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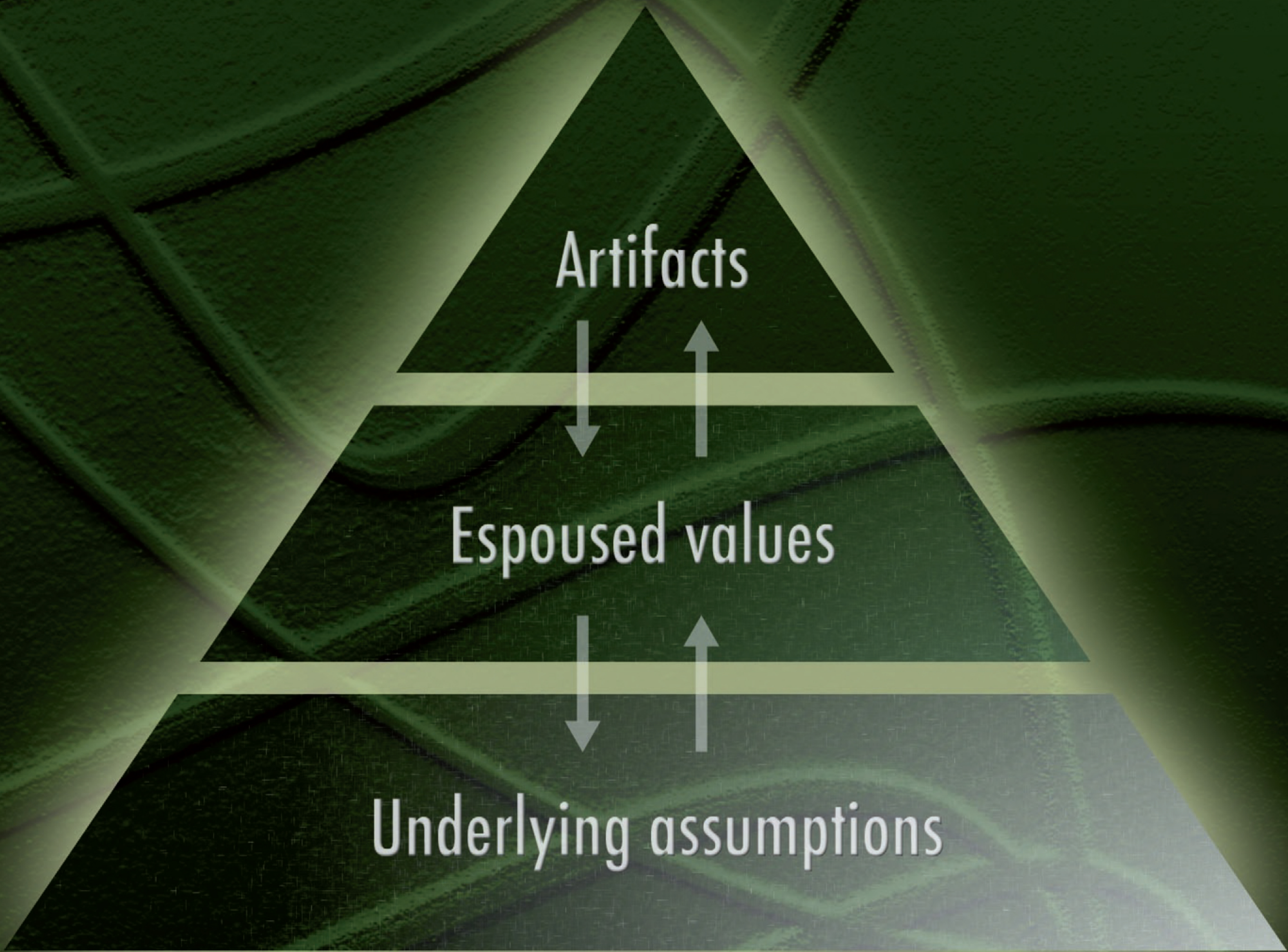

Safeguards culture?

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ESARDA
European Safeguards Research and Development Association

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Editorial

Change

K. Axell
Chairperson

We live in a world of constant change: there is even a president who won a recent election on that motto. Maybe we could now foresee a change regarding the nuclear arsenals in the world.

Ever since the formation of the NPT, Nuclear Weapon States have been held by the obligation not to proliferate nuclear weapons technology. On the other hand, Non-Nuclear Weapon States parties to the NPT have agreed not to manufacture or acquire nuclear weapons. This has been successful, as the number of States that hold nuclear weapons has not increased much over the years. There are even examples of States that have had programmes but by outside (and domestic) pressure abandoned such ideas. Since the ratification of the NPT, the number of nuclear tests has constantly decreased. After more than 40 years, the treaty is still alive and kicking.

Part of the NPT calls on the Nuclear Weapons States to reduce their number of warheads as a step towards nuclear disarmament. So far, the NPT has not been so successful in that respect. Even though the number of countries that has acquired nuclear weapons is much lower than the worst case scenarios, every new country that does, or tries to acquire nuclear weapons, is a threat to the NPT and international peace and security. It is therefore timely that the aforementioned president has taken steps towards a reduction of nuclear stockpiles, as the first US president to promote disarmament with a reference to the NPT and concerns over nuclear parity. This initiative is an important change as it demonstrates to the rest of the world a willingness to adhere to the NPT. It will not be easy, but in a world of constant change this is a necessary step to take towards a world free from nuclear threat.

One article in this Bulletin concerns Safeguards Culture: Lessons Learned, by Frazar and Mladineo. In it, the authors propose a metric for evaluating a country's non-proliferation posture. This can be a valuable tool for discussing actions and priorities.

On a personal note, 2010 means change for me. I started out the year being appointed vice-chair for the ESARDA Editorial Committee, and a few months later I find myself succeeding Bruno Autrusson. Bruno is leaving for new challenges and he has really done an excellent job for ESARDA, which we all are indebted to him for.

Also, 2010 brought a new organisation for research at my workplace, the Swedish Radiation Safety Authority (SSM). Since the formation of this new authority, with responsibility for all matters concerning radiation (described in detail in Bulletin nr. 43) the organisation has struggled to meet the research challenges of today. The new organisation that will be in effect from July 1, 2010 will strengthen SSM in this endeavour.

ESARDA News

The Central Analytical Laboratory Activities Related to Analysis of Nuclear Material, Nuclear Safeguards and Forensics

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Abstract

The report introduces the Central Analytical Laboratory of Nuclear Research Institute Řež plc and describes research and services related to analysis of nuclear material, nuclear safeguards and forensics.

Keywords: analysis; nuclear material; environmental sample; safeguards.

1. Introduction

The Nuclear Research Institute Řež plc. (NRI) is a research organization with more than fifty years of experience in research and development activities, design and engineering services and technical engineering. Its services for the Czech State Office for Nuclear Safety and nuclear power plants play a considerable role in ensuring safe plant operation, efficient use of the nuclear fuel cycle and safety in radioactive waste management. All NRI activities are based on a high quality standard and professional capability of its personnel, strict compliance with legal requirements, safety of all operated equipment and an environment-friendly approach.

1.1. Institute mission

The dominant mission of the NRI is to remain a key technical engineering and research organization contributing to the development of a long-term sustainable power supply in the Czech Republic. Further missions of the NRI are to significantly participate in European energy research, to use its knowledge for serving customers in the European Union (EU), and to transfer its energy-related knowledge into other industry sectors within the EU.

2. Central Analytical Laboratory

The Central Analytical Laboratory (CAL) as an analytical section of chemistry of the nuclear fuel cycle and waste treatment division is an accredited laboratory for nuclear, radioactive and environmental materials analysis. Since 1975, CAL has provided nuclear material analysis for the Czech Safeguards Laboratory and collaborated with the Seibersdorf Laboratory – the member of International Atomic Energy Agency´s Network of Analytical Laboratories.

In the area of nuclear and radioactive materials, CAL performs: forensic analysis of materials of unknown origin (determination of material origin, chemical composition, structure, material age and impurities), destructive analytical procedures for the detection of undeclared nuclear activities in soils and sediments, analysis of swipe samples from nuclear power plants for the determination of radionuclides and undeclared nuclear activities, and, finally, destructive analytical procedures for nuclear fuel burn-up determination.

For purposes of waste management and environmental pollution control CAL performs the determination of U and Th as well as of isotopes from natural radioactive families in soil and sediment samples; furthermore, the determination of ^{210}Pb, ^{210}Po, ^{228}Th, ^{230}Th, ^{231}Pa, and ^{226}Ra in samples related to decommissioning of U ore processing technology, waste management and tailings management technology. In the frame of nuclear power plant operation and their decommissioning CAL determines long-lived nuclides in waste produced by nuclear power facilities including ^{14}C, ^{41}Ca, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc, ^{129}I, ^{137}Cs, ^{239}Pu, and ^{241}Am. With regards to soil and sediments, CAL determines the transuranium elements $^{239+240}$Pu, ^{241}Am, and, in nuclear power plant effluents, tritium and ^{14}C, respectively.

3. Safeguards research and development

In the second half of the 1990s, within the IAEA Project entitled “Special Analytical Methods for Determination of Traces Radioactivity and Detection of Undeclared Nuclear Activities”, basic procedures were prepared for the determination of selected isotopes of the spontaneous disintegration series in nuclear materials, in water, sediments and technological waste solutions after the uranium ores mining and for age determination of uranium and plutonium materials based on the $^{230}Th/^{234}Th$, $^{226}Ra/^{234}U$ and $^{241}Am/^{241}Pu$ pairs.

3.1. Response to illicit trafficking

In 1998, the PHARE PH5.01/95 project, “Assistance in setting up special analytical services including a data bank for analysis of radioactive substances and nuclear materials of unknown origin” was started. The project was funded under the European Commission’s PHARE Programme. The activities were carried out at the NRI Central Analytical Laboratory under the co-ordination of the European Commission Joint Research Centre “Institute for Transuranium Elements” (ITU) in Karlsruhe.

In the framework of this PHARE project, the corresponding analytical capabilities of the CAL have been substantially upgraded.

At the request of state authorities it is now possible, after categorization by standard isotopic measurements, to perform a rapid precision measurement of impurity content in nuclear material of unknown origin.

This upgrade has been successfully applied to complementary measurements of nuclear material stored at CAL and material previously seized in the Czech Republic.

Analysis of highly enriched material, seized in the Czech Republic in 1994 (URAN-A), was continued at the ITU within the framework of the PECO Project TOR entitled “Support on Combatting Illicit Trafficking of Nuclear Materials”.

The results of the determination of selected impurities found in UO2-type HEU and LEU pellets, material for mass spectrometry and seized material were presented.

The age determination of U bulk samples was also performed by scientific staff of CAL.

In the area of nuclear material forensics the Central Analytical Laboratory collaborates with the State Office for Nuclear Safety and with the police of the Czech Republic.

4. Quality management system

The NRI Řež has implemented the Integrated Management System including Quality Management System according to ČSN EN ISO 9001:2008, Environmental Management System according to ČSN EN ISO 14001:2004, Occupational Health and Safety Management System according to OHSAS 18001:2007, and Quality Management System of the testing laboratories according to ČSN EN ISO/IEC 17025:2005.

4.1. Certificate of accreditation

The Central Analytical Laboratory – the testing laboratory of the NRI Řež was certified for the first time by the Czech institute for accreditation in June 2001. The accreditation certificate was issued on the basis of fulfilment of the accreditation criteria in accordance with ČSN EN 45001.

In August 2009, the laboratory was awarded the new accreditation certificate No. 493/2009 according to ČSN EN ISO/IEC 17025:2005. The scopes of accreditation are: determination of radionuclides for monitoring of operational safety of nuclear facilities, determination and monitoring of radioactive, toxic and other elements (isotopes) in environment and of samples of natural materials and analyses of samples of gases and biomass.

4.2. Interlaboratory comparisons – proficiency testing

Participation in proficiency testing is a valuable continuous improvement tool for external assessment of the CAL quality system.

In 2001, NRI CAL participated in the second interlaboratory comparison (Round Robin) exercise, organized by the Nuclear Smuggling International Technical Working Group (ITWG), oriented towards forensic analysis of a selected highly enriched uranium sample. CAL findings were presented in corresponding reports.

