknesses of the individual parts of the course. Each student also has ample space for hand-written comments. The students overwhelmingly gave high evaluations for all facets the course. A group photo of the student participants, course instructor, teaching assistant and the RID staff outside the reactor is shown in Figure 1.



Figure 1 Group Photo Outside the Reactor

6. Conclusion

This was the first time that a study abroad program in nuclear and science and engineering has been offered by the University of Texas Cockrell School of Engineering. Overall the program was very successful with a very high satisfaction by the students.

7. References

(1) S. Landsberger, Book Review of Radiation and Modern Life: Fulfilling Marie Curie's Dream, The Journal of Clinical Investigation, Volume 116 Number 2 February 2006.

8. Acknowledgements

The course instructor is very grateful for support from the Study Abroad Program at the University of Texas and the excellent support staff at the Reactor Institute of Delft Technical University. Funding from the Office of Naval Research for two students is also greatly appreciated.

HUMAN RESOURCES CHALLENGE AND KNOWLEDGE MANAGEMENT IN SLOVAK NUCLEAR POWER ENGINEERING

V. SLUGEN

Slovak University of Technology, UJFI, FEI STU, Ilkovičova 3, 812 19 Bratislava, Slovakia

ABSTRACT

The crucial pre-condition of a successful implementation of the ongoing nuclear renaissance is a sufficient amount of properly educated and skilled workers in the area of nuclear safety for operation, design and maintenance. Experiences from the Slovak Republic are discussed in detail. This country produces more than 50% of electricity in NPPs and has actual experiences in built, operation as well as decommissioning. For all these activities, highly educated and skilled workers are crucial.

Paper is focused on the actual activities connected to the improving of education and training in the nuclear area at the national as well as international level.

INTRODUCTION

In the last decade, preservation and optimal nuclear knowledge management are becoming a rising challenge worldwide. Many papers and experts' talks at different conferences stressed attention on stagnating or decreasing expertise connecting to decreased numbers of graduates, professors or research workers. [1-3]. Several networks were created in Europe in the frame of the 5th, 6th or 7th Euratom Framework Programme accentuating international collaboration in training and education physics (EUPEN, STEPS) or in nuclear power engineering (ENEN, NEPTUNO or TRASNUSAFE) [4-6].

Preparation of operating staff for nuclear industry is and also has to be one of the most serious education processes. This requires a high level of education and knowledge in nuclear physics and technology supported by a wide spectrum of academic as well as research institutions on national and international level. Nuclear physics requires a good base in mathematics, analytical way of thinking. Additionally a lot of special technical knowledge in combination with training has to be collected. There is no doubt that this education is one of the most difficult for the young generation. The attractiveness of nuclear physicist or nuclear engineer is really not blooming. Unfortunately, decreased number of employees in nuclear sector and "human ageing" of experts seems to be a serious problem in many countries around the world. I am afraid that also well-proven magic words like bio-, nano-, will not rescue this profession.

The nuclear knowledge management is actually in fashion. It can be performed via education process during undergraduate (Bc.), graduate (MSc.) and postgraduate (PhD.) studies, via specialized training courses in a frame of continuous education system, research activities and projects, e-learning, database creation, workshops, seminars, model situation, etc. All ways can be effective only if there exists both-side interest, from employer as well as from employee.

The extremely high expectation (as well as responsibility) is on the shoulders of university professors in nuclear. University can contribute not only to the education but also

to attract students to nuclear field, which is a base also for the safety culture at NPP as well as essential need for accepting nuclear industry by the public. Readers at the university (professors, assistants, etc.) can stimulate students for nuclear physics or at least they can relieve them of distress from nuclear issues. The first contact is very important. University enables an optimal selection of students. The option for "nuclear education" is completely free and independent. The problem is that the amount of students taking these lectures is low. Proper education at the university is a source of knowledge and attitudes for the whole life. Theoretical and practical experiences, professional approach and consistency are very important also from the safety culture point of view. University lectures and seminars are basically opened for public and this academic field can be made better use of in public relations. It is an investment mainly to young generation. During discussions with students, teachers can form their professional orientation according to their abilities and needs. Good teacher encourages also the growth of student and shapes his personality. Graduated students have to learn to take responsibility for their decisions and their academic level of education.

POSITIVE EXAMPLES

In the Central-European region, there exists a very extensive and also effective international collaboration in nuclear industry and education. Similarly good situation is also among universities and technical high schools in this area. Actually, the Slovak University of Technology in Bratislava has established contacts with many universities abroad in the area of utilization of research and training reactors. One of good examples of international collaboration is ENEN – European Nuclear Education Network Association [7] which resulted in a formation of “Eugene Wigner Training Courses on Reactor Physics Experiments” [8, 9] running in the last years as a mutual effort of the Budapest University of Technology and Economics (Budapest, Hungary), Czech Technical University (Prague, Czech Republic), University of Technology (Vienna, Austria), and Slovak University of Technology in Bratislava (Bratislava, Slovakia). In total 69 participants from different European countries as Austria, Belgium, Bulgaria, Czech Republic, Finland, Italy, Israel, Romania, Slovakia, Slovenia, Sweden and Switzerland took part at these international training courses so far. In the frame of these courses, students of nuclear engineering visited three different experimental facilities located at the course organizers’ institutes and carried out experimental laboratory practices. It is highly recommended to continue in this practical oriented course.

The preservation of nuclear knowledge is possible only via effective use of all tools (Fig.1).

The high level nuclear education is very important also due to permanent increasing of nuclear expert’s age. To replace some of them are not easy. Beside this, the nuclear community needs some internal dynamic, which is connected to the young people activities.

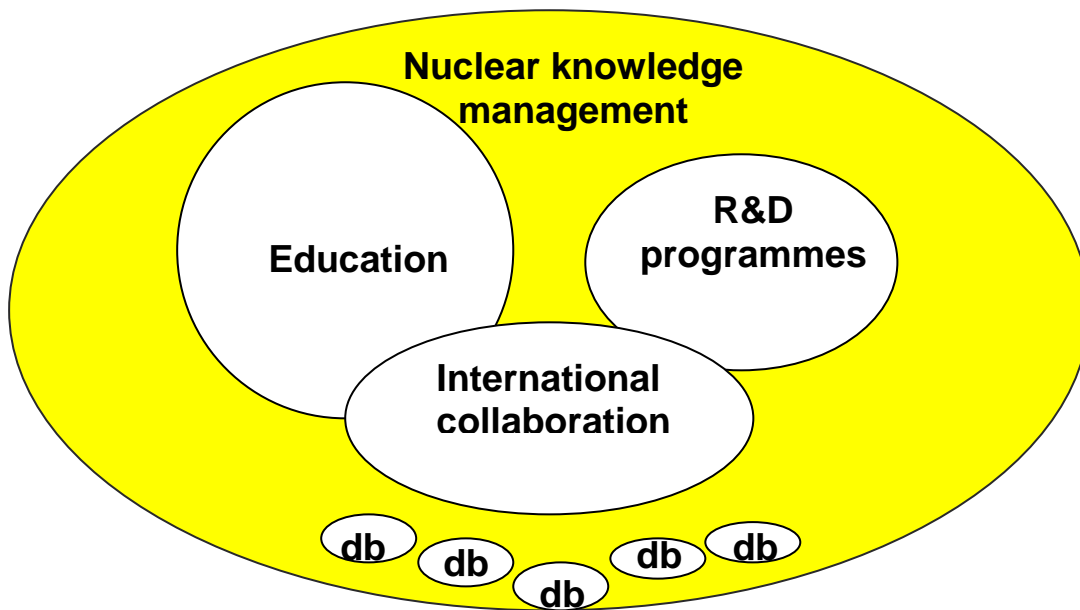


Figure 1. Example for VVER database.

The problem is that the amount of students taking these lectures is low. Proper education at the university is a source of knowledge and attitudes for the whole life. Theoretical and practical experiences, professional approach and consistency are very important also from the safety culture point of view. University lectures and seminars are basically opened for public and this academic field can be made better use of in public relations.

It is an investment mainly to young generation. During discussions with students, teachers can form their professional orientation according to their abilities and needs. Good teacher encourages also the growth of student and shapes his personality. Graduated students have to learn to take responsibility for their decisions and their academic level of education.

Unfortunately, there was not real interest for educated nuclear engineers from industry till now. Although oral declaration how these graduates are necessary for NPP operators, in reality the nuclear industry does not attract young specialist. Fig. 2 shows that about 50 percent of graduates of specialized nuclear power engineering study at STU Bratislava went completely out from this area. Hopefully next years connected to the commissioning of Mochovce 3, 4 will change this approach.

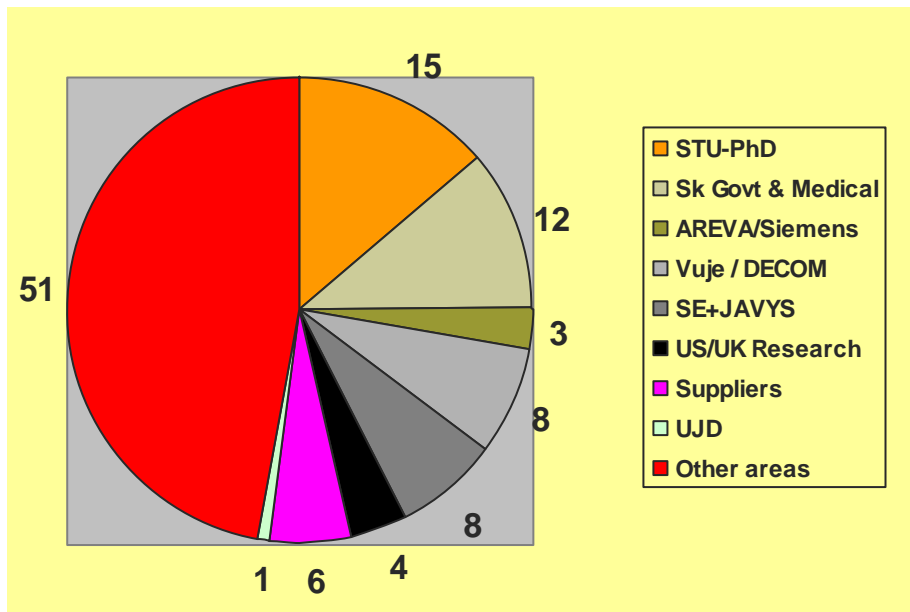


Figure 2. Working addresses of STU graduates in nuclear power engineering in last 12 years.