From 2002 onwards, NRI CAL participated successfully in the EQRAIN experiments (U No. 11, 12, Pu 10) organized by CETAMA (France).

33rd ESARDA ANNUAL MEETING: CALL FOR PAPERS

Helia Conference Hotel, Budapest, Hungary, 16-20 May, 2011

The 33rd ESARDA Annual Meeting will be a symposium on "Safeguards and Nuclear Material Management", held in Budapest, Hungary, on May 16-20, 2011.

The symposium will be an opportunity for research organisations, safeguards authorities and nuclear plant operators to exchange information on new aspects of international safeguards and non-proliferation, as well as recent developments in safeguards-related research activities and their implications for the safeguards community.

The symposium is anticipated to include a number of contributions from internationally-renowned authorities in the field.

Information about abstract submission, venue and registration can be found at www.esarda.eu.

Draft programme

The following themes will give **direction** to the symposium:

- Integrated safeguards and a changing Europe
- Euratom safeguards in a global context
- Non-proliferation and export control
- nuclear security and safeguards

Contributions may cover but are not necessarily limited to the following **topics / disciplines**:

- Safeguards concepts (policies, perspectives, limitations, Strengthened and Integrated Safeguards, State and Regional Systems, Quality Assurance Approach)
- Euratom system: Beyond State level approach (European Union level approach)
- Nuclear safeguards implementation: experience, evaluation; plant specific experience on techniques, inspections and operations
- Experience in the implementation of Strengthened Safeguards systems and Integrated Safeguards
- Non-proliferation and future issues (Fissile Material Cut-off Treaty, CTBT and disarmament, excess materials, sub/cross-national threats, etc.)
- Export control (and related activities)
- Synergies with other verification regimes (radiological, chemical, biological, dual use, etc.)
- Containment and surveillance methods and techniques; interface between safeguards and physical protection methods
- Co-operative programmes in safeguards;
- Human resources and knowledge management issues including public information
- Measurement techniques and standards
- Data and information evaluation methodology, remote monitoring and secure data transmission
- Integrated measurement and monitoring systems
- Materials control and accounting, auditing and information systems
- Illicit Trafficking and border controls
- Response to safeguards and security related events
- Applications of GPS and GIS and information security

Presentations with original content are strongly encouraged.

Abstract submission deadline: 21st November 2010

By sending an abstract, the authors confirm having their organisation's approval for public release and agree to submit a paper suitable for inclusion in the symposium's proceedings and to present that paper at the symposium.

To submit their abstract(s) for review, authors are requested to consult the ESARDA web-site at www.esarda.eu where they will find the *"instruction for authors"*.

The abstracts must be written in **English** and have the following format:

- title, author(s), affiliation;
- a maximum length of about 300 words to be used for paper selection (maximum 1 standard page);
- **a maximum of 5 keywords related to the topic(s) of their paper.**

The author(s) may already indicate whether they would like to present their contribution orally and/or as a poster. The Technical Programme Committee will decide on the acceptance of contributions, allocating between paper and poster sessions. The notification of acceptance and the draft programme will be communicated by mid January 2011.

The compendium of the accepted abstracts will be available on the ESARDA website.

Papers submission deadline: April 30 2011

Full contributions must be submitted electronically as indicated on the web-site.

The proceedings will be published shortly after the meeting and a copy sent to each participant.

The Editorial Committee reserves the right to decline to accept any abstract or paper submitted after the deadline.

Information on the Symposium

Registration opened from Dec. 1st 2010.

Early registration fees
December 1st 2010 – January 31st 2011: 550 Euro

Registration fees
January 31st – April 15th 2011: 650 Euro

Deadline for registration April 15, 2011.

Registration forms, a copy of the programme and updated information about the meeting will be available on the ESARDA web-site:

www.esarda.eu

Adequate space can be arranged for commercial presentations / exhibitions. For further information including commercial displays, please contact directly the symposium secretariat esarda2011@jrc.ec.europa.eu

Symposium on International Safeguards

Preparing for Future Verification Challenges

1–5 November 2010
Vienna, Austria

Organized by the

IAEA
International Atomic Energy Agency

In cooperation with

INMM — INMM, Institute of Nuclear Materials Management

ESARDA — ESARDA, European Safeguards Research and Development Association

www.iaea.org/meetings
CN–184

Symposium on International Safeguards: Preparing for Future Verification Challenges

In November 2010, the International Atomic Energy Agency (IAEA) hosts an international safeguards symposium, in cooperation with the European Safeguards Research and Development Association (ESARDA) and the Institute of Nuclear Materials Management (INMM). The purpose of this event is to foster dialogue and information exchange between the IAEA and experts from Member States, the nuclear industry and the broader nuclear non-proliferation community. The focus of this year's symposium is how best, from a technical perspective, to prepare for future verification challenges during this time of change.

The nuclear landscape is evolving, offering both challenges and opportunities to the IAEA and its Member States. Global interest in nuclear power generation is increasing. This expansion will bring additional nuclear activities, facilities and more nuclear material under safeguards around the globe. It also suggests growing international nuclear cooperation and trade in nuclear and related equipment, items and materials. All this is likely to significantly increase the IAEA's safeguards activities.

With technological progress, the IAEA will need to be prepared to safeguard new, more advanced and larger scale nuclear fuel cycle facilities. At the same time, future nuclear technology and facilities may be designed to be more proliferation resistant and safeguards friendly. Scientific and technological progress can also help improve the evaluation of information and enhance detection capabilities, as well as provide further opportunities to improve both safeguards implementation and organizational effectiveness and efficiency.

As the world gives more attention to nuclear disarmament, so the IAEA may also be requested to take on further verification tasks, for example, in relation to fissile material declared as excess to defence requirements.

Of course, just as it rightly considers challenges yet to come, the IAEA will still need to continue addressing those it already faces today. In recent years, a number of developments have tested the nuclear non-proliferation regime and have led to increasing expectations of the IAEA safeguards system. Proliferation risks related to globalisation — such as covert supply of nuclear and related technology as well as the greater availability of proliferation-sensitive information — are likely to grow.

All these developments highlight the evolving nature of the IAEA's operating environment and the importance of adapting to change and continually improving both the effectiveness and the efficiency of the safeguards system. By bringing together the leading experts in the field from across the world, the 2010 safeguards symposium aims to provide an opportunity for stakeholders jointly to explore possible solutions to the various current and future challenges outlined above in support of the IAEA's nuclear verification mission.

7th ESARDA Course on Nuclear Safeguards and Non Proliferation

ESARDA Working Group on Training & Knowledge Management

1. Origin of the course

The knowledge retention problem in the nuclear field was acknowledged by the OECD in 2000. The United Nations study on disarmament and non-proliferation education (2002) made detailed recommendations for urgently required improvements. ESARDA, the European Safeguards Research and Development Association reacted to these shortcomings with a strategy to tackle the problem and created a Working Group on Training and Knowledge Management (ESARDA WG TKM). The final objective of the ESARDA WG TKM is the setup of academic course modules to an internationally recognised reference standard.

This project is in line with the movement of establishing a European curriculum for Nuclear Engineering. Teaching in the Nuclear Safeguards field is indeed strongly influenced by national history so the objective of the course is to provide homogeneous material in Nuclear Safeguards and Non-Proliferation matters at the European and international level.

2. Learning objectives

This compact course is open to master degree students, in particular nuclear engineering students, but also to young professionals and international relations/ law students. It aims at complementing nuclear engineering studies by including nuclear safeguards in the academic curriculum.

The basic aim of the course is to stimulate students´ interests in safeguards. The course addresses aspects of the efforts to create a global nuclear nonproliferation system and how this system works in practice: the Treaty on Nonproliferation of Nuclear Weapons (NPT), safeguards technology, and export control. Also regional settings, such as Euratom Treaty, are presented and discussed. The course deals particularly technical aspects and application of safeguards; i.e. how to implement the safeguards principles and methodology within the different nuclear facilities. Therefore the course will create an overview on inspections techniques, ranging from neutron/ gamma detectors, to design information verification, to environmental sampling, etc.

3. Course content

Introduction: The evolution of the Non Proliferation Treaty -regime, safeguards, international control regimes in theory and practice, and present trends in the nuclear nonproliferation efforts.

What is safeguarded: Definition of nuclear material that is subject to nuclear safeguards and related safeguards goals (significant quantity, timeliness and detection probabilities).

Where is it found: Description of the nuclear fuel cycle from mining to final repository, focusing on enrichment in the front-end and reprocessing in the back-end.

Which legal protection means exist: Overview on international and regional Non-Proliferation Treaties and established Institutions and Organizations.

What is the methodology to verify: Nuclear material accountancy principles and statistics for auditing.

How are inspections performed: Overview on inspector tools and their use to verify the nuclear activities as declared under the safeguards agreements (Non Destructive Assay, Monitoring, Containment/ Surveillance); additional safeguards measures under the Additional Protocol (complementary access, satellite imagery, environmental sampling) and how they are applied in field (storage facility, process facility, enrichment facility, research institute, spent fuel transfer).

How to control Import/ Export: Guidelines of the Nuclear Suppliers Group, trigger list and dual-use list. Means to combat illicit trafficking, inclusive nuclear forensics.

What additional information offers: Collection of open source data and demonstration of some case studies (Iraq, 1993).

4. Practical organization

The course features a full five-days program with 1h lectures by experts in the field of nuclear safeguards. The program foresees every day a visit to one of JRC's safeguards laboratories and/or a classroom exercise.

The course material, consisting of a complete set of presentations and literature will be provided to the participants. It is recommended that the students prepare themselves with the reading material on the website.

For this limited enrolment course early registration is recommended. A numerus clausus of 60 is introduced. Under the website:

http://esarda2.jrc.it/internal_activities/WC-MC/Web-Courses/index.html

you find the registration form that has to be completely compiled and sent to:

JRC-NUSAF-SECRETARIAT@ec.europa.eu

before the deadline of 31st December 2010. University students can apply for accommodation free of charge, but only a limited number of places per university are available. Travel costs are not reimbursed by the JRC.

There is no course fee; lunches are offered free of charge.

All participants are encouraged to make an essay on a given topic selected from the list, which is handed out at the end of the course. Up to 2 best essays can be selected for being published in the ESARDA Bulletin or for being presented in the poster session at the next ESARDA Symposium.

Students can include this course, recognised by BNEN/ENEN for 4ECTS, in their academic curriculum. To be quoted for this course an additional Take-Home-Exam is foreseen.

Venue: JRC Ispra, Building 36, Amphitheatre

Schedule: From Monday, March 28th, 2011 at 8:30
till Friday, April 1st, 2011 until 17:00

5. Pool of Course Lecturers

Y. Aregbe is responsible for analytical methods for nuclear material measurements at JRC Geel (IRMM)

J. Baute joined the IAEA in 1994 and became director of Iraq's Nuclear Verification Office. Presently he is director of the IAEA Safeguards Information Management Directorate.

P. Daures worked as a nuclear engineer 10 yr at the CEA. He joined the JRC' Karlsruhe in 1994 to setup the OSL Lahague/ Sellafield, moved to Ispra as TACIS coordinator.

D. Dickman joined the Pacific Northwest National Laboratory in 1985, and is currently manager for Non proliferation and Global Threat Reduction Program.

N. Edmonds is responsible for non-destructive assay at the British Nuclear Decommissioning & Waste Authority

P. Funk is since more than 10 years involved in French and international safeguards as leader of C/S lab at IRSN.

D. Grenèche is assistant director of Research and Innovation (formerly COGEMA: Companie Générale des Matières Nucléaires) of AREVA.

M. Hunt has been Nuclear Safeguards inspector of IAEA for the CIS, and is presently IAEA training coordinator.

O. Jankowitsch is head of the IAEA Office of External Relations and Policy Co-ordination, & Office of the IAEA Director General.

W. Janssens joined the EC in 1995 as nuclear inspector analyst for La Hague and Sellafield. He is presently head of the nuclear security unit at IPSC JRC Ispra.

T. Jonter is heading the Department of Economic History at the Stockholm University, leading educational programs on Nucl. Non proliferation at diff. univ. in former Soviet Union.

M. Kalinowski is director of the Carl-Friedrich von Weizsäcker Center for Science & Peace Research at the University of Hamburg and works for the Prep. Com. of the CNTBT organization .

G. Maenhout joined in 2001 the nuclear safeguards unit at JRC Ispra and is part of the Belgian Nuclear Engineering teaching committee.

Q. Michel is Professor in European Studies and President of the Department of Political Science of Liège University.

M. Oddou of the Commissariat d'Energie Atomique is responsible for the follow-up of the EURATOM regulations in France.

P. Peerani leads the physical modeling (e.g. Monte Carlo) for nuclear measurements (NDA, solution monitoring) at JRC Ispra with experience as analytical inspector.

L. Rockwood joined in 1985 the Office of Legal Affairs of the IAEA and is Section Head for Non-Proliferation and Policy Making Organs.

P. Schwalbach joined the EC as EURATOM inspector in 1992 and is heading the logistic support for nuclear material verification.

M. Tarvainen is heading the Nuclear Trade Analysis Unit (NUTRAN) at the Department of Safeguards.

M. Wallenius works on destructive assay measurements and is responsible for nuclear forensics at JRC Karlsruhe (ITU).

News from the Association

F. Sevini
ESARDA Secretary

The latest Steering Committee meeting on May 3rd, 2010 in Luxembourg was attended for the first time by the National Atomic Energy Agency of Poland (PAA), new Party to ESARDA, and took a series of decisions.

After 40 years of success, ESARDA is attracting more and more interest, and for the first time in its history, the Steering Committee had to vote to choose its new ESARDA vice-President! The two official candidates were Lucian Biro (CNCAN, Romania) and Klaas van der Meer (SCK-CEN, Belgium), who was voted by the majority of the attending Parties.

On January 1st, 2011 he will replace Kristof Horvath (HAEA, Hungary), who will become the new ESARDA President, taking over from Elina Martikka (STUK, Finland).

The Steering Committee also welcomed and approved the following new ESARDA individual members, who have all contributed to the success of the association over the years:

- Marc Cuypers
- Goran Dahlin
- Gottard Stein
- Bernd Richter

Michael Franklin was proposed and nominated Honorary Member of ESARDA.

The ESARDA Executive Board composition has been decided as follows:

Until Dec. 31st , 2010	From January 1st 2011
André-Turlind E. (SSM, Sweden)	André-Turlind E. (SSM, Sweden)
Boella M. (EC ENER Luxembourg), Observer	Boella M. (EC ENER Luxembourg), Observer
Horváth K. (HAEA, Hungary), ESARDA vice-President	Horváth K. (HAEA, Hungary), ESARDA President
Janssens W. (EC JRC IPSC)	Luetzenkirchen K. (EC JRC ITU)
Joly J. (IRSN, France)	Richard M. (CEA, France)
Korbmacher T. (WKK, Germany)	Korbmacher T. (WKK, Germany)
Martikka E. (STUK, Finland), ESARDA President	Stanley B. (Sellafield Ltd, UK)
Sevini F. (EC JRC IPSC), ESARDA Secretary	Sevini F. (EC JRC IPSC), ESARDA Secretary
van der Meer K. (SCK-CEN, Belgium)	van der Meer K. (SCK-CEN, Belgium), ESARDA vice-President

The Executive Board met to approve the list of Chairs and vice-Chairs of ESARDA Working Groups for the period 2010-2011 after rotation within some WGs:

Working Group	Chair	Vice-Chair
C/S	J. Goncalves (EC JRC IPSC)	P. Funk (IRSN, France)
DA	Y. Aregbe * (EC JRC IRMM)	J. Tushingham * (NNL, UK)
Editorial Committee	K. Axel (SSM, Sweden)	t.b.d.
IS	A. Rezniczek (Individual member)	A. Vincze (HAEA, Hungary)
NA/NT	H. Toivonen (STUK, Finland)	J. Wichello, acting (IAEA)
NDA	P. Peerani (EC JRC IPSC)	A. L. Weber (IRSN, France)
TKM	T. Jonter (Stockholm University – representing SSM, Sweden)	M. Marin-Ferrer (EC JRC IPSC)
VTM	M. Richard (CEA, France)	G. Stein (Individual member)

** Decision taken after the meeting, to be formally approved by the Executive Board*

All WGs are invited to nominate more contributors to the Editorial Committee. A new vice-Chair will be chosen at the next meeting.

NMAC AG (Chaired by R. Weh) and FFP WG (Chaired by B. Stanley) have reached their goals. The related implementation activities will be dealt with by the IS WG, whose terms of reference will be redefined accordingly.

Peer reviewed section

Safeguards Culture: Lessons Learned

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Abstract

After the discovery of Iraq's clandestine nuclear program in 1991, the international community developed new tools for evaluating and demonstrating states' nuclear intentions. The International Atomic Energy Agency (IAEA) developed a more holistic approach toward international safeguards verification to garner more complete information about states' nuclear activities. This approach manifested itself in State Level Evaluations, using information from a variety of sources, including the implementation of integrated safeguards in Member States, to reach a broader conclusion. Those wishing to exhibit strong nonproliferation postures to a more critical international community took steps to demonstrate their nonproliferation bona fides. As these Member States signed and brought into force the Additional Protocol, submitted United Nations Security Council Resolution 1540 reports and strengthened their export control laws, the international community began to consider the emergence of so-called safeguards cultures. Today, safeguards culture can be a useful tool for measuring nonproliferation postures, but so far its impact on the international safeguards regime has been underappreciated. There is no agreed upon definition for safeguards culture nor agreement on how it should be measured.

Keywords: safeguards culture; culture metrics; international safeguards; safeguards evaluation.

1. Introduction: the development and value of safeguards cultures

In this paper we argue that a clear definition of safeguards culture coupled with a definitive set of metrics can be used to evaluate and demonstrate a country's nonproliferation posture. We briefly review a set of theoretical models of organizational cultures to structure the discussion regarding the role culture plays in international safeguards. Next, we suggest a definition for safeguards culture and propose a set of metrics for evaluating its existence within nation states. Finally, we discuss the utility of these models and demonstrate how the concept of safeguards culture can contribute to the evaluation of a country's nonproliferation posture.

Before the first Gulf War, the International Atomic Energy Agency's (IAEA) verification responsibilities were constrained by the conditions and authorities outlined in various legal documents, including the Treaty on the Nonproliferation of Nuclear Weapons (NPT), the IAEA statute and Model Safeguards Agreements Information Circulars (INFCIRC) 153 and 66. According to these documents, the IAEA's responsibilities in the area of safeguards were to detect the diversion of nuclear materials in declared locations from peaceful uses to military purposes. The IAEA did not have the authority, except in special circumstances, to investigate possible undeclared nuclear movements or other clandestine nuclear activities. This limited mandate left gaps in the IAEA's knowledge about a country's nuclear activities, allowing Iraq to develop a clandestine nuclear program in parallel with its declared nuclear program.

Recognizing the impact these gaps had on the agency's safeguards conclusions, the IAEA sought new tools to evaluate a state's nuclear intentions. It took steps to tighten the fabric of information that could be gathered about a country's nuclear activities. One major step in this evolution was the development of the Additional Protocol (AP), which augmented the IAEA's existing authorities and established new ones, expanding the types and amount of information that could be gathered about a country's nuclear program, increasing the potential of uncovering undeclared activities. With new information coming from a variety of sources such as satellite imagery, wide area environmental samples, and open sources, the agency could look beyond declared activities to develop a more complete picture about the nuclear activities being conducted in the state as a whole. State Level Evaluations became the backbone for what is today a more flexible and holistic approach toward the Agency's verification responsibilities, enabling the application of an optimized set of safeguards measures, or integrated safeguards, in states with a Comprehensive Safeguards Agreement and an AP in force.

Meanwhile, as the international community began to impose financial and diplomatic sanctions upon noncompliant states such as Iran and the Democratic People's Republic of Korea, other Member States began to demonstrate their *bona* *fides* through a variety of actions[1]. Most elected to sign and bring into force the Additional Protocol. Many submitted reports about their safeguards, physical protection and export control activities to the United Nations Security Council 1540 Committee. Some concluded safeguards agreements with the IAEA, and others signed nuclear cooperation agreements containing nonproliferation clauses with partner countries. A few invested substantial resources in their nonproliferation education infrastructure. These and other steps have become the elements of each state's safeguards culture. As this growth of safeguards cultures in Member States emerged over time, it produced a new indicator of a state's nonproliferation posture.

Recognition of the importance of safeguards culture in strengthening the international safeguards regime has only recently started to materialize. For instance, at the 2005 Santa Fe INMM/ESARDA Workshop entitled: *Changing the Safeguards Culture: Broader Perspectives and Challenges*, the summary by the Co-Chairs of Working Group 1, "The Further Evolution of Safeguards," noted:

> It is clear that 'safeguards culture' needs to be addressed if the efficiency and effectiveness are to continue to be improved. This will require commitment and change at all levels, from States to facility operators. Cultural change has to come from good leadership, doing the right thing and 'beliefs' are not sufficient – behaviour is what counts. We are optimistic that with sufficient effort and the right incentives, change can be accomplished quickly.

This statement aptly demonstrates the challenge facing the safeguards community, which recognizes the importance of a concept with no agreed upon definition or metrics. There is a vague understanding that cultural change is somehow linked to "good leadership" and "behavior" and that such change can be advanced with the so far undefined "right incentives." As a result of this ambiguity, there is no agreed upon rationale as to why the IAEA should officially recognize the concept of safeguards culture as an indicator of a state's nonproliferation posture. Nor is there explicit guidance for Member States who wish to strengthen their safeguards cultures to enhance their nonproliferation stature.

2. Theoretical models for evaluating cultures

There are a number of social science models that can serve as a theoretical basis for the improvement of culture.[2] Most notable is Schein's model[3], depicted in Figure 1, in which the beliefs of an organization serve as a foundation, what an organization says about itself is in the middle, and what it actually does and what can be measured is at the top. To evaluate the organization's culture, it is necessary to infer beliefs from what is measureable.

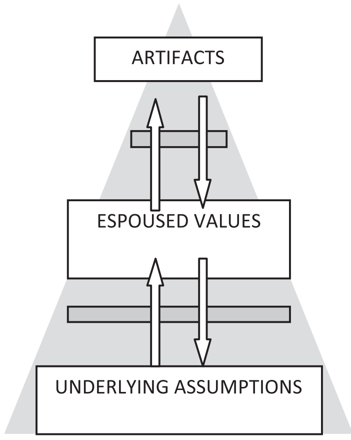

Figure 1: Schein's Model.

A second model considers a hierarchical structure.[4] In that approach the actions of the individuals in an organization are assumed to be influenced by the policies established at the top political level, and effected through the actions of management and organizations. These models provide a useful structure for discussing the role culture plays in international safeguards. Our discussion begins with a look at the concept of 3S or the integration of regulatory approaches to safety, security and safeguards.

The idea of 3S is that there is organizational overlap and synergy among safety, security, and safeguards. This is usually expressed by a Venn diagram, (Figure 2), showing exclusive areas of activity and areas of intersection. For example, fire safety might be exclusively in the safety circle, while physical protection might be shared by security and safeguards. Access control would be shared by all three.

So in this concept where would we place safety culture, security culture, and safeguards culture? All three cultures exist separately and simultaneously, yet they have similar characteristics. A strong safety culture will help prevent accidents. A strong security culture will help prevent theft or diversion

[1] For a more in depth discussion about nonproliferation bona fides, please see: Ajemian CK, M Hazel, CE Kessler, CE Mathews, FA Morris, AM Seward, DJ Peterson, and BW Smith. 2007. *Peaceful Uses Bona Fides: Criteria for Evaluation and Case Studies*. PNNL-16641, Pacific Northwest National Laboratory, Richland, WA.