CONCLUSIONS

The actual status of education and training in nuclear power engineering is the real cause for concern. This education has to be based on the serious long term basis organised and guaranteed by high quality academic institution. It is a duty of educated and responsible people to highlight the necessity for a renaissance in nuclear education and training and recommend the following points:

We must act now

Strategic Role of Governments

The Challenges of revitalising nuclear education

Vigorous research and maintaining high quality training

Benefits of Collaboration and Sharing Best Practices

I hope that it still not to late.

Acknowledgement

Financial contribution of the grant VEGA 1/0129/09 and EC project CAPTURE is acknowledged.

REFERENCES

- [1] OECD/NEA, *Nuclear education and training: cause for concern?* OECD 2000, ISBN 92-64-18521-6.
- [2] Fernandez-Ruiz, P., Forsström, H. and Van Goethem, G., *The sixth European framework programme 2003-2006: a driving force for the construction of the nuclear European research area*, Nuclear Engineering and Design 235 (2005) pp. 127 - 137
- [3] Moons, F., Safieh, J., Giot, M., Mavko, B., Sehgal, R.R., Schäfer, A., Van Goethem, G. and D'haeseleer, W., *European Master of Science in Nuclear Engineering*, Nuclear Engineering and Design, 235 (2005), pp. 165-172
- [4] ECTS, <http://www.europa.eu.int/comm/education/programmes/socrates/ects.en.html>
- [5] ENEN, <http://www.sckcen.be/ENEN>
- [6] NEPTUNO, <http://www.sckcen.be/NEPTUNO>
- [7] <http://www.enen-assoc.org>
- [8] Böck, H., Matejka, K., Miglierini, M., Sklenka, L., Sukosd C. and Villa, M. (2004) *A central European training course on reactor physics and kinetics-the "Eugene Wigner Course"* Book of extended synopses from International Conference on Nuclear Knowledge Management: Strategies, Information Management and Human Resource Development, 7-10 September, 2004, Saclay, France, IAEA-CN-123/04/P/4, pp.120-122
- [9] http://www.reak.bme.hu/nti/Education/Wigner_Course
- [10] Slugen, V., Lipka, J., Hascik, J., Miglierini, M. (2004) *Utilisation of research and training reactors in the study programme of students at the Slovak University of Technology*. International Journal of Nuclear Knowledge Management Vol.1, pp. 68-77.
- [11] Slugen, V., Lipka, J., Hascik, J. (2000) *STU education program in nuclear physics focused for nuclear industry needs*, Physics Education Vol. **17**, 13.

PERSPECTIVES OF THE SMALLEST NUCLEAR COUNTRY FOR THE RESEARCH AND EDUCATION IN NUCLEAR SAFETY

L. CIZELJ, I. TISELJ

*Jožef Stefan Institute, Reactor Engineering Division
Jamova cesta 39, 1000 Ljubljana, Slovenia*

and

*University of Ljubljana, Slovenia, Faculty of Mathematics and Physics
Jadranska cesta 19, 1000 Ljubljana, Slovenia*

ABSTRACT

Research and education are fundamental in the successful development and implementation of contemporary complex technologies, including peaceful utilization of nuclear energy. The national responsibility to organize and sustain appropriate research and education is clearly set forward in the IAEA Nuclear safety convention and in the EURATOM treaty. Recent regionalization and globalization of power markets provided new opportunities and challenges, which might be more pronounced in countries with rather limited resources. The research and education activities in nuclear engineering and safety pursued at the Jožef Stefan Institute and the University of Ljubljana are reviewed. Examples of integration within the European Union and OECD also include access to large experimental programs and exchange of students and teachers within the ENEN Association (European Nuclear Education Network).

1 INTRODUCTION

Slovenia is the smallest amongst the 30 countries with operating nuclear power plants. The construction of the single nuclear unit located at Krško has been started in 1975. The first criticality was achieved in September 1981, followed by the first synchronization to the grid in October 1981. The commercial operation began on January 1, 1983.

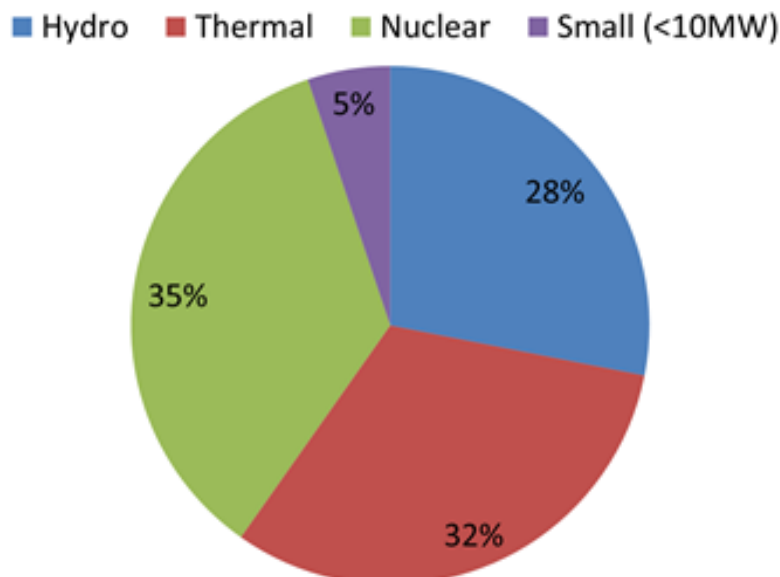


Fig. 1 Electricity production in Slovenia in 2010: the major shares by source

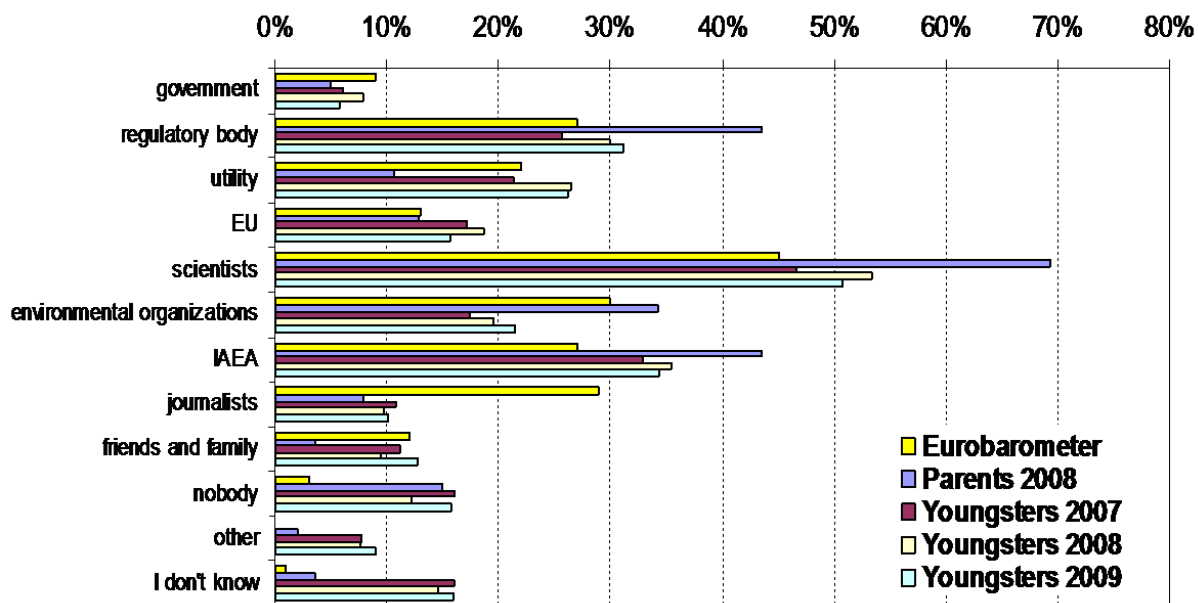
The pressurized water reactor with thermal power of 2000 MW was designed by Westinghouse. After the replacement of both steam generators in 2000 and both low pressure steam turbines in 2006, the net electric output of the plant reached 696 MW. Currently, the 18 months long fuel cycles with outages performed in about 30 days facilitate

the yearly production of 5,46 TWh in 2009 and 5,38 TWh in 2010. The plant availability in 2010 was at 89,91% with capacity factor of 92,23%.

The single nuclear unit at Krško contributes slightly less than 30% of electricity production in Slovenia (Fig. 1). The plant is operated by a limited liability company Nuklearna elektrarna Krško (NEK). The basic capital of NEK is divided into two equal shares owned by the partners Gen energija Ltd, Krško, Slovenia, and Hrvatska Elektroprivreda p.l.c., Zagreb, Croatia. NEK produces and supplies electricity exclusively in favor of the two partners, who each have the right and obligation to use 50% of its total output. NEK operates on a non-profit basis. Electricity production costs are covered by the two partners.

The research and research based education are fundamental in the successful development and implementation of nuclear power. The national responsibility to organize and sustain appropriate research and education is recognized and clearly set forward in the IAEA Nuclear safety convention and in the EURATOM treaty.