[2] These models, as applied to safeguards culture, were previously described in: *Changing the Safeguards Culture: Broader Perspectives and Challenges*, Stephen V. Mladineo, Karyn R. Durbin, Andrew Van Duzer, ***Proceedings***, Fifth Joint INMM/ESARDA Workshop, Santa Fe, New Mexico, October 30-November 2, 2005; and Safeguards Culture: Lessons Learned, Stephen V. Mladineo, ***Proceedings, 31st Annual ESARDA Meeting, Symposium on Safeguards and Nuclear Material Management, Vilnius, Lithuania, 26-28 May, 2009.***

[3] Schein, Edgar H.; Organizational Culture and Leadership. 2nd Edition, Jossey-Bass; 1997

[4] The hierarchical model is depicted in IAEA Safety Series No. 75-INSAG-4, ***Safety Culture***, p.6as it applies to Safety Culture; and is repeated in IAEA Nuclear Security Series No. 7 ***Nuclear Security Culture***, Implementing Guide, p. 7.

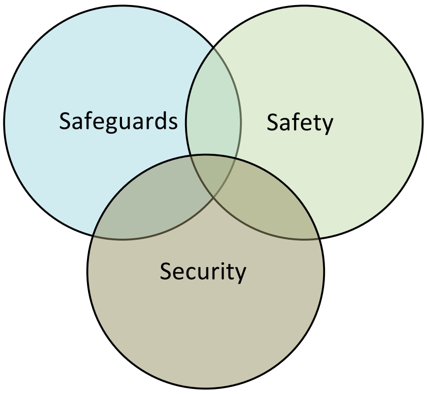

Figure 2: 3S Venn Diagram.

of nuclear material by non-state actors. A strong safeguards culture will help prevent unauthorized use of nuclear material by state actors. Meanwhile, there is a fourth dimension, that we will call "mission," which includes operations, production, output, or results, (Figure 3). After the Chernobyl accident, some nuclear power station operators resisted a call for increased emphasis on safety because it was thought to detract from their mission to produce electricity. In fact, as the emphasis on safety became instilled in plant operators, and safety metrics improved, the metrics associated with mission (such as fewer unplanned outages and increased capacity factor) improved as well. It seems that, over time, cultural norms become embedded into the mission. Experience with a pilot project on nuclear security culture in the Russian Federation has generated only anecdotal evidence, but the outcome appears to be similar. For example, some facilities that have incorporated a new emphasis on security culture report a reduction in the number of security incidents.

3. Defining safeguards culture[5]

It is useful to view this intersection between the mission and each of the 3S disciplines when proposing a definition

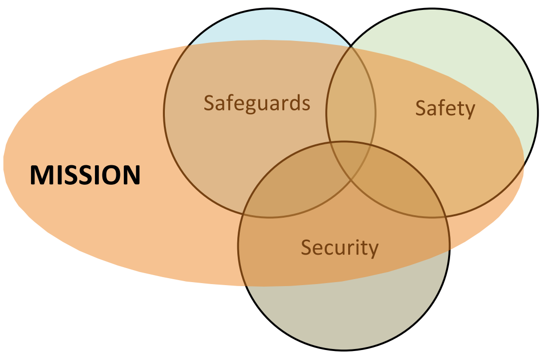

Figure 3: 3S Venn Diagram plus.

[5] Definitions exist for safety and security culture. Safety Culture: That assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance. (IAEA INSAG-4); Security Culture: The assembly of characteristics, attitudes and behavior of individuals, organizations and institutions which serves as a means to support and enhance nuclear security. (IAEA Nuclear Security Series No. 7)

of safeguards culture. We believe this definition should move beyond the implementation of safeguards measures and incorporate the values of countries, organizations, managers, and individuals. It is these values that effectively bridge the gap between international safeguards implementation and mission. Therefore, we propose the following definition of safeguards culture:

A shared belief among individuals, organizations, and institutions that strict attention to international safeguards requirements and affirmative cooperation with safeguards authorities will enhance their nonproliferation stature and benefit their missions.

Using this definition of safeguards culture as a starting point, we can begin the discussion about metrics. First, it is important to consider the difference between safeguards metrics and safeguards culture metrics. Safeguards metrics measure whether the state has fulfilled its obligations under its safeguards agreement with the IAEA. Safeguards Culture metrics measure whether the state and the organizations, institutions and individuals that make up that state are demonstrating a clear commitment to international safeguards through their actions.

One could argue that fulfilling obligations under an agreement is a clear demonstration of a state's commitment to international safeguards. As history has shown, however, a state can seem to fulfill its obligations to the IAEA while simultaneously conducting clandestine activities. Moreover, the facilities and individuals supporting the nuclear program may be fulfilling their obligations with limited understanding as to why those obligations are important to meet, undermining the overall effectiveness and sustainability of their efforts. Therefore, it's important that there be a set of metrics that demonstrate the extent to which a state and the organizations and individuals it represents remain committed to the international safeguards regime, supporting it in letter and spirit. Ultimately, these metrics would be reflected in the Agency's State Evaluation Reports and the Safeguards Implementation Report.

4. Safeguards culture metrics

In this section, we suggest a set of unified metrics for measuring or demonstrating the strength of a safeguards culture within a state. While these metrics are intended for analysis of both the IAEA and its Member States, we recognize that each will be viewed through different lenses. Analysts may find Schein's model to be a more useful lens through which to understand Member State intentions, but to evaluate Member State activities, analysts may prefer the insights raised by the hierarchical model.

Member States

Member States wishing to demonstrate their compliance with the nonproliferation regime have done so through a number of actions on the international stage, signing the NPT, bringing into force the AP, submitting accurate declarations about their nuclear activities to the IAEA, etc. These are invaluable steps that demonstrate the intention to comply with the norms and obligations of the nonproliferation regime. As the hierarchical model suggests, these reflect policies established at a top political level, and these policies influence the actions taken at other levels of society, namely organizations and individuals.

The challenge here is that organizations and individuals have different responsibilities from the top political levels in countries that wish to comply with international nonproliferation norms. While the top political levels are responsible for demonstrating their country's nonproliferation posture through specific actions, an operator's principal responsibility may be to generate electricity, produce scientific findings, or produce isotopes for its customers in ways that are safe and cost-effective. Individuals working at the plant are responsible for fulfilling their duties as safety officers or engineers or public affairs officers. These actors are less concerned about whether their day-to-day actions demonstrate a nonproliferation posture. This is not to say that organizations and individuals do not care about or have an interest in their country's nonproliferation posture. They are simply responsible for meeting a different set of objectives, which means the metrics that are used to demonstrate a country's safeguards culture must take into account these different missions. Recognizing these missions while creating metrics will ensure greater relevance to those who are responsible for meeting them.

IAEA

For years, the IAEA has been developing new, more cost-effective and efficient tools for verifying a state's compliance with its safeguards obligations. It uses a wide variety of information sources, including open source information, satellite imagery, and wide-area environmental samples, to prepare its State Evaluation Reports. As a result, it now has better ways to evaluate what a country believes – its true proliferation posture – by studying what it says about itself, its actions, and to what degree these are in congruence. As noted previously, these values, beliefs, actions and statements have come to define a country's safeguards culture. The IAEA can use safeguards culture as an indicator of a country's nonproliferation posture because the country's safeguards-related actions enable the IAEA to make inferences about its nonproliferation beliefs. Fortunately, defining metrics within this context becomes straightforward since the metrics are a measure of the country's activities.

Metrics

We have identified four high-level metrics that collectively measure a country's safeguards culture – its values and commitment to safeguards – and its ability to meet its safeguards obligations. The bulleted measures in each section offer specific data points that can be used to evaluate the state's fulfillment of the metrics. Further research is needed to produce a measurable scale against which many of these metrics must be considered. For example, future research could establish a quantitative scale that defines the degree to which a country has cooperated with IAEA inspections.

International level metrics:

Metric: **The country fully complies with international best practices and complies with safeguards norms, conventions, treaties, protocols and resolutions.**

- Signed the Treaty on the Nonproliferation of Nuclear Weapons.
- Signed a Safeguards Agreement with the IAEA and a modified Small Quantities Protocol (if necessary).
- Signed and brought into force an Additional Protocol (AP).
- Integrated safeguards are accepted by and implemented in the country.
- Has a positive Conclusion from the IAEA with regard to its adherence to the Nonproliferation Treaty.
- Cooperated with IAEA inspections (e.g. issued visas, complied with complementary access inspections).
- Submitted a 1540 report and subsequent reports responsive to 1540 Committee comments.

National level metrics[6]:

Metric: **The country has an effective legal, regulatory, human and private sector infrastructure capable of supporting safeguards implementation.**

- Passed national laws that establish a State System of Accountability and Control (SSAC) contain penalties for misuse of nuclear materials, establish an independent regulator, authorize independent inspections by national authorities and the IAEA and commit funding and support for safeguards needs.
- SSAC has adequate staff, political and financial support from national authorities and adequate funding.
- Has regulatory guidelines, procedures, standards and codes for conducting nuclear material control and accounting measures.
- Regulatory documents contain enforcement mechanisms, and an independent organization conducts regular inspections of the facilities and takes enforcement actions.
- Inspection findings are tracked, corrected and available for review.

[6] The authors would like to thank Rebecca Stevens, Shirley Johnson and Carrie Mathews for their contributions to this section.

Human Resource Development

- There is a human resource development plan with a specific section dedicated to safeguards professionals.
- There are safeguards education and training programs.
- Country has invested in safeguards technology research and development programs.
- There is a program for passing on safeguards knowledge to new safeguards professionals.

Private Sector Involvement

- Country maintains accurate records of all nuclear exports/imports and makes them available to the IAEA.
- Private industry supports international safeguards through self-regulation and good corporate governance practices.
- Industry collaborates with the government in sharing nonproliferation information and training activities.
- Industry and safeguards professionals participate in professional and trade associations.
- Consulting companies and vendors provide guidance and technical support that align with international best practices.

Facility level metrics:

Metric: **The operator places a priority on implementing international safeguards best practices and views safeguards implementation as complementary to its primary mission.**

- Provides complete and accurate declarations and facility attachments.
- Conducts physical inventory and submits material control and accounting reports on time.
- Fully cooperates with IAEA inspections, including complementary access inspections.
- Conducts self assessments of its safeguards practices.
- Facilitates the use of advanced safeguards technologies and state-of-the-art safeguards equipment by the IAEA.
- Employs staff trained in safeguards-related functions.
- Has a plan for recruiting and training safeguards professionals.
- Has a personnel reliability plan with clear enforcement mechanisms.
- Requires the incorporation of safeguards-by-design when refurbishing or building new facilities.
- Communicates its safeguards, safety and security best practices to the public.
- Maintains effective cyber security measures to protect safeguards data.
- The facility supports redundant safeguards measures, including containment and surveillance, and additional methods, to account for and control their nuclear materials.

Individual level metrics:

Metric: **The country's nuclear personnel, including managers, scientists, engineers, technicians, and regulatory personnel view safeguards implementation as important to them personally and complementary to their missions.**

- Qualified candidates apply for safeguards professional jobs.
- Students view safeguards as a long-term career option and seek safeguards-related coursework at universities and training at nuclear facilities.
- If students go abroad for training, they return to the country to fill safeguards positions.
- Students and nuclear professionals participate in professional associations, such as INMM and ESARDA.
- Students and staff apply for and obtain jobs at the IAEA.
- Staff members feel they have a responsibility and are enabled to report wrong-doing, malfeasance or other problems to management.

Few states will be capable of demonstrating adherence to or fulfillment of all of the measures listed under each metric. However, the more measures they can meet, the more confident the international community will be in their positive nonproliferation postures and the more safeguards culture may become embedded in relevant missions.

5. Utility of evaluating safeguards culture in Member States

The IAEA has been reluctant to use safeguards culture as an indicator in its state evaluations. It has avoided political judgments and resisted using social and political factors to make its conclusions, choosing instead to rely on technical factors out of a sense of fairness. Consistent with the shift toward information-driven safeguards, the IAEA should consider whether and how the social and political factors inherent in safeguards culture can be used to support the Agency's state-level evaluations. States may be willing to support factors that they judge to provide fair evaluation of any state's safeguards culture. Where the IAEA is able to conclude that a country has a robust safeguards culture, using discrete, unambiguous evidence to support this conclusion, the outcome can positively affect the overall safeguards conclusion about the country, reducing the burden on the Agency and the state.