This is in-line with the public opinion in Slovenia [1] and Europe [2]. Scientists enjoy the highest trust among the general population in Europe. Similar picture has been obtained among youngsters and their parents in Slovenia. The public trust in science probably stems from the fact that the status of the scientists is typically considered independent. It is also interesting to note that both youngsters and their parents trust scientists, regulatory body and IAEA appreciably more than the journalists (Fig. 2).



Question:

Which 3 of the following would you trust most to give you information about nuclear safety?

Fig. 2 Results of the public opinion polls in 2009: public trust [1], [2]

The main purpose of this paper is to briefly review the results of the recent research projects carried out by the Reactor Engineering Division of the Jožef Stefan Institute in the field of nuclear engineering and safety. The main focus is given to the results of projects involving multiphysics, multiscale and international consortia.

Nuclear Engineering education at the Faculty of Mathematics and Physics of the University of Ljubljana (M. Sc., Ph.D.) will be outlined next, followed by some recent examples of technical support to the utility and regulatory body.

2 RESEARCH ACTIVITIES

The majority of the research activities of the Reactor Engineering division are performed with the ambition to contribute to the safety of nuclear installations. The main directions of the research include thermal hydraulics safety analyses, ageing and integrity of the reactor pressure boundary, probabilistic safety analyses and severe accidents. As depicted in Fig. 3, all four major directions are currently dealing with the generations II, III and III+ of nuclear power plants. The topics related to heat transfer and component integrity also extend towards the conceptual Gen IV and fusion reactors. The majority of the research work relies on the development and application of numerical simulations and relies on the experimental support available through wide networks of regional and global cooperation.

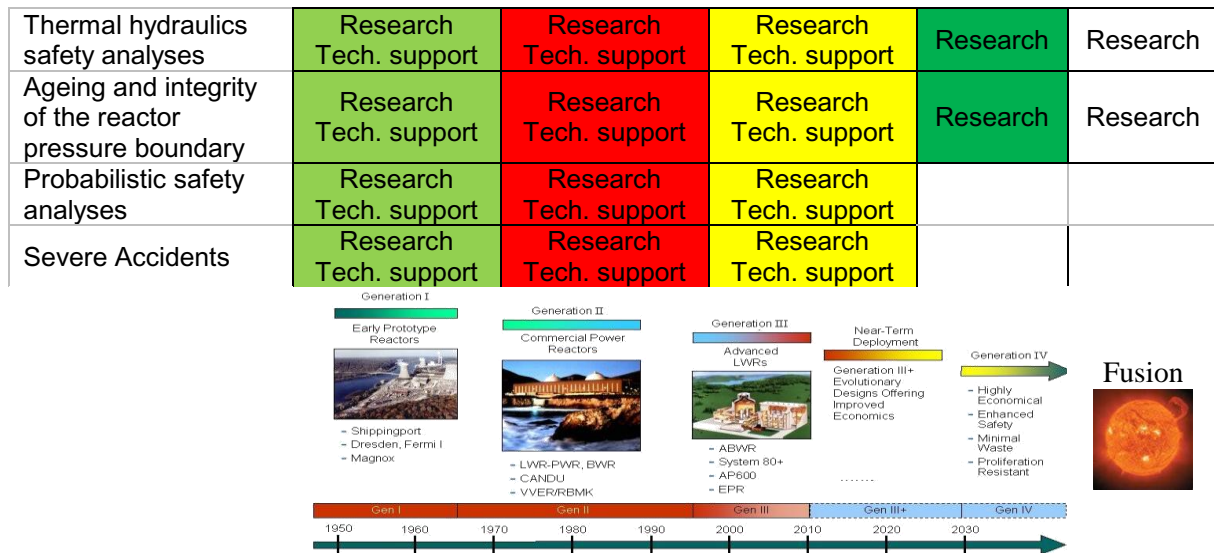


Fig. 3 Map of the current research activities with respect to the generation of the NPP

The stagnation of the nuclear power during the recent decades and the rather scarce resources available in Slovenia facilitated the development of a widespread international cooperation. The joint projects in progress include:

- Framework programmes of the European Commission (EURATOM):
 - NURISP (Nuclear Reactor Integrated Simulation Project)
 - THINS (Thermal Hydraulics of Innovative Nuclear Systems)
 - NULIFE (Nuclear Plant Life Prediction)
 - SARNET2 (Severe Accident Research Network of Excellence)
 - LACOMEKO (Large Scale Experiments on Core Degradation, Melt Retention and Containment Behaviour)
- Bilateral cooperation with the French Commissariat à l'énergie atomique (CEA):
 - Modelling of Condensation Induced Water Hammer and Boiling Crisis in Subcooled Boiling
 - Flow Influence of Melt Solidification on Steam Explosion
 - Analysis of Ex-Vessel Molten Fuel-Coolant Interaction

- Simulation of Hydrogen Combustion Experiments in the ENACCEF Experimental Facility

Other important co operations include the Phebus Fission Project lead by the European Joint Research Centre and the French Institut de radioprotection et de sûreté nucléaire (IRSN), the European Sustainable Nuclear Energy Technology Platform and the CAMP (Code Application and Maintenance Program) led by the US Nuclear regulatory Commission.

2.1 Thermomechanical analysis of a thimble and tile in the divertor of a DEMO fusion reactor [3]

The divertor of the DEMO fusion reactor will be exposed to thermal fluxes of up to 15MW/m². The upper side of the tile (Fig. 4 right) is exposed to the radiation of plasma, while the lower part is cooled with jets of helium.

A steady state thermo-mechanical analysis was performed with using ANSYS-CFX-11 and ABAQUS 6.9 codes. The RANS approach with SST turbulence model was used to describe the fluid flow. The fluid after leaving the nozzles impinges on the fluid-thimble interface, resulting in a strong local variation of heat fluxes. This local variability is described using the heat transfer (film) coefficients (Fig. 5 left). The resulting temperatures and thermal stresses in the tile and thimble are shown in Fig. 5 middle and right, respectively.

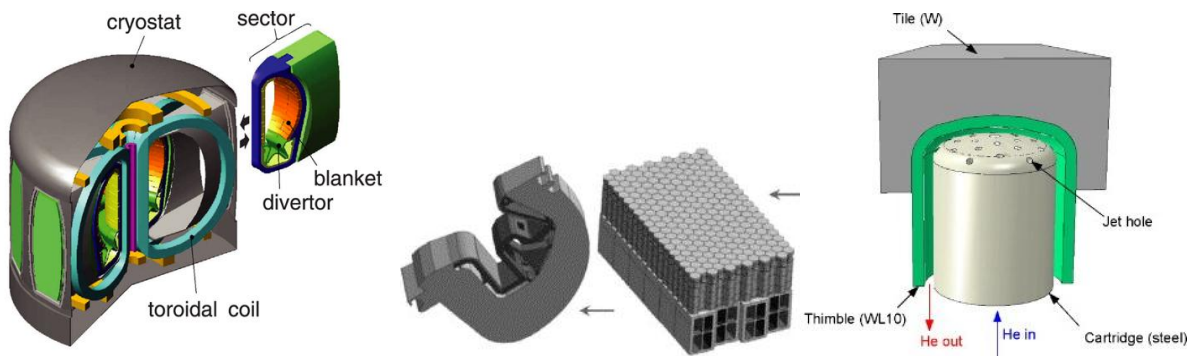


Fig. 4 The basic outline of the divertor in DEMO reactor and the cooled thimble and tile

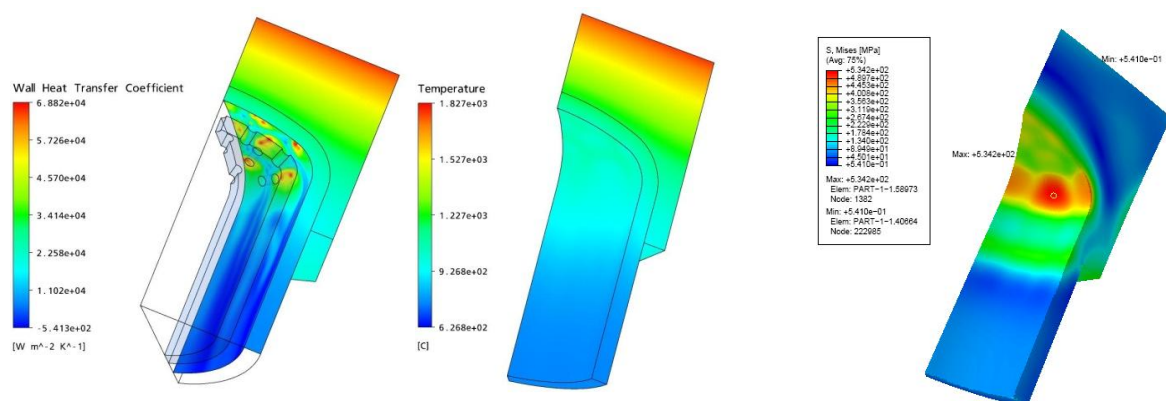


Fig. 5 Heat transfer coefficient at the fluid-thimble interface (left). The temperatures (middle) and von Mises stresses (right) in the thimble and tile.

2.2 Two-fluid model with interface sharpening [4]

Two-fluid models are applicable for simulations of all types of two-phase flows ranging from separated flows with large characteristic interfacial length scales to highly dispersed flows with very small characteristic interfacial length scales. The main drawback of the two-fluid model, when used for simulations of stratified flows, is the numerical diffusion of the

interface. Stratified flows can be easily and more accurately solved with interface tracking methods; however, these methods are limited to the flows that do not develop into dispersed types of flows. A new approach, has been proposed where the advantage of the two-fluid model is combined with the conservative level set method for interface tracking.

The advection step of the volume fraction transport equation is followed by the interface sharpening, which preserves the thickness of the interface during the simulation. The proposed two-fluid model with interface sharpening was found to be more accurate than the existing two-fluid models. The mixed flow with both: stratified and dispersed flow was simulated with the coupled model. In the coupled model, the dispersed two-fluid model and two-fluid model with interface sharpening are used locally, depending on the parameter which recognizes the flow regime.

Further examples of recent research findings include simulations of fluid structure interaction in the piping systems [5], surface tracking algorithms in two fluid systems [6, 7], development of two-phase wall function for boiling flow [8], simulation of short cracks at the grain scale [9], vulnerability of the nuclear plant to the terrorist attack [10, 11], PSA with explicit account for ageing of passive equipment [12], reliability of power grids [13], steam explosions [14], fuel – coolant interactions [15], two phase water hammer simulations [16] and simulation of conditions within the containment [17, 18].

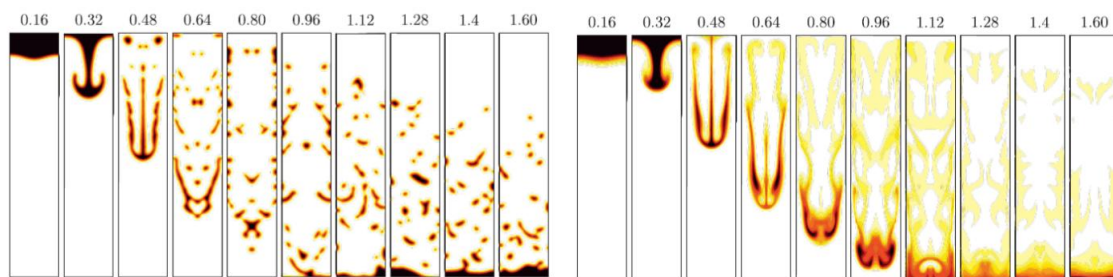


Fig. 6 A Rayleigh–Taylor instability simulated with (left) and without surface sharpening (right): volume fraction at different times t (s)

3 EDUCATION ACTIVITIES

Since October 2009, the higher education in Slovenia conforms fully to the Bologna Declaration. The programs and degrees in Nuclear Engineering include M.Sc. (2nd degree after Bologna declaration) and Ph. D. (3rd degree). These programs (<http://www.fmf.uni-lj.si/si/studij-fizike/>) are offered by the Faculty of mathematics and physics of the University of Ljubljana.

3.1 M.Sc. Program

The M.Sc. program is scheduled for 2 years and is evaluated with 120 ECTS (European Credit Transfer System). The basic requirements to enroll this program include completed B.Sc. (180 ECTS, 3 years) in physics, mathematics, chemistry or engineering. The curriculum includes 5 obligatory courses and an individual selection of up to 13 courses out of a list of 24 available. The individual research work leading to a thesis is evaluated with 30 ECTS (one semester).

Students who acquire 20 or more ECTS at institutions, which are members of the ENEN Association (short description below), may be awarded the title of European Master of Nuclear Engineering by the ENEN Association.

3.2 Ph.D. Program

The Ph. D. program in Nuclear Engineering is evaluated with 180 ECTS (3 years). The basic requirements to enroll this program include completed 2nd degree after Bologna declaration

(e.g., M.Sc. with total of 300 ECTS). The curriculum includes 1 obligatory course and a selection of 2 optional courses leading to at least 30 ECTS. 15 ECTS are granted for successful defense of the disposition of the thesis. 15 ECTS can be obtained with exchange courses at other institutions. The individual research work leading to the Ph. D. thesis is evaluated at 120 ECTS. Mobility of students is strongly encouraged.

3.3 International cooperation

Slovene educational efforts in nuclear engineering are closely connected with the activities of the European ENEN association (European Nuclear Education Network, www.enen-assoc.org). ENEN association connects more than 50 European universities and research institutes with nuclear programs. Its mission is the preservation and further development of expertise in the nuclear fields by higher education and training. The major activities include the mobility of students and teachers within the members. The goals and the structure of the ENEN association are discussed in detail in [19]. Both the “Jožef Stefan” Institute and the University of Ljubljana are founding and active members of the ENEN Association.

4 TECHNICAL SUPPORT

The Reactor Engineering Division acts as a Technical and Scientific Support Organization (TSO) to the regulatory body. Additionally, technical support to the utility is performed occasionally.

The following two examples illustrate development work, which has been pursued primarily to improve the tools and models used in the technical support activities.

4.1 Animation model for RELAP5 simulation of the Krško nuclear power plant [20]

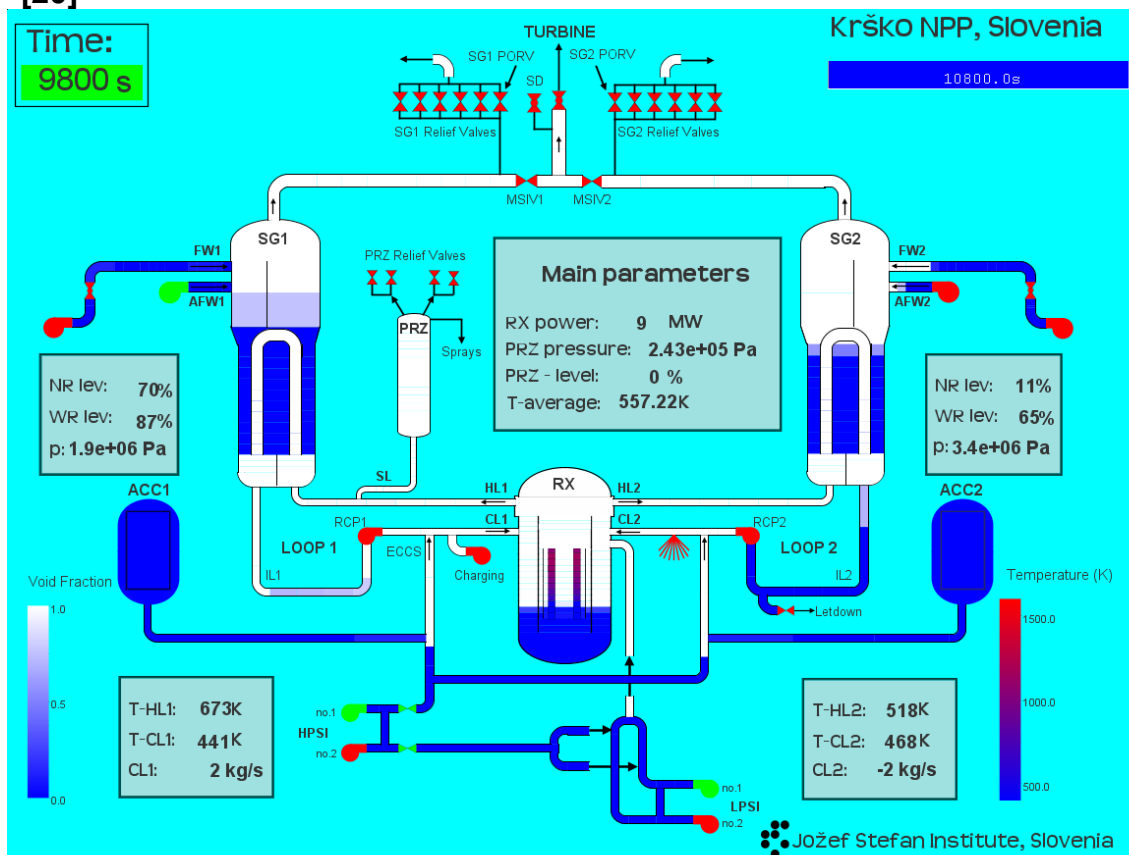


Fig. 7 SNAP animation mask showing void conditions at 14 s – 20.32 cm break size small break loss of coolant accident (SBLOCA)

Today most software applications, also in the nuclear field, come with a graphical user interface. The first graphical user interface for the RELAP5 thermal-hydraulic computer code

was called the Nuclear Plant Analyzer (NPA). Later, Symbolic Nuclear Analysis Package (SNAP) was developed. In the present study SNAP animation model of Krško nuclear power plant (NPP) was developed to animate RELAP5 calculations. In the example the reference calculations for Krško full scope simulator validation were performed with the latest RELAP5/MOD3.3 Patch 03 code and compared to previous RELAP5 versions to provide verified source data, needed to demonstrate animation model. In total six scenarios were analyzed: two scenarios of the small-break loss-of-coolant accident, two scenarios of the loss of main feedwater, a scenario of the anticipated transient without scram, and a scenario of the steam generator tube rupture.

The use of SNAP for animation of Krško nuclear power plant analyses showed several benefits, especially better understanding of the calculated physical phenomena and processes. It can be concluded that an animation tool was created, which facilitates analyses of very complex accident scenarios. The graphical surface helps keeping the overview and focusing on the main influences. Also, the use of such support tools to system codes may significantly contribute to better quality of safety analysis.

The activities for the future include the simulations with TRACE, which is advanced thermal-hydraulic computer code for safety analyses. The animation model will be of help also to TRACE.

This activity has been performed within the Code Application and Maintenance Program) led by the US Nuclear regulatory Commission.

4.2 Modular 3-D Finite Element Model for Fatigue Analyses of a PWR Reactor Coolant System [21]

A set of computational tools has been developed, which assist a user in the deployment of modular spatial finite elements of the main components of the reactor coolant system, e.g. pipes, pressure vessels and pumps. The modularity ensures that the components can be analyzed individually or in a system. Also, individual components can be meshed with different mesh densities, as required by the specifics of the particular transient studied. All components are meshed with hexahedral elements with quadratic interpolation.