One example of a successful application of a variation of this concept occurred when the IAEA reached agreement with the European Union (EU) to implement integrated safeguards in non-nuclear weapon States of the EU. According to Olli Heinonen, Deputy Director General and Head of the IAEA Safeguards Department: "Once we have sufficient confidence that a State's nuclear activities are purely peaceful, we can apply safeguards measures in a less prescriptive, more customized manner. This reduces the inspection burden on the State and the inspection effort of the IAEA, while enabling the IAEA to maintain the conclusion that all nuclear material has remained in peaceful activities".[7] Once a state can convince the agency that every aspect of its nuclear program is dedicated to peaceful uses, both the agency and the state will enjoy the benefits of a more optimized inspection process. This benefit extends to the facilities and the staff who support them. Less time devoted to IAEA safeguards inspections permits greater concentration on the facility's and individual's mission.

There is an international institutional benefit as well. As a country's safeguards culture grows, its cadre of safeguards professionals also grows. This creates a body of professionals who are available to contribute their expertise either in teaching roles, or as safeguards professionals in international organizations. As a strong safeguards culture becomes an international norm, violations of that norm become more obvious. This helps perpetuate the safeguards culture.

6. Conclusion

Organizational cultures can be modeled and measured, but more research is needed to establish a truly quantitative scale against which each measure can be evaluated. By suggesting a plausible set of safeguards culture metrics for consideration, we have attempted to demonstrate the value of using safeguards culture as another indicator for evaluating a state's nonproliferation posture. However, further research is needed to examine this premise. If a country's leadership wants to be in compliance with its nonproliferation obligations but is seen as having a weak safeguards culture, these metrics can help the state and the international community identify the steps necessary to strengthen it. However, if a country is deemed to have a weak safeguards culture because it has no intention of meeting the goals and objectives of the international safeguards regime, how can the international community respond? Can an effective enforcement regime make use of the safeguards culture metrics we propose? Future research should explore ways to strengthen enforcement measures.

7 *Agreement reached on Integrated Safeguards in the European Union*, IAEA.News@iaea.org, Vienna and Brussels, 8 January 2010.

Non-Proliferation Assessment of the XT-ADS MYRRHA

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Abstract

In the framework of the MYRRHA International Review Team MIRT, an assessment based on multi-attribute value analysis was made of the proliferation risks of the MYRRHA ADS in comparison with the BR2 MTR. In this paper we evaluate not only the reactors, but also some of the associated nuclear fuel cycle facilities. The assessment concludes that MYRRHA is more vulnerable for State-supported diversion of nuclear material, while the BR2 is more vulnerable for diversion by non-State actors. Based on this assessment, guidelines can be developed to improve the safeguards approach of the MYRRHA ADS.

Keywords: vulnerability assessment; MYRRHA; ADS; safeguards; proliferation resistance.

1. Introduction

In the framework of an international assessment of the experimental Accelerator Driven System design MYRRHA (XT-ADS MYRRHA) by an OECD expert group, it was decided to complement a previous safeguards study of MYRRHA [1] with a preliminary assessment of the proliferation resistance of the MYRRHA design. This preliminary assessment could form the basis of so-called "safeguards-by-design" [2,3], in which adaptations are included during the design phase of a nuclear installation in order to facilitate safeguards inspections by international organisations or to increase the "proliferation resistance" of the installation by making the diversion of nuclear material more difficult for both state actors and non-state actors (e.g. terrorists).

Based on a previously reported methodology [4], an assessment has been made of the MYRRHA design and closely connected fuel cycle facilities and compared with a nuclear facility with a similar purpose and magnitude, viz. the BR2 Material Testing Reactor (MTR) at SCK•CEN.

The proposed methodology is based on a segmentation of the fuel cycle facilities and an analysis of several predefined parameters that may have impact on the proliferation resistance of the facility. The analysis is performed per fuel cycle facility segment where appropriate.

Different proliferation threats may be defined and the above-mentioned analysis is performed for each defined proliferation threat.

In the next section we give a short general description of the MYRRHA ADS and the BR2 MTR. In section 3 we discuss in detail the methodology. Section 4 summarises the results obtained and highlights some practical implications, while in section 5 possible consequences are discussed. Conclusions with respect to the proliferation resistance of MYRRHA are sketched out in section 6.

2. Technical description of MYRRHA and BR2– Design Information

2.1. Technical description of MYRRHA

Since 1998 SCK•CEN, in partnership with many European research laboratories, is designing a multipurpose Accelerator Driven System (ADS) for R&D applications –MYRRHA– and is conducting an associated R&D support programme. MYRRHA aims to serve as a basis for the European experimental ADS to provide protons and neutrons for various R&D applications. It consists of a linear proton accelerator delivering a "350 MeV at 5 mA" to "600 MeV at 2mA" proton beam to a windowless liquid Pb-Bi spallation target that in turn couples to a Pb-Bi cooled, subcritical fast core of 50 MW_{th}.

2.1.1. Design objectives

MYRRHA is designed as a multi-purpose facility [1] to support research programmes on fission and fusion reactor structural materials and nuclear fuel for ADS, for critical reactors of present generation targeting higher burn up limits or for next generation reactors and for the production of radioisotopes for medical purposes. MYRRHA will mainly be a major contribution to demonstrate on the one hand the ADS concept at a reasonable power level, and on the other hand the technological feasibility of transmutation of Minor Actinides (MA) and Long-Lived Fission Products (LLFP) arising from highly radioactive waste (from reprocessing). It will also help the development of the Pb-alloys technology needed for the LFR (Lead Fast Reactor) Generation IV concept.

The MYRRHA concept is based on the coupling of a proton accelerator with a liquid Pb-Bi windowless spallation target, surrounded by a Pb-Bi cooled sub-critical neutron multiplying medium in a pool type configuration with a standing vessel. Details on the different components are given in the following paragraphs.

2.1.2. The accelerator

The accelerator is a LINAC that provides the high energy protons that create the neutrons in the spallation target, needed to feed the subcritical core. The proton beam characteristics of “350 MeV at 5 mA” (and in a later version “600 MeV at 2 mA”) allow to reach high flux levels (Φ_{tot} > 5×10^{15} n/cm²s) and a fast neutron flux of 1×10^{15} n/cm²s (E>0.75 MeV) at the Minor Actinides irradiation position under the geometrical and spatial restrictions of the sub-critical core and the spallation source. The time structure of the beam is pulsed operation with beam interruptions of 200 µs every second. A beam stability of 1% in terms of energy, 2% in terms of intensity and 10% in terms of size is foreseen.

2.1.3. Spallation target

The performance of an ADS in terms of flux and power levels is dictated by the spallation source strength, which is proportional to the proton beam current at a particular energy and by the sub-criticality level of the core. The sub-criticality level of 0.95 has been considered as an appropriate level for a first type medium-scale ADS. The maximum reactivity injection due to incidental conditions in the MYRRHA systems have been evaluated to about 3% that would lead to a maximum k_{eff} of 0.98 that leaves still 2% margin to the criticality.

The spallation circuit connects directly to the beam line and ultimately to the accelerator vacuum. It contains a mechanical impeller pump and a Liquid Metal/ Liquid Metal heat exchanger to the pool coolant (cold end). For regulation of the position of the free surface on which the proton beam impinges (whereby this defines the vacuum boundary of the spallation target), it comprises an auxiliary Magneto Hydro Dynamic pump. Further on, it contains services for the establishment of proper vacuum and corrosion limiting conditions.

The spallation target circuit is fully immersed in the reactor pool and interlinked with the core but its liquid metal content is separated from the core coolant. This is a consequence of the windowless design presently favoured in order to use low energy protons on a very compact target at high beam power density in order not to loose on core performance.

2.1.4. Fuel design

Mixed plutonium-uranium oxide fuel (MOX) with a maximum content of 30 %wt. reactor grade Pu has been chosen as the driver fuel in the pre-design of the MYRRHA sub-critical core. The reactor fuel pins have an active length of 600 mm arranged in hexagonal assemblies of 85.5 mm flat-to-flat including the fuel assembly canister thickness. MOX fuel was selected as the candidate for its better neutron properties in a fast neutron spectrum than uranium dioxide. However, the compatibility with lead alloy coolant has been demonstrated only for uranium dioxide in a limited range of temperature and exposure to irradiation. The maximum attainable burn-up is estimated to 100 MWd/kg-HM, depending on the mechanical and physical constraints on the fuel, but is based on a demonstrated value for the sodium cooled fast reactor.

This fuel choice should still be checked against the non-proliferation requirements imposed to new test reactors by the RERTR (Reduced Enrichment fuel for Research Testing Reactors) programme launched by DOE US in 1996 and supported, in general, by the EU, Russian Federation and IAEA [5].

The MOX content in MYRRHA is considerable. It amounts to 800 kg HM in the core with a Pu content of 30-35%, resulting in 240 to 280 kg Pu or an equivalent of 30-35 Significant Quantities (SQ). The SQ is the estimated amount of nuclear material for one nuclear weapon, production losses taken into account [6].

2.2. Technical description of BR2

The BR2 is a high flux engineering test reactor which differs from comparable materials testing reactors by its specific core array.

The core is composed of hexagonal beryllium blocks with central channels. These channels form a twisted hyperboloid bundle and hence are close together at the mid-plane but more apart at the lower and upper ends where the channels penetrate through the covers of the reactor pressure vessel. With this array, a high fuel density is achieved in the middle part of the vessel (reactor core) while leaving enough space at the extremities for easy access to the channel openings.

The standard BR2 fuel elements consist of several concentric tubular shells (up to 6) of uranium-aluminium alloy cladded by aluminium which provide a central channel for locating irradiation experiments. Besides these fuel element channels which offer a particularly high fast neutron flux (up to 7 x 10^{14} n/cm^2.s), a large number of channels exist in the beryllium matrix where no fuel elements are loaded.

These reflector channels can be occupied by experiments which demand only a thermal neutron flux or they are obturated by beryllium filling plugs.

With an adequate core configuration, a peak thermal neutron flux of 1 x 10^{15} n/cm^2.s can be achieved in the central reflector island of the BR2 core matrix. The large number of identical channels in the beryllium matrix provides the possibility for a great variety of different core configurations depending on the demands of the experimental load.

By the use of highly enriched fuel with high density and with incorporated burnable poison (boron and samarium), a considerable amount of negative reactivity caused by strongly neutron absorbing experiments can be accepted while realizing still a sufficiently long reactor operating cycle (till 28 days). 'Up to 10 $ of negative reactivity have been handled already with certain experimental loads.

The actual reactor power varies with the core configuration being used and may attain a maximum of about 100 to 120 MW_{th}, the maximum reached in the past being 106 MW. For the present time the reactor is operated at about 50-80 MW_{th}.

The BR2 reactor is cooled by light water flowing downward in the beryllium matrix. The cooling water represents, together with the hexagonal beryllium blocks, the neutron moderator. A constant pressure drop is maintained over the height of the core matrix (about 0.28 MPa) which creates cooling water flow rates in the different channels corresponding to the flow sections made available.

The coolant flow velocity in the 3 mm thick annular sections between the BR2 fuel element plates is about 10 m/s. It allows a specific heat flux of 470 W/ cm^2 at the fuel plates' surface (hot plane) without reaching surface boiling. During particular tests a peak value of 600 W/cm^2 was even realized.

The pressure of the primary cooling water is 1.26 MPa at the entry of the reactor vessel. Its entry temperature ranges between 40 and 50 °C depending on the recooling conditions of the secondary circuit which passes through four cooling towers.

A water pool houses the reactor vessel and gives the necessary biological shielding when operating the reactor or when charging and discharging active material. This is done via the top cover of the reactor vessel by unlocking the channel shut-off plugs. Also the lower cover of the reactor vessel is accessible during shut-down periods by passing through the shielded sub-pile room. Some standard irradiation channels (84 mm diameter) and all of the 5 big 200 mm diameter channels have also shut-off plugs at the lower cover for connecting experimental devices.

Around the reactor pool, on 6 different floor levels sufficient space can be made available for installing outpile control equipment of irradiation experiments.

Similarly for the BR2 fuel cycle the HEU fuel fabrication plant was segmented in metallic HEU, UAl (alloy of U and Al) and fuel elements. The BR2 was segmented in fresh HEU fuel elements, HEU fuel in the reactor and spent HEU fuel. Finally the HEU reprocessing is segmented in spent fuel storage, HEU in solution and separated HEU.