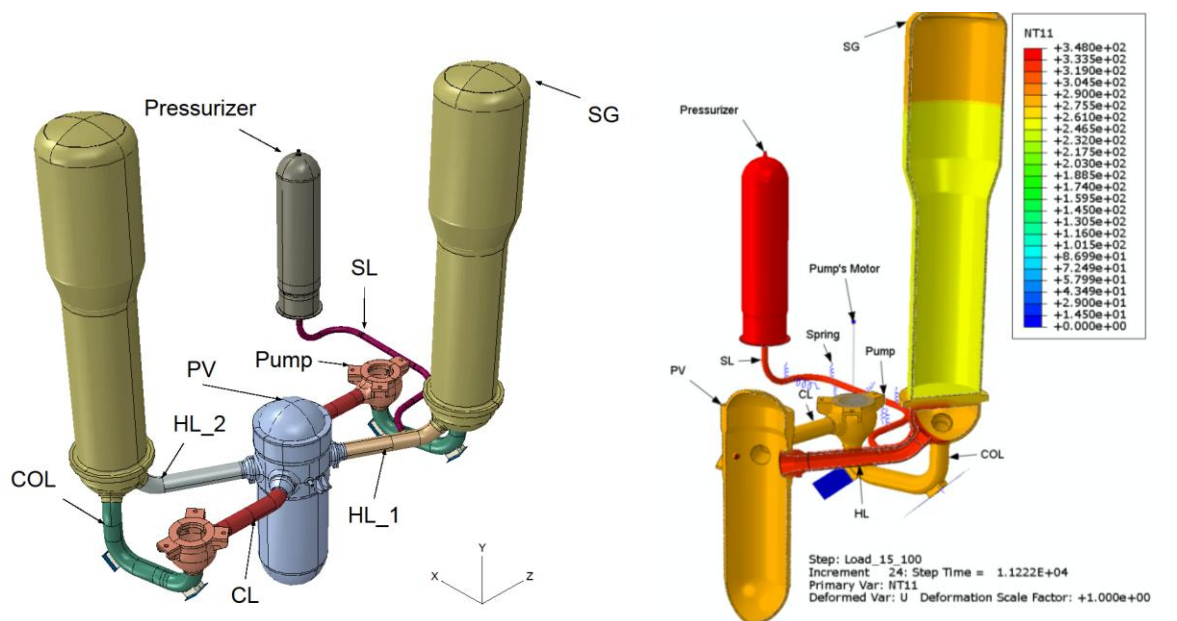


Fig. 8 Model of a PWR Reactor Coolant System (left) and temperatures during step load (right)

The components have been located spatially to perform a complete assembly of a 3D modular solid model for a generic 2 loops second generation PWR. Basic objective of this

tool is to be used in the future for fatigue analyses assessment using the finite element method.

The simulations already performed with the entire 2 loop PWR reactor coolant system (RCS) are: heat transfer and stress analysis for a complete loading and unloading cycle of the RCS. The implemented transients are as follows: the system loading from room temperature until full reactor power, and the system unloading down to cold shutdown conditions. The loads applied to the system are gravity (deadweight), temperatures and pressures

5 CONCLUSIONS

The research and education activities in nuclear engineering and safety pursued at the Jožef Stefan Institute and the University of Ljubljana are reviewed. Examples of integration within the European Union and OECD include access to large experimental programs and exchange of students and teachers within the ENEN Association (European Nuclear Education Network). Finally, some illustrative examples of technical support to the regulatory body and utility are given.

6 ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support from the Slovenian research agency through research program P2-0026 and projects J2-9168, J2-4078, J2-6614, J2-6565 and J2-6564.

7 REFERENCES

- [1] R. Istenič and I. Jenčič, "Public Opinion About Nuclear Energy - Year 2009 Poll," presented at the International Conference - Nuclear Energy for New Europe 2009, Proceedings, Portorož, Slovenia, 2003.
- [2] European Commission, "Europeans and Nuclear Safety, Special Eurobarometer 324," Special Eurobarometer 324, 2010.
- [3] I. Simonovski, B. Končar, and L. Cizelj, "Thermo-mechanical analysis of a DEMO divertor cooling finger under the EFREMOV test conditions," *Fusion Engineering and Design*, vol. 85, pp. 130-137, 2010.
- [4] L. Štrubelj and I. Tiselj, "Two-fluid model with interface sharpening," *International Journal for Numerical Methods in Engineering*, vol. DOI: 10.1002/nme.2978, 2010.
- [5] J. Gale and I. Tiselj, "Godunov's method for simulations of fluid-structure interaction in piping systems," *Journal of Pressure Vessel Technology, Transactions of the ASME*, vol. 130, pp. 0313041-03130412, 2008.
- [6] L. Štrubelj and I. Tiselj, "Numerical simulations of basic interfacial instabilities with incompressible two-fluid model," *Nuclear Engineering and Design*, vol. In Press, Corrected Proof, 2010.
- [7] L. Štrubelj, I. Tiselj, and B. Mavko, "Simulations of free surface flows with implementation of surface tension and interface sharpening in the two-fluid model," *International Journal of Heat and Fluid Flow*, vol. 30, pp. 741-750, 2009.
- [8] B. Koncar and I. Tiselj, "Influence of near-wall modelling on boiling flow simulation," *Nuclear Engineering and Design*, vol. 240, pp. 275-283, 2010.
- [9] I. Simonovski and L. Cizelj, "Computational multiscale models of intergranular cracking," *Computational Material Science*, vol. submitted, 2010.
- [10] L. Cizelj, M. Leskovar, M. Cepin, and B. Mavko, "A method for rapid vulnerability assessment of structures loaded by outside blasts," *Nuclear Engineering and Design*, vol. 239, pp. 1641-1646, 2009.
- [11] M. Čepin, L. Cizelj, M. Leskovar, and B. Mavko, "Vulnerability analysis of a nuclear power plant considering detonations of explosive devices," *Journal of Nuclear Science and Technology*, vol. 43, pp. 1258-1269, Oct 2006.
- [12] M. Čepin and R. Briš, "Consideration of ageing in the probabilistic safety assessment," in *Proceedings of the European Safety and Reliability Conference 2007, ESREL 2007 - Risk, Reliability and Societal Safety*, 2007, pp. 1441-1444.

- [13] A. Volkanovski, M. Čepin, and B. Mavko, "Application of the fault tree analysis for assessment of power system reliability," *Reliability Engineering and System Safety*, vol. 94, pp. 1116-1127, 2009.
- [14] M. Leskovar and M. Ursic, "Estimation of ex-vessel steam explosion pressure loads," *Nuclear Engineering and Design*, vol. 239, pp. 2444-2458, 2009.
- [15] M. Uršič, M. Leskovar, and B. Mavko, "Improved solidification influence modelling for Eulerian fuel-coolant interaction codes," *Nuclear Engineering and Design*, vol. In Press, Corrected Proof, 2010.
- [16] I. Tiselj, A. Horvat, and J. Gale, "Numerical scheme of the WAHA code," *Multiphase Science and Technology*, vol. 20, pp. 323-354, 2008.
- [17] I. Kljenak and B. Mavko, "Simulation of containment thermal-hydraulics in the Marviken Blowdown 16 experiment with ASTEC and CONTAIN codes," *Nuclear Engineering and Design*, vol. In Press, Corrected Proof, 2010.
- [18] M. Babić, I. Kljenak, and B. Mavko, "Prediction of light gas distribution in experimental containment facilities using the CFX4 code," *Nuclear Engineering and Design*, vol. 238, pp. 538-550, 2008.
- [19] F. Moons, J. Safieh, M. Giot, B. Mavko, B. R. Sehgal, A. Schäfer, G. V. Goethem, and W. D'Haeseleer, "European Master of Science in Nuclear Engineering," *Nuclear Engineering and Design*, vol. 235, pp. 165-172, 2005.
- [20] A. Prošek and B. Mavko, "Animation model of Krško nuclear power plant for RELAP5 calculations," *Nuclear Engineering and Design*, vol. In Press, Corrected Proof, 2010.
- [21] O. C. Garrido, L. Cizelj, and I. Simonovski, "Modular 3-D solid finite element model for fatigue analyses of a PWR coolant system," *Nuclear Engineering and Design*.

SUPPLEMENTING NUCLEAR EDUCATION AT UNIVERSITIES WITH INDUSTRY KNOW-HOW AND EXPERIENCE

STEFAN GLAUBRECHT, CHRISTIAN SCHOENFELDER

*Training Center AREVA NP GmbH
Kaiserleistr. 29, 63067 Offenbach - Germany,*

ABSTRACT

The nuclear industry is continuing to recruit graduates as new employees. Experience has shown that on the one hand, promising candidates did not always undergo a comprehensive education in nuclear technology, but on the other hand such an education is not always mandatory for completion of the tasks at hand in nuclear industry. The understanding of issues currently relevant to the industry will consequently supplement the education delivered at universities. This paper reviews the current situation and presents the *University Knowledge Package*, an AREVA product, which offers a series of lectures adapted to academic audiences.

1. INTRODUCTION

The nuclear power education at universities usually concentrates on nuclear basics. Targeting mainly bachelor or master students, they will have to systematically build up competence on basic issues like nuclear physics, in particular neutron physics, nuclear reactions, ionizing radiation, nuclear fission, reactor kinetics and dynamics, but also related topics such as fluid dynamics, materials and their behavior under ionizing radiation. In addition, students will be introduced into design and operation of nuclear facilities, in particular nuclear power plants, and their nuclear specific components. Methods and tools (especially computer codes) used to design these components and to optimize their safety, construction and operational behavior are also discussed in university courses. Furthermore, energy issues are often introduced - power plants, energy policy, energy needs - and dealt with in some detail.

Offering different levels of expertise, covering overview, introductory and expert level, various university courses are also provided for students in other subjects of study than nuclear. This will enable them to complement traditional study subjects like mechanical or electrical engineering with nuclear topics, allowing them to qualify for the nuclear industry.