3. Used methodology

Vulnerability, or its complement resistance (=1-vulnerability), is recognized in the literature as a difficult multidimensional concept, for which the indicators are most often described only in qualitative terms. In the latest years however a number of quantitative vulnerability analysis approaches have been proposed, for instance by [7] and [8] for complex systems and/or critical infrastructures. In the latter study it is argued that vulnerability assessment is a component of risk assessment. While risk assessment considers the triplet "scenario/threat, likelihood, consequences" and focuses on likelihood and consequences, vulnerability focuses on the *susceptibility to a scenario or threat.*

For safeguards aims, the likelihood of a threat is not of particular relevance since all proliferation threats should be covered equally well by the safeguards approach, regardless of e.g. budgetary implications.

In order to assess all proliferation threats equally well, proliferation resistance is a useful concept to evaluate different proliferation threats with respect to their power to divert fissile material from a specific (part of a) nuclear installation; the concept has proven its usefulness in other working groups [16, 17]. To address the multi-dimensionality of resistance and the interaction between the different influencing factors, methods stemming from multi-attribute value theory have been employed in a number of studies. Accordingly, the global resistance R of a system can be defined through a multi-attribute description of the type:

$$R = \Sigma w_i V_i \ , \ \text{with } \Sigma w_i = 1, \qquad (1)$$

where V_i are the different, normalised, value functions used to express the proliferation resistance with respect to various barriers (e.g. detectability of the material) and wi are the corresponding weights of the barriers. The weights are related to the importance of the different proliferation barriers. The assessment of the weights and value functions for the different barriers is given in section 3.4.

3.1. Segmentation of the concerned fuel cycle installations

In order to make a more general assessment of the proliferation resistance of MYRRHA, a larger part of the fuel cycle was considered than just the MYRRHA installation itself. In the assessment also the MOX fabrication plant that will produce the fuel for MYRRHA and the reprocessing facility that will reprocess the spent MOX fuel elements are taken into consideration. For the BR2 HEU fuel fabrication and HEU reprocessing are considered.

A further segmentation of the fuel cycle facilities is performed based on the physical form of the fuel during the fuel cycle. It is the physical form that determines the attractiveness of the fissile material for diversion. The main factor here is the presence or absence of high radiation fields that complicate manipulation of the fissile material, but also its chemical composition plays a role in how fast the material can be converted in metallic Pu or U that can be used in a nuclear weapon.

For the MOX fuel fabrication, a segmentation in MOX powder, MOX pellets and MOX fuel elements was done. The fuel in MYRRHA is segmented in fresh MOX fuel, MOX in the reactor and spent MOX fuel in the storage pond. The fuel in the reprocessing facility was segmented in spent fuel storage, Pu/U in solution and separated Pu and U.

Similarly for the BR2 fuel cycle the HEU fuel fabrication plant was segmented in metallic HEU, UAl and fuel elements. The BR2 was segmented in fresh HEU fuel elements, HEU fuel in the reactor and spent HEU fuel. Finally the HEU reprocessing is segmented in spent fuel storage, HEU in solution and separated HEU.

The segmentation is summarised in table 1.

3.2. Proliferation threats

In [4] several proliferation threats are discussed, ranging from the threat from a sub-national group to acquire fissile material for one nuclear weapon to the threat of a state developing a large-scale weapon programme in the order of some 100 nuclear weapons with second-strike capability.

In this study we limit ourselves to two threats as being the most pertinent.

The first threat is defined as an overt diversion of fissile material that is sufficient for the construction of one improvised nuclear weapon. The diversion is done by a sub-national group without the support of the national authorities.

The second threat is defined as a covert diversion of fissile material that is sufficient for the construction of 10-20 nuclear weapons. The diversion is done by the state with support of all its institutions.

3.3. Proliferation barriers

Proliferation barriers can be subdivided into three different groups [4]. The first group deals with the fissile material, the second group with the technical difficulty barrier and the third group with external factors. Since both installations considered are located in the same country, political aspects are not taken into account. Moreover, this is in agreement with the methodology proposed by Mladineo [4].

The first group includes the barriers isotopic composition, chemical composition, radiological dose, concentration and detectability of the material. The second group includes attractiveness, accessibility, quantity of mass available, diversion detectability, skills & knowledge and time needed for diversion. The third group deals with aspects like safeguards system, physical protection and location of the facility.

3.4. Assessment of the proliferation barriers

The assessment of the proliferation barriers is schematically shown in figure 1. The further segmentation as described in table 1 is not reproduced in figure 1 to keep a better overview of the problem.

MYRRHA fuel cycle		BR2 fuel cycle	
MOX fuel fabrication	MOX powder	HEU fuel fabrication	Metallic HEU
	MOX pellets		UAl
	MOX fuel elements		HEU fuel elements
MYRRHA	Fresh MOX fuel elements	BR2	Fresh HEU fuel elements
	MOX fuel elements in reactor		HEU fuel elements in reactor
	Spent MOX fuel elements		Spent HEU fuel elements
MOX reprocessing	Spent MOX fuel elements storage	HEU reprocessing	Spent HEU fuel elements storage
	Pu/U in solution		HEU in solution
	Separated Pu and U		Separated HEU

Table 1: Schematic view of segmentation of the MYRRHA and BR2 fuel cycles for proliferation assessment.

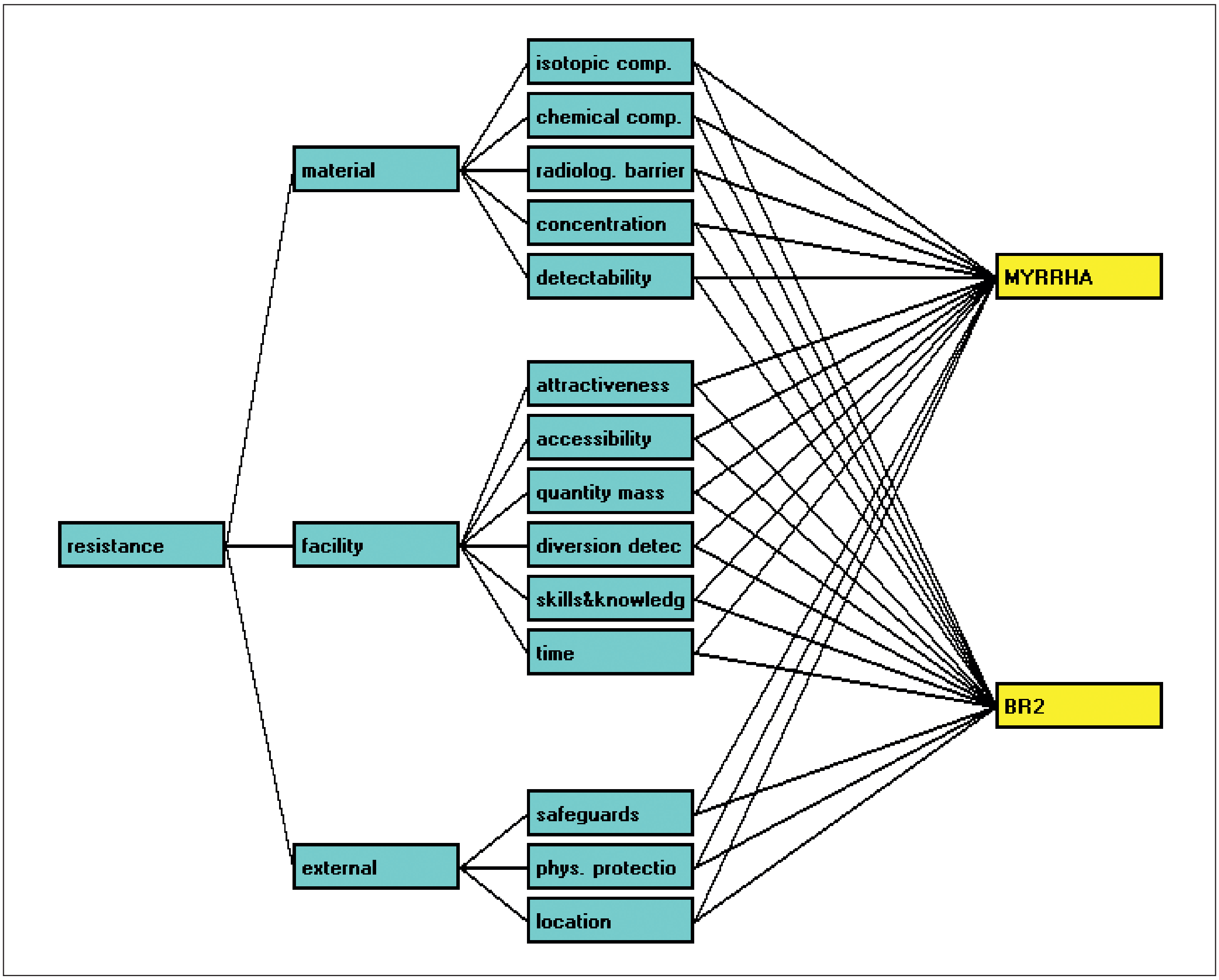

Figure 1: Schematic representation of the proliferation resistance assessment.

3.4.1. Value functions

The value functions reflect in how far a certain barrier will prevent the diversion of fissile material. A value of 1 means very high proliferation resistance, i.e. that there is no possibility for a diverter to acquire sufficient fissile material for a nuclear weapon; a value of 0 means very low proliferation resistance, i.e. that if a diversion takes place, it will be successful.

The value functions are constructed most of the time based on subjective expert's judgement. Where applicable, literature references are indicated.

Material barriers

Isotopic composition

The value function for uranium is based on the definition of highly enriched uranium (HEU). HEU is defined as uranium having a ^{235}U content of 20% or higher. Uranium with a lower ^{235}U content is considered to be not applicable in a nuclear weapon and has therefore a resistance value of 1.

Although the definition of HEU suggests a step function (1 for E<20%, 0 for E≥20%), we prefer to base ourselves on [9] and assume a linear decrease of the value from 1 at E=50% to 0 at E=90%. HEU with an enrichment of 90% or more is considered to be applicable in a nuclear weapon without any problem.

Since the isotopic composition of plutonium is somewhat more complicated due to the presence of five different isotopes, we have simplified the problem by only looking to the 239Pu content. Basing ourselves again on [9], we assume a linear decrease of the value from 1 at ^{239}Pu content of 0% to 0 at ^{239}Pu content of 90%. Pu with an enrichment of 90% or more is considered to be applicable in a nuclear weapon without any problem. The simplification is justified based on calculations of the Pu isotopic composition at beginning and end of cycle of MYRRHA by Nishihara [18], showing that the various Pu isotopes vary only a few % of their absolute abundances.

Both value functions are depicted in figure 2.

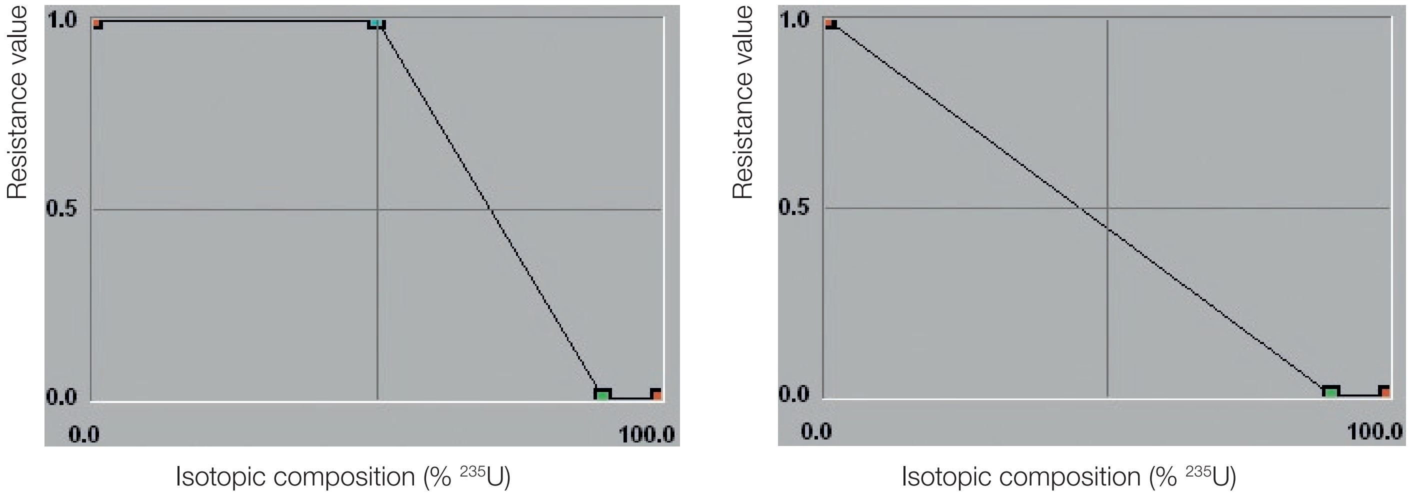

Figure 2: Value functions for the isotopic composition of uranium (left) and plutonium (right).

Chemical composition

The chemical composition of the fissile material in the considered parts of the fuel cycle does not pose a significant problem for any chemist to convert the material to metallic uranium or plutonium. A basic chemical knowledge and relatively simple chemical infrastructure (including glove boxes) will be sufficient for such a conversion. The value functions for all chemical compositions are assumed constant, equal to 0.2, based on the expert judgment that the necessary chemical conversion processes could be performed in a relatively simple chemical laboratory [10].

Radiological dose

The radiological dose has a significant impact on the proliferation resistance of fissile material. Fresh fuel (with almost no dose) is considered to have a value of 0, while irradiated fuel (dose rate > 2000 Sv/h) is considered to have a value of 1. In between some kind of S-curve has been assumed with the centre around 1000 Sv/h (value of 0.5). The reason is that the deterministic health effects of radiation increase considerably above the threshold of 1Sv. At a dose rate of 1000 Sv/h we consider it less likely that a diverter, even suicidal, will be able to manipulate the fuel for proliferation purposes. The available time for manipulation per person would be between 20 and 40 seconds. This reasoning is based on rather conservative assumptions.

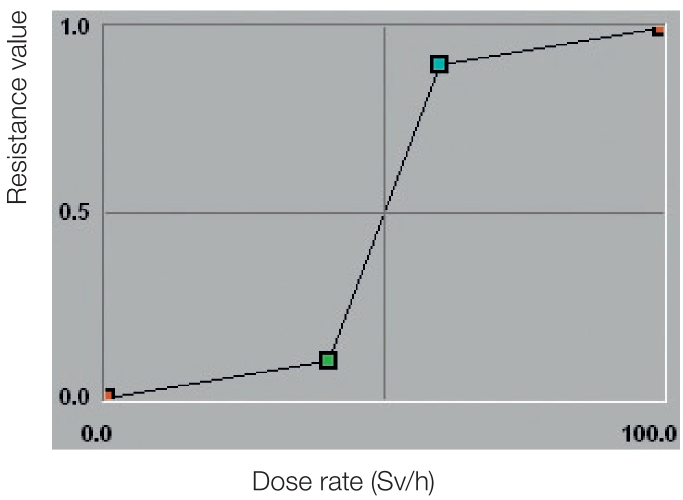

Figure 3: Value function for the radiological dose (rate).

The S-curved value function is approximated by a piecewise linear function, as depicted in figure 3.

Concentration

The concentration of the fissile material plays hardly any role in the considered fuel cycle installations, since in most cases the concentration is close to 100%. Exceptions are irradiated HEU fuel elements (more than 50% burn-up) and the case when the material is in solution in the reprocessing facility. In these cases we have attributed a resistance value of 0.5, while for all the other cases the resistance value is considered to be 0.

Detectability of the material

This measure depends on the physical parameters of the material, facilitating the use of (non-destructive) detectors, especially passive ones, and the identification of the gamma signatures. A higher detectability of the fissile material will facilitate the verification of the correctness of the nuclear material accountancy. The detectability of the fissile material depends on factors like concentration, isotopic composition, but most importantly on the level of mixing with other radioactive material that will disturb the signature of the fissile material. Therefore, the value function is related to measurement performance, which means quite straightforward for fresh fuel, and rather complex for spent fuel, having to account for combined burn-up and cooling time. For fresh (unirradiated) fissile material the resistance with respect to detectability is assigned a value of 0.9, whereas for fissile material in irradiated fuel or in solution the value is 0.1.

Technical difficulty barriers

Attractiveness

The attractiveness of the facility is related to the unreported production of plutonium in the facility by irradiating ^{238}U targets and depends on factors like required modifications, costs of these modifications, safety implications of the required modifications, time required for the modifications, the facility throughput and the effectiveness of observable environmental signatures. Facility throughput is considered to be the most important factor.

The annual throughput of the BR2 with respect to unreported plutonium production is estimated to be 20 kg ^{239}Pu per year [11]. Calculations of unreported plutonium production capacity of the fast sodium-cooled BOR-60 [12] resulted in a plutonium production capacity of 10 kg/year with a load factor of 80% and an operational power of 50 MW. This confirms that the plutonium production capacity of a fast-neutron system like MYRRHA is comparable to that of the BR2. Based on reactor physics considerations [13], we conclude that the capacity for unreported plutonium production is the same for BR2 and MYRRHA.[1]

For the sub-national threat the resistance value for both MYRRHA and BR2 is evaluated to be 0.7, based on the fact that the annual throughput is sufficient for 2-3 SQs, but the non-state actor depends on almost full cooperation of the reactor crew. For the national threat the resistance value for both MYRRHA and BR2 is lower, 0.5. Full cooperation of the reactor crew is assumed but the throughput is relatively small.

The associated facilities for fuel fabrication and fuel reprocessing do not have, according to [4], the capability for unreported production of plutonium, and therefore the resistance value is taken as 1, although Pu and HEU may be diverted by misuse or covert diversion in these installations.

Accessibility

Accessibility of the nuclear material for a potential diverter in the considered segment of the fuel cycle facility is mandatory for a potential diversion. Fresh fuel in a storage is considerably easier to divert than fuel in a reactor or dissolved fuel in a reprocessing facility. Spent fuel in an underwater storage that requires manipulation tools is between the above-mentioned cases with respect to accessibility.

Fuel in the reactor or dissolved fuel in reprocessing is estimated to have a resistance value of 0.9, spent fuel in underwater storage (reactor or reprocessing) is given a resistance value of 0.5 and fresh fuel storage is considered easy-to-access (value of 0.2).

Quantity of fissile material available

The quantity of fissile material present in a facility plays an important role for proliferation considerations. The most obvious example is the case when there is considerably less material present than needed for the construction of a nuclear weapon. In this case the facility may be considered as highly proliferation-resistant.

The BR2 reactor contains fissile material in a quantity sufficient for one or a few nuclear weapons, whereas MYRRHA contains considerably more fissile material, sufficient for 10-20 nuclear weapons. Both facilities have therefore a zero proliferation resistance to the threat of a subnational group aiming at one nuclear weapon, but BR2 has a certain resistance to the threat of a larger-scale national nuclear weapon programme. This resistance is given a value of 0.5.

The other considered fuel cycle installations have been given similar resistance values, based on the consideration that we only take into account the influence that BR2 and MYRRHA have on the annual throughput of the facilities.

Diversion detectability

This parameter acknowledges how the type of facility can ease, or complicate, carrying out material accountancy. The main distinction is among items / bulk facilities and batch / continuous flow.

Items can be more easily counted and measured for their content than material in a bulk facility, where the presence of a continuous flow complicates the measurements.

The bulk materials MOX powder in fuel fabrication and U/Pu in solution and separated Pu and U in MOX and HEU reprocessing have been assigned a resistance value of 0.2, MOX pellets, HEU and UAl plates have been assigned a resistance value of 0.5, and the fuel elements have been assigned a resistance value of 0.9.

Skills & knowledge

Skills & knowledge have been considered as not applicable. The used assessment methodology has originally been developed for assessment of export of nuclear technology to other countries that may not possess yet nuclear know-how. Belgium can be considered as a country that has developed a significant nuclear know-how and the development of MYRRHA will not lead to a significant additional proliferation-sensitive know-how in Belgium.

1 The analysis of the Pu production capacity of a research reactor by Binford is based on simple reactor physics, where per MW of produced energy is calculated how many neutrons are produced and how much Pu can be bred with these neutrons. Corrections are applied in a conservative way for e.g. maintaining the nuclear chain reaction and absorption of neutrons by reactor materials, coolant and leakage. Since the number of produced neutrons in thermal and fast reactors may differ at most 10-20%, and the absorption of neutrons by other than fission reactions is limited by the respective designs as much as possible, it is fair to state that a fast system will produce a comparable amount of Pu than a thermal system.

Time needed for diversion

This parameter is important when considering a protracted diversion. The expected differences in irradiation schedules (and designs) in the two reactors, could in principle influence the possibility to access the material during irradiation.

Protracted diversion is much more likely for bulk material than for items like fuel elements, that contain per item already a considerable amount of fissile material. So although in principle applicable, this has not been considered as important for the overall assessment of proliferation resistance [4], since differences in irradiation schedules will only affect fuel elements.

External barriers

Safeguards system

The safeguards system provides a proliferation resistance against the diversion by the state, but not against diversion by a sub-national group. The resistance values used in the analysis were 0 for the threat by a sub-national group and 1.0 for the threat of a diversion by a state, respectively.

Physical protection

The physical protection system provides a proliferation resistance that is complementary to the safeguards system. For a diversion by a state this system does not provide any resistance since it is the state that operates it, but for a sub-national group it provides a proliferation resistance for which an estimated value of 0.8 was used. The latter value is not 1 since we consider that there is a certain likelihood of collaboration between the sub-national group and physical protection responsible persons.

Location of the facility

Due to the fact that Belgium is a country without remote areas, this factor is considered as not applicable. Additionally MYRRHA is scheduled to be built at the same location as the BR2, so this factor would not give different results for the two facilities.

3.4.2. Relative weight

The relative weights for the different barriers have been derived using the AHP method (Analytical Hierarchical Process) by [14] , with the help of the Web-HIPRE software ([15], www.hipre.hut.fi). The AHP method can be used to convert subjective assessments of relative importance of different criteria (here represented by barriers) to a set of weights. The input to AHP are the answers to a series of questions of the type “how important is criterion A with respect to criterion B”?. Questions of this type are also called pairwise comparisons.

In the further analysis the three groups of barriers (material, facility, external) have been considered separately to facilitate the comparison between the BR2 and MYRRHA.

Material barriers

Isotopic composition and radiation dose have been considered as the most important for the proliferation resistance of the material. They were considered as equally important. Still relevant, but to a lesser extent were material concentration and chemical composition. Again these two barriers were considered as equally important. Detectability was considered as the least important.

Facility barriers

Material present in the facility is considered as the most important for proliferation resistance. Accessibility of the facility is also very relevant, but less important than the quantity of material. Attractiveness of the facility is of minor importance, but still more important than diversion detectability, skills & knowledge and time for diversion were considered not applicable in this assessment.

External barriers

Safeguards and physical protection are considered as equally important in view of the different threats (sub-national and state). The location of the facility is less relevant.

Results

Table 2 lists the weighting of the different barriers resulting from the AHP analysis. For each type of barrier the sum of the relative weights of the individual components is 1.

Parameter	Weight
Material barriers	
Isotopic composition	0.348
Chemical composition	0.129
Radiological dose	0.348
Concentration	0.129
Detectability	0.046
Facility barriers	
Attractiveness	0.10
Accessibility	0.36
Mass present in facility	0.49
Diversion detectability	0.05
Skills & Knowledge	NA
Time for diversion	NA
External barriers	
Safeguards	0.5
Physical protection	0.5
Location	NA

Table 2: Relative weights of the proliferation barriers.

4. Results of the assessment

4.1. Calculated individual values for proliferation resistance

Per barrier group and per segment of the fuel cycle facilities the proliferation resistance values have been determined. These values are given in table 3.

In order to evaluate the proliferation resistance per installation and not per segment, the values in the table above corresponding to the different segments of an installation should be aggregated.

However, a high resistance for one segment in a facility cannot compensate for a low resistance in another segment. Drawing on this, we use the operator "min" for the aggregation of proliferation resistance across the segments of the fuel cycle facilities (see Table 4). This takes as overall resistance of a fuel cycle facility the value corresponding to the most vulnerable of its segments, i.e. the one with minimal resistance.