However, industry, and in particular AREVA, has often identified knowledge gaps with new recruits that require additional in-house training activities. The aim of these training activities (often a mixture of classroom, hands-on and on-the-job training) is usually to qualify these people for industrial activities. Here we have to mention licensing, basic or detailed engineering, procurement of supplies and services, supervision of subcontractors or manufacturers, construction, commissioning, operation and maintenance of nuclear facilities. In all these cases, the competences gained during university education often only provide a basic understanding of relevant issues, and assist with the above task areas.

There is consequently a need for complementing university education with additional measures that will better prepare students for their future job positions in nuclear industry, while at the

same time provide them with guidance for selecting relevant education opportunities that can be harmonized with their private career path.

Based on its experiences with the expansion of its workforce, AREVA has started to design, develop and implement dedicated training programs for its young engineers early on. These programs complemented the basic university education, thereby preparing new recruits for their AREVA activities. Training was performed not only as on-the-job-training, but also as specific classroom and hands-on training. Parts of this training could however be easily transferred to universities by a dedicated AREVA offer dealing with the required content, as described below.

2. COMPETENCE ISSUES RELEVANT TO THE NUCLEAR INDUSTRY

Focusing on the nuclear industry dealing with electrical energy production (i.e. utilities, operators, suppliers and related sub-contractors, but also safety authorities and expert organizations), the range of activities of the human workforce extends over the complete life cycle of nuclear facilities. This will cover licensing, basic or detailed engineering, procurement and qualifying manufacturers and their products, construction, commissioning, operation and maintenance.

Safe and economical operation is the main objective of these facilities. This requires a stringent alignment of all activities on all levels (overview and detailed), as well as the consideration of all diverse interactions between the various components and systems of a nuclear facility.

For example, consider the reactivity during power operation of a nuclear power plant: all reactivity parameters such as control rod position, boron concentration, fuel temperature, moderator temperature, Xenon concentration and fuel burn up are coupled via reactivity feedback, and show a behaviour completely different to that one of a zero load reactor, see fig. 1.

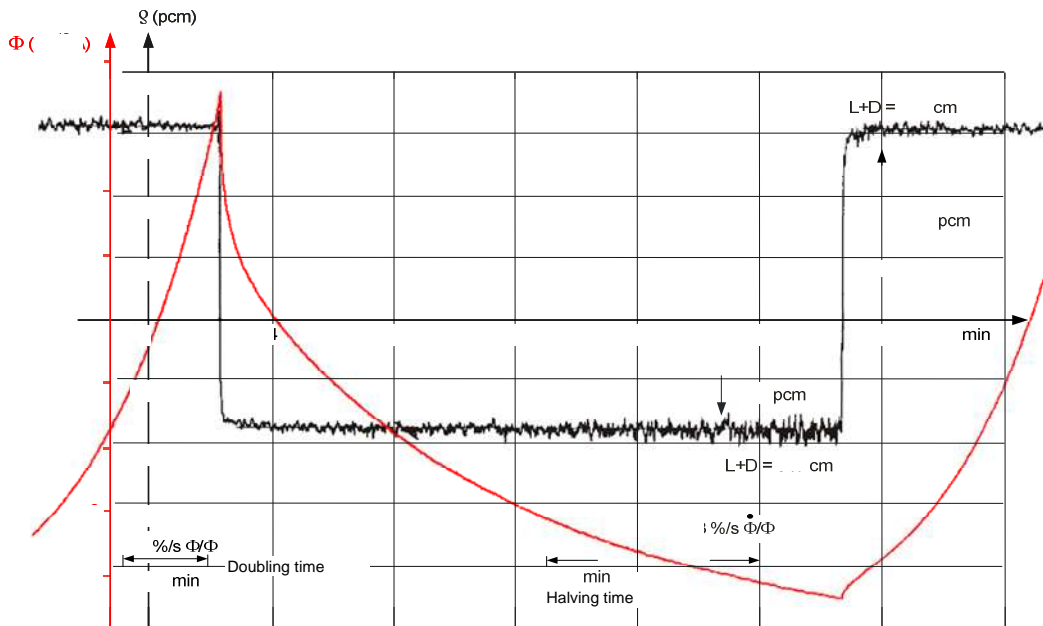


Fig. 1 Kinetic behaviour of the zero load reactor

As a result, during power operation the operators of a nuclear power plant will observe and will have to understand the complex interaction between control rod movements, boron concentration and related reactivity during power load cycles, see for example fig. 2.

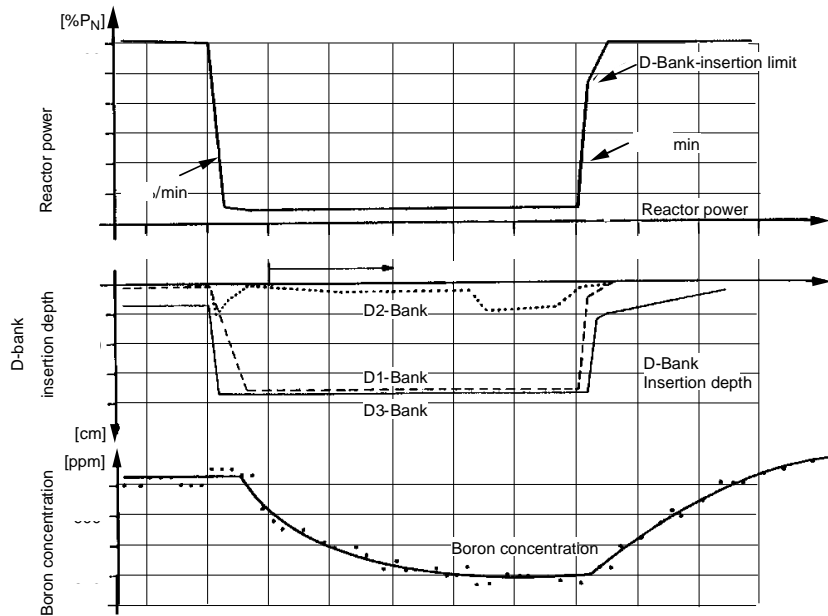


Fig. 2 1300 MW PWR, 1st cycle, 6 hour load cycle

Another example is the layout and design of all operational and safeguard systems of a pressurized water reactor, and how to control them under normal, abnormal and accident situations. In this case the challenge is the understanding and handling of the different interactions of the reactor control, limitation, surveillance, and reactor protection system on a global level as well as on a system specific level.

Consequently, on the system level the design of operational and safeguard systems requires to consider not only the interfaces between all technical disciplines (process, system, layout, civil, electrical and automation), but also the interfaces and correlations with local and global controls, limitations, protection and interlock systems, see fig. 3.

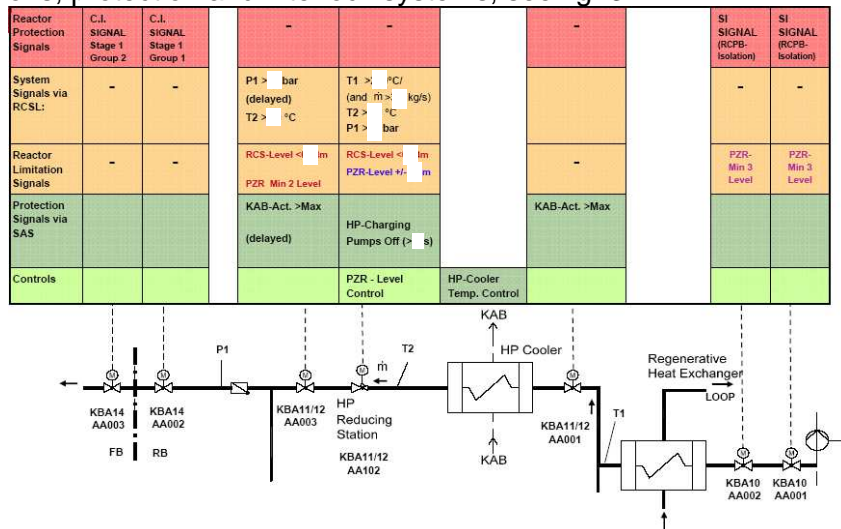


Fig. 3 Main Closing Criteria in the CVCS- Letdown Line

All the issues listed above, as well as the related data, and much more information, are usually only available in industry, so they cannot be addressed during university education. The expertise and competence already available in industry should be consequently properly handled and transferred to new engineers.

3. AREVA'S UNIVERSITY KNOWLEDGE PACKAGE

In order to close the apparent knowledge gap, AREVA's Reactors and Fuel Cycle training center has decided to offer different modules based on the existing stock of standard training courses. All these courses have been designed and developed for the personnel of AREVA's customers, in particular the operating and maintenance personnel, but also engineers and management personnel. Ranging from 1 day to 27 weeks of duration, a variety of detail level is already available.

AREVA's University Knowledge Package thus offers modules on different levels of detail. Level A courses – Introductory Level – may be provided on topics like Overview Nuclear Fuel Cycle / Basics of Nuclear Safety within GEN III+ Reactors / Overview of GEN III+ Reactors / Nuclear Power Plant (NPP) Basics (training duration one day each). They are designed for students in the first years of studies, but depending on the degree to which students are involved in nuclear education, they are also suitable for master, PhD or Postdoctoral degree students.

Level B courses – Technology Level – have been designed for students with a Bachelor and/or Master of Science Qualification within an engineering degree, but are also suitable for Master Programs in Nuclear Engineering. Some examples include Basics of GEN II Pressurized Water Reactor (PWR) and Boling Water Reactor (BWR) / Short Introduction to GEN III+ PWR / Short Introduction to GEN III+ BWR (training duration one week each).

Level C courses – Expert Level – are suitable for professionals taking in account subjects of interest at Master, PhD and Postdoctoral Studies. They include courses on Core Physics and Nuclear Operation Practice / Digital Instrumentation and Control Systems in NPP / Thermodynamics and Thermohydraulics in a Pressurized Water Reactor / Advanced Design features of GEN III+ NPP / PWR Nuclear Instrumentation. The duration may vary from 1 day to 3 weeks, depending on the specific subject.

However, content, expert level, and duration of the various courses are not rigidly fixed. As the courses are structured into different modules and subject topics, a specific offer can be easily constructed. In this manner, specific requirements of a university and a special target group can easily be taken into account, allowing AREVA to provide a customized solution.

4. FIRST EXPERIENCES

As a first example we may report on a training course recently delivered by a trainer of AREVA's Reactors and Fuel Cycle training center.

In the framework of a cooperation agreement that AREVA has signed with a Polish university, it was also decided to deliver seminars to students of the Department of Power and Aeronautical Engineering respectively the Power Engineering Division. After a detailed discussion on objectives and content of an appropriate seminar, and a decision was made regarding the

timing and how to integrate into the current university curriculum, it was agreed to start the cooperation by performing a one week training course on nuclear operation practice.

The course covered the following subjects:

Basics of Neutron Physics / Fuel and Core Design / Plant Overview / Neutron Kinetics of the Zero-load Reactor / Boron Worth / Control Rod Worth / Temperature Coefficients / Xenon and Samarium Reactivity / Reactor Kinetics / Power Density Distribution / Xenon Oscillations.

Based on available standard training courses, this course was specifically designed and composed for the university in question. Training was delivered as lectures in a classroom environment in English. The training material (presentation slides) contained a lot of different data and examples from operating nuclear power plants for the illustration of the different phenomena in an industrial nuclear application.

The training was well received by the students (about 28 people). Feedback collected after the course showed that the students considered it extremely valuable for their future education and professional occupation as engineers with nuclear engineering specialization.

Feedback from the university itself, i.e. the academic staff, concluded that the cooperation and in particular the seminar is very important for the university, allowing their students to have a larger variety of classes and closer contact with the nuclear industry.

In a next step, a further seminar will shortly be delivered to the university, dealing with PWR nuclear instrumentation.

5. CONCLUSIONS

Know-how and experiences of the nuclear industry, delivered within university curricula, and specifically adapted to the education needs of the target group, will significantly contribute to an increased quality level of university education, and help students to better prepare and plan their professional activities within the nuclear industry.

On the other side, it will help nuclear industry to better engage students for the important and challenging tasks within the nuclear energy sector in the next years, and contribute to an enhanced level of safety of nuclear installations as well as a sustainable and economic delivery of nuclear energy.

UNDERSTANDING BY SEEING THERMAL HYDRAULICS USING A GLASS MODEL OF A PRESSURIZED WATER REACTOR

MICHAEL SEEWALD, ESSEN (GERMANY)
*EXPERT LECTURER IN THE FIELD OF THERMAL HYDRAULICS, HEAD OF GLASS MODEL
DEPARTMENT*
KSG KRAFTWERKS-SIMULATOR-GESELLSCHAFT MBH
GFS GESELLSCHAFT FÜR SIMULATORFORSCHUNG MBH
DEILBACHTAL 173
45257 ESSEN (GERMANY)

ABSTRACT

The simulation centre runs a glass model of a two-loop pressurized water reactor using a 1:10 scale. The reactor cooling circuit, pressurizer, pressurizer relief tank as well as the steam generator are made of glass.

Tutorials in the area of operational control strategies, malfunctioning and incidents can be conducted and thermal-hydraulic effects in a nuclear power plant can be shown.

Licensed shift personnel from domestic and foreign nuclear power plants is trained as well as anyone else interested in technology, who would like to see thermal-hydraulic effects.

The official report of the commission appointed by President Carter on the reactor accident on Three Mile Island comes to the conclusion that the accident could have been avoided if the personnel had noticed the open valve on the pressurizer and closed it; the accident in TMI would have been an insignificant event.

We are prepared for a possible event that hopefully never occurs.

The simulation centre

All those who do not know the Essen-based simulation centre of KSG/GfS yet might find some key data and facts taken from our company profile useful to understand what we do:



Figure 1: The simulator centre

Here are some key facts:

Task:	Simulator training for 10 nuclear power plant units
First courses:	1977
Shareholders:	E.ON, RWE, EnBW, Vattenfall, EPZ (NL)
Staff:	145 employees (50 certified trainers/instructors)
Equipment:	8 simulators in operation 1 glass model
Courses:	approx. 400 / year (duration: 4-5 days)
Participants:	approx. 2,000 / year
Investment:	> €350m
Budget:	approx. €26m / year
Certificate:	DIN EN ISO 9001:2008

History of the Glass Model

On 28 March 1979 a serious accident (INES level 5) occurred at the nuclear power plant Three Mile Island (TMI). The Three Mile Island nuclear power plant is located on the identically named island in Susquehanna River in Pennsylvania, USA.

A partial meltdown occurred in reactor block 2, in the course of which about a third of the reactor got fragmented or melted. For a long period of time the shift team was not aware that, even though the filling level of the pressurizer was very high, more than half the core was not covered with coolant anymore.

Poor equipment of the control room as well as insufficient training of the shift team were stated as the main reasons for the accident. [1]

A wise man is able to learn from the misfortune of others.

Martin Luther (1483 - 1546), German theologian and reformer

On 12 October 1981 (3:52am) an emergency power situation occurred in block A of the Biblis nuclear power plant. The plant was shut down in accordance with the operation manual. While lowering the coolant pressure, the pressurizer filling level suddenly increased rapidly. The shift team witnessed a thermal-hydraulic phenomenon never seen before - the pressurizer cap bubble.

Those responsible for the Biblis nuclear power plant had a glass model built in the mid-80's which was capable of demonstrating thermal-hydraulic phenomena.

From 1985 onwards the glass model was used (on average) 40 days a year to demonstrate thermal-hydraulic effects in seminars for domestic and foreign power plant personnel.

The glass model

The glass model is a model of a two-loop pressurized water reactor (KWU production series) with deionized water (deionate) used as a coolant. It generally conforms to a 1:10 scale.

The theory of similarity allows for alterations with regard to the flow velocity and viscosity of the model fluids in a downscaled model of the reactor cooling system to an extent, where the resulting flow velocity equals the flow of reactor cooling systems in nuclear power plants.

This makes it possible - through experiments on a downscaled model with appropriately altered parameters - to make forecasts about the actual performance behaviour / reactions.

The PKL test facility (thermal hydraulics in the primary circuit) in Erlangen is an experimental facility, which is scaled down with regard to the important parameters in view of the theory of similarity.

The reactor cooling system of the glass model including the pressurizer and the pressurizer relief tank as well as the steam generator are almost completely made of borosilicate glass, which is highly temperature and chemical-resistant. We use, due to its obvious advantages, demineralized water as a coolant. The rules of the similarity theory require - if water is used - values regarding the properties of pressure and temperature which are not feasible with glass being used as a material.

The construction of the glass model is not based on the similarity theory!



Figure 2: The glass model

The maximum heat output of the reactor amounts to 60 kW. The maximum temperature inside the reactor cooling system amounts to 130°C, which equals a saturation pressure of 3 bar.

The phenomena observable in the glass model have provably occurred in nuclear power plants or experimental facilities, and can be demonstrated and kept in stable condition by skilfully selecting the frame settings.

A physical process within the original is transferred to a model process within the glass model, not vice versa!

“What is a steam engine?”

“Let’s pretend we are ignorant fools and put it this way: A steam engine is a big black room. It has one hole at the front and one at the back. The first hole is the firebox. The other hole - well, we shall come to that later.”

In the classic movie “Die Feuerzangenbowle” (“Brandy Punch” or “Fire Tongs Punch”), head teacher Bömmel sends his pupils on a mental journey of discovery by describing a steam engine in a more creative way. In a more formalized way, we would say that a heat engine is being explained in a physics lesson - how unromantic!

Most Germans know this movie scene very well. We chuckle and smile at the way Bömmel teaches. According to Vera Birkenbihl [2] we come to the following conclusion: He does it right!

If “dormant” associations inside us are “awakened”, less new subject matter / content needs to be learned and thus, the “effort” for our brain is reduced.

Associations inside us virtually are our resources that we ought to include / activate when learning!

In order to connect new information to our network of knowledge, strings can be attached to serve as mnemonics; these can disappear later on [2].

Now the question remaining is, who bears responsibility for ensuring that knowledge is conveyed and received, that it is incorporated and that it can be recalled later?

In communication theory, it has been assumed for decades that the sender is responsible for ensuring that the message is received and understood.

The sender must choose a language that is understood by the recipient.

"Language" does not only refer to words, of course. The term "language" expressly includes the method, i.e. an approach to systematically integrate new findings into the knowledge network of the recipient, the learner.

Nature offers - via physics - i.e. fluid mechanics in particular, but also via thermodynamics - context and a framework that describes changes of state in a power plant. This is absolutely possible by mathematical formulation. The Navier-Stokes equations are a system of non-linear partial differential equations of secondary order, and can, if the Nabla operator is applied, safely do this in regards to the thermodynamic parameters density, pressure and velocity (in their most generic form).

Interested readers will certainly realize upon first glance that it seems desirable to try and find a method which is easier to understand and possibly even more lively.

We, the glass model team, present thermal-hydraulic effects using our glass model!

The participants of our courses are licensed shift personnel of domestic and foreign nuclear power plants on the one hand, as well as a large number of interested people from all areas of technology on the other.

Staff from specialist departments

Non-licensed shift personnel (specialized craftspeople, shift fitters and shift electricians)

Authorities and expert organizations (Federal and county authorities, GRS [Gesellschaft für Anlagen- und Reaktorsicherheit - German association for facility and reactor safety], TÜV [Technischer Überwachungs Verein - German association for technical inspection])

Students from different subject areas

Participants of special conferences (e.g. "Druckstöße in Rohrleitungen" Haus der Technik - HdT [special event of a German institute on pressure surges in pipes])

Any other interested people (Lions Club, associations, fire brigade)

"Presenting" doesn't mean "performing tricks", it doesn't mean watching the circus with your eyes wide open and being stunned - we explain the observable events in a systematic fashion. Additionally, we always incorporate the background knowledge of the participants. This means we use lively and illustrative examples from our kitchen at home - coffee makers are used with particular pleasure - whenever necessary using background knowledge from mathematics and physics.

You quite rightly ask yourself "coffee maker?" Sure! As almost all thermal-hydraulic phenomena occurring in atomic power plants can be found in domestic kitchens, from the pressure cooker and the milk watcher to the coffee maker. If you've become curious, why don't you come and visit us?

Our courses are conducted in German and English.

The move

In 2002 investments were due for the glass model in Biblis. The "Siemens S5" control system had to be replaced. At the location of the Biblis nuclear power plant it was decided that the investment required, which amounted to several €100,000 would not be made any more.

But what should become of the glass model now? By decision of the supervisory board of KSG/GfS, the glass model was integrated into the simulator centre. Concrete ceilings were removed, new ceilings cast, fire protection areas defined, the air conditioning system reconstructed and - last but not least - upgrades for the glass model were installed to improve safety and broaden the thermodynamic spectrum.

A new control cabinet including the adaptation to the Siemens PCS7 control system was installed. The safety and availability of the glass model was improved through the installation of additional control equipment. Apart from the controls and mechanical safety valves, limitation systems were installed which protect the model from extreme conditions and overloads. Additional motor-operated valves as well as a condenser cooler with 9°C cold water have eased the operability and increased the cool-down speed significantly to 50K/h.

The seminar room is protected from the glass model by a 50 mbar pressure resistant anti-splinter screen and offers the possibility to monitor the condition of the model and the trends of selected status parameters at any time using three wide-screen projectors.

The total investment for the move and the upgrade of the glass model has so far amounted to €1m. Further upgrades to improve the observability of phenomena are scheduled for 2012 and 2013.

The language the glass model speaks has been and still is worth its price. This is the joint opinion of nuclear power station operators in Germany, the Netherlands, Switzerland and Belgium.

The team

The term “glass model team” has already been used in the previous paragraphs. During a seminar, this team is formed by an instructor and a technician. The instructor is an experienced engineer in simulator training. Besides extensive knowledge in the field of power plant engineering, which is comparable to that of a shift supervisor in a nuclear power plant, our trainers have the methodical and didactical abilities to breathe life into thermal hydraulics. The technician is a trained boiler attendant and he operates the model.

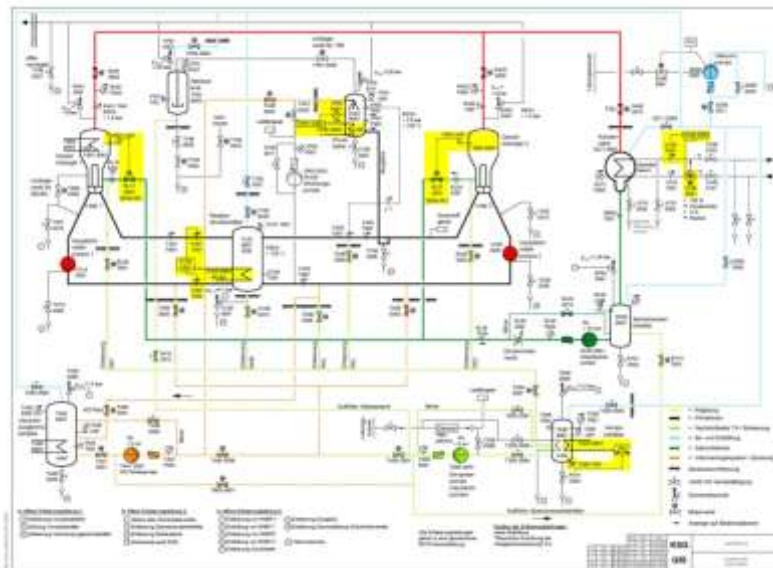


Figure 3: System circuit diagram of the glass model

The technician represents the entire operators team of our small power plant “Glasmodell”. He heats up the reactor cooling system in the morning, degases the coolant (non-condensable gases are particularly troublesome at pressure levels <math><1\text{ bar}</math>) and he supports the trainer during various exercises.

The exercises are described and set in the framework of power plant-specific control scenarios. The entire team consists of two instructors and two technicians and can be supported by the staff of the simulator centre if required.

Training areas and modules

Using the glass model, tutorials in the area of operational control strategies, malfunctioning and incidents can be conducted and thermal-hydraulic effects in a nuclear power plant using a pressurized water reactor can be shown.

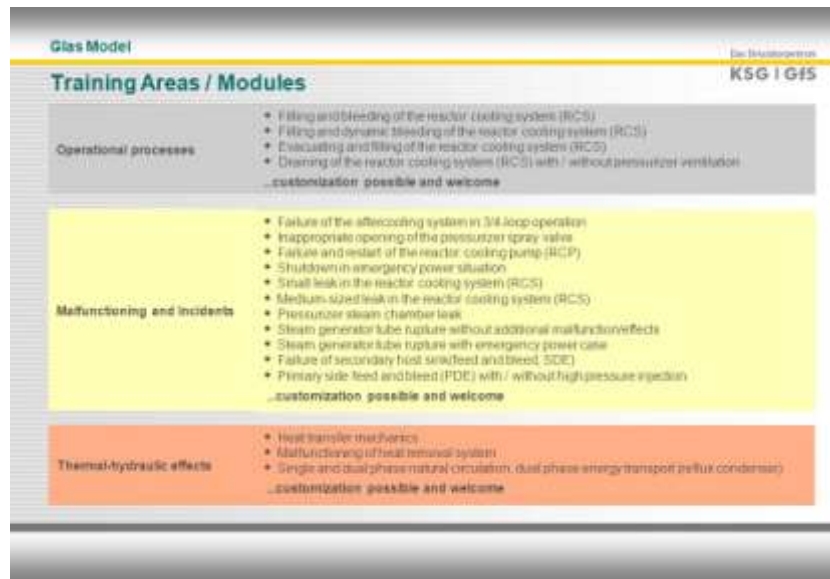


Figure 4: Training areas / modules at the glass model

Phenomena which require special operational control were developed for nuclear power plants in the Netherlands, Switzerland, Belgium and Finland and have successfully been applied in our seminars.

The following phenomena can occur in a nuclear power plant with a pressurized water reactor:

- Single phase natural circulation
- Dual phase natural circulation
- Dual phase energy transport (reflux condenser)
- Water hammers in the loop pipes
- Separation of water differing in density
- Convective heat transfer
- Subcooled boiling
- Nucleate boiling

Special phenomena occurring in nuclear power plants with pressurized but also with boiling water reactors are:

- Cavitation
- Problems cooling the pressurizer dome (pressurizer cap bubble)
- Evaporation within hot pipes
- Cold water bag
- Blow-down of chilled water receiver at different temperatures until boiling
- Flashing
- Cold creeping flows in hot pipes
- Suction vortices



Figure 5: A steam generator during secondary side depressurization (SSD)

The phenomena are not limited to one single reactor type and they are by no means complete.

Even nuclear power plants with boiling water reactors greatly appreciate the visualization possibilities of our glass model and use them frequently. Using the glass model, special courses for nuclear power plants with boiling water reactors are conducted, and the phenomena are adapted to the operation of boiling water reactors using exemplary operation control strategies.

The courses

Courses around the glass model are becoming more and more popular and required. Whilst courses in Biblis were limited to special courses, one or several-day courses including start-up process and shut down, additional and supplementary seminars take place at the simulator centre as well. These trainings at the glass model take place during the seminar room times of the simulator training (one simulator training usually consists of four hours at the simulator and four hours in the seminar room). In other words:

In the morning a steam generator tube rupture can be run according to the operator's manual at the power plant-specific simulator, and in the afternoon the shift team can "see" the same tutorial at the glass model.

The simulator centre offers special courses (1 to 4 days) at the glass model. Furthermore, "simulator accompanying courses" for the purposes of initial training, repeat trainings and special training courses can be planned at any time.

On average, we conduct more than 130 course days (90 days plus 40 days of summed up simulator course accompanying training) on 180 calendar days each year.

Conclusion

A clear trend is noticeable: Not only licensed shift personnel is trained at the glass model. It has become increasingly important for power plant operators to train the entire technical staff.

The physical context and reactions must be understood, even though a worker's personal contribution to a safe operation of the power plant might be negligibly small.

The official report of the commission appointed by President Carter on the reactor accident on Three Mile Island comes to the conclusion that the accident could have been avoided if the personnel had noticed the open valve on the pressurizer and closed it; the accident in Three Mile Island would have been an insignificant event.

Through our seminar at the glass model we make a contribution to demonstrating the complex phenomena of thermal hydraulics in a lively fashion, so that the shift personnel is prepared for a possible event that hopefully never occurs.

[1]Der Unfall von Harrisburg - Der offizielle Bericht der von Präsident Carter eingesetzten Kommission über den Reaktorunfall auf Three Mile Island. Erb Verlag, Düsseldorf 1979, ISBN 3-88458-011-6

(Documentary book on the incident in Harrisburg)

[2] Wer agiert als LEHRKRAFT? Jeder Mensch, der Dinge erklärt...

von Vera F. Birkenbihl

(Who acts as a teacher? Everybody who explains things...by Vera F. Birkenbiehl)



European Nuclear Society
Rue Belliard 65
1040 Brussels, Belgium
Telephone: +32 2 505 30 50 - FAX: +32 2 502 39 02
enc2012@euronuclear.org
www.enc-2012.org