For each segment, each type of barrier is associated with a measure of the related resistance. It could appear meaningful to aggregate the values per segment, e.g. by a weighed sum, in order to estimate the total resistance of each segment. However, this has not been performed for two reasons: it was found to be very difficult and rather arbitrary to allocate weights to the various barriers. Moreover, a further aggregation would result in less specific information on where the system is most vulnerable. For example, the present tables show that additional effort should in a first instance be applied to strengthen the material and facility barriers.

	MOX fuel fabrication			MYRRHA			MOX reprocessing		
	MOX powder	MOX pellets	MOX fuel elements	Fresh MOX fuel	MOX in reactor	Spent MOX fuel	Spent fuel	Pu/U in solution	Separated Pu and U
Threat 1									
Material	0.18	0.18	0.18	0.18	0.49	0.49	0.49	0.56	0.18
Facility	0.18	0.20	0.22	0.19	0.44	0.30	0.33	0.43	0.18
External	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Threat 2									
Material	0.19	0.19	0.19	0.19	0.50	0.50	0.50	0.56	0.19
Facility	0.18	0.20	0.22	0.17	0.42	0.28	0.33	0.43	0.18
External	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

	HEU fuel fabrication			BR2			HEU reprocessing		
	HEU plate	UAl alloy	HEU fuel elements	Fresh HEU fuel	HEU in reactor	Spent HEU fuel	Spent fuel	Pu/U in solution	Separated Pu and U
Threat 1									
Material	0.07	0.07	0.07	0.07	0.45	0.45	0.45	0.45	0.07
Facility	0.20	0.20	0.22	0.19	0.44	0.30	0.33	0.43	0.18
External	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Threat 2									
Material	0.07	0.07	0.07	0.07	0.45	0.45	0.45	0.45	0.07
Facility	0.44	0.44	0.46	0.41	0.66	0.52	0.57	0.68	0.43
External	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Table 3: Results of proliferation resistance values per barrier group and per fuel cycle segment.

	MOX fuel fabrication	MYRRHA	MOX repro-cessing	HEU fuel fabrication	BR2	HEU repro-cessing
Threat 1						
Material	0.18	0.18	0.18	0.07	0.07	0.07
facility	0.18	0.19	0.18	0.20	0.19	0.18
External	0.40	0.40	0.40	0.40	0.40	0.40
Threat 2						
Material	0.19	0.19	0.19	0.07	0.07	0.07
facility	0.18	0.17	0.18	0.44	0.41	0.43
External	0.50	0.50	0.50	0.50	0.50	0.50

Table 4: Proliferation resistance values per fuel cycle facility using the most vulnerable element approach.

For a better illustration, the results in table 4 are depicted in figures 4a-d.

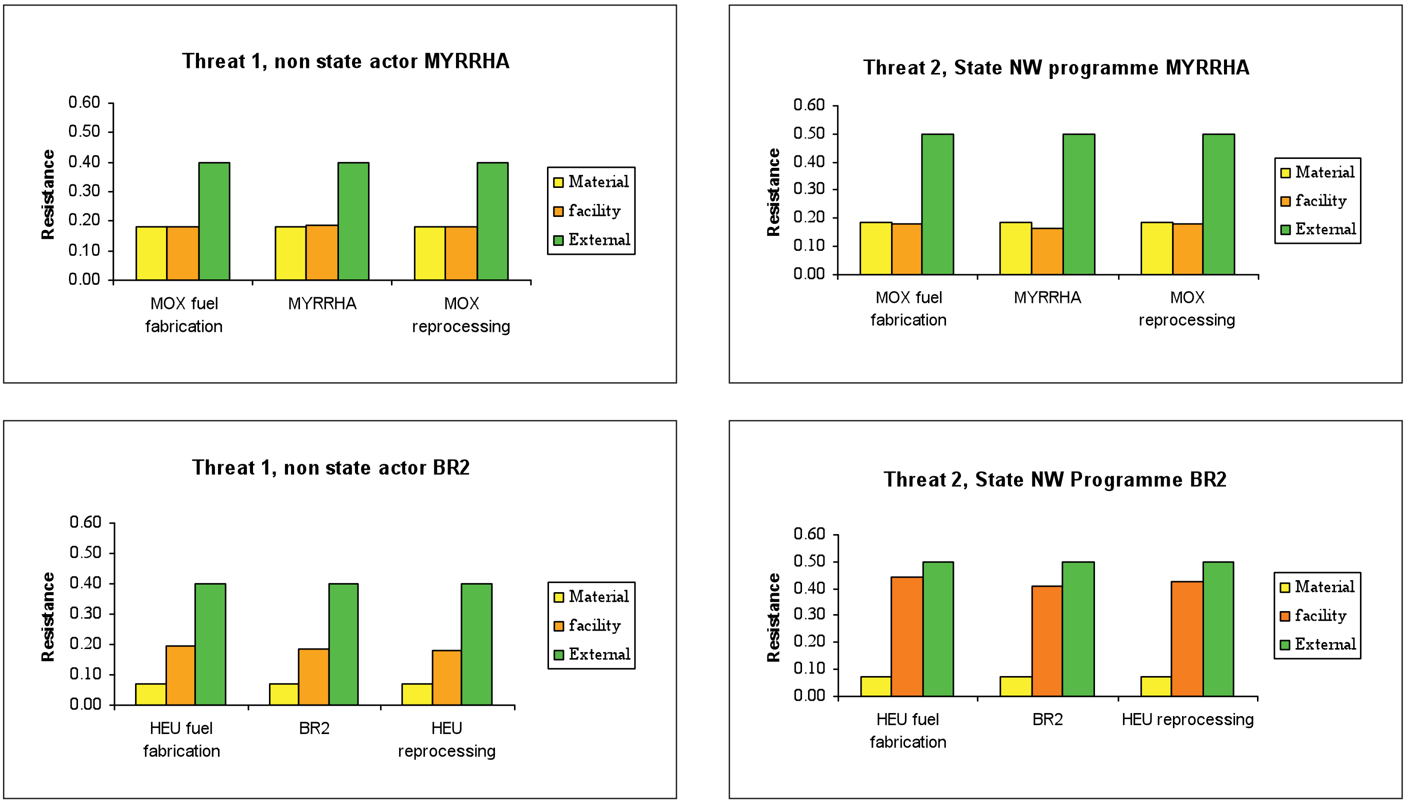

Figure 4a-d: Comparison of proliferation resistance values per fuel cycle facility.

5. Discussion

5.1. Subnational threat

For a sub-national threat it is observed that the MYRRHA facility is on the whole more proliferation resistant than the BR2. This is mainly due to material properties; reactor-grade plutonium is considered as more proliferation resistant than 93% enriched uranium, despite the IAEA definition to qualify both as "Direct-use materials". It should be noted that the higher technical difficulty to ignite a plutonium weapon in comparison to a uranium weapon has not been taken into account. Therefore in practice the proliferation resistance of MYRRHA will be even higher.[2]

Both the facility aspects and the external factors give similar results for BR2 and MYRRHA.

[2] In the framework of the RERTR programme to abolish the use of HEU in research reactors the introduction of LEU is studied for the BR2 reactor. In case the introduction of LEU (19.9% enriched uranium) would be successful in the BR2, the proliferation resistance due to the material properties would be significantly increased and higher than that of MYRRHA.

5.2. State nuclear weapon programme threat

For a State nuclear weapon programme it is observed that the facility barrier of BR2 facility provides a much higher proliferation resistance than that of MYRRHA. On the other hand, with respect to the material barrier, MYRRHA provides a slightly higher proliferation resistance than BR2. The dominant factor is the nuclear material present in the facility. Whereas the BR2 contains nuclear material in the order of 1 SQ, MYRRHA contains considerably higher amounts of nuclear material. This aspect does not really influence the evaluation of the sub-national threat, since these groups will only be interested to acquire sufficient material for one nuclear weapon, but in case of a national weapon programme aiming at manufacturing numerous nuclear weapons, the availability of a sufficient amount of nuclear material becomes an important factor in the proliferation assessment.

Again external factors give similar results for the BR2 and MYRRHA.

5.3. General remarks

The determination of the value functions and of the relative weights for the various barriers, the choice of the threats and the separation of the fuel cycle facilities could be all subject for discussion and possible improvement.

However, the results obtained clearly obey the rules of common (safeguards) sense and we are confident that a further improvement of the used input parameters will not fundamentally change the results and conclusions of this study.

This paper evaluates the proliferation resistance values for the various fuel cycle facilities and barriers. Future work could focus on the optimisation of the barriers, among others with respect to the cost-effectiveness of potential modifications to improve the overall proliferation resistance.

6. Conclusions

A proliferation assessment has been performed for MYRRHA. The model proposed by Mladineo was followed, that itself relied on proliferation resistance studies made in relation to Gen IV developments. A comparison with the BR2 MTR reactor was made in order to have a term of reference with an existing facility.

Two threats were considered: the State and a sub-national group.

In this report only technical aspects are considered for the proliferation assessment. For a final assessment of proliferation risks, the political aspects of the host State could be taken into account as well. Such a political assessment goes beyond the scope of this report, but should include aspects like the presence of sub-national groups, the performance record of the concerned State with respect to non-proliferation and many more.

MYRRHA appears to be more proliferation resistant than the BR2 for a sub-national threat, mainly due to the fact that the reactor-grade plutonium is less applicable for a nuclear weapon than the HEU in the BR2.

MYRRHA is less proliferation resistant than the BR2 for a large-scale nuclear weapon programme by the State itself due to the large amounts of nuclear material present in the facility.

The analysis shows that a further strengthening of the proliferation resistance of MYRRHA should focus on the material and facility barriers rather than on the external barrier.

For the BR2 the same analysis shows that strengthening its proliferation resistance should focus on the material barrier. This supports the justification of the RERTR project, aiming at reducing the use of HEU in research reactors.

This type of quantitative analysis could be helpful for a Safeguards-by-design iterative process, which would require a thoroughful assessment of value functions and weights and a sensitivity analysis.

It should be kept in mind that the definition of the value functions remains subjective, and that further discussion is needed to reach a better harmonization at an international level, and to come to a consensus, if possible at all.

Acknowledgements

The authors would like to thank the MYRRHA team for their valuable and indispensable information about MYRRHA.

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JRC CANDU Sealing Systems for Cernavoda (Romania) and Upcoming Developments

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Abstract

A new sealing system for CANDU® reactor spent fuel bundles, to replace the AECL ARC seal, was developed, according to the IAEA requirements.

The new bolt for underwater sealing is derived from the design of the sealing bolts already used in the La Hague reprocessing plant. The design was revisited in order to comply with the CANDU® interface requirements.

This paper discusses the design of this sealing system and the current implementation status of the JCSS (JRC CANDU® Sealing System) in Cernavoda (Romania): seals, reading system, seals database. Lessons learned during two years of experimentation together with Safeguards inspectors are also discussed. A description of the upgraded system that is going to be deployed at Cernavoda-2 is presented.

On-going developments of various JRC Ultrasonic Sealing Systems for both underwater and dry spent fuel storages applications, in particular for dry storages using cask with concrete biological shielding cover are also presented.

Keywords: Spent fuel storage, ultrasonic sealing bolts, underwater seals, CANDU® design, Cernavoda (Romania).

1. Introduction

The Seals & Identification Laboratory (*SILab*) is part of the Joint Research Centre of the European Commission. As one of its main activities, *SILab* develops technologies and equipment based on ultrasonic techniques, suitable for sealing and/or identification of nuclear or commercial items.

Regarding seals for nuclear applications, *SILab* has many years' experience with ultrasonic seals and equipments for underwater applications, used by both nuclear safeguards agencies (International Atomic Energy Agency (IAEA) and Euratom Safeguards Directorate) in Sellafield (UK) and La Hague (F) installations.

CANDU® reactors are on-load refuelled reactors manufactured by AECL (Atomic Energy of Canada Limited), i.e., without reactor shut-down fresh fuel assemblies are continuously inserted into the reactor core, while spent fuel assemblies are simultaneously withdrawn. The exploitation license at Cernavoda requires that spent fuel bundle stacking frames be sealed. AECL supplied the ARC seal (AECL Random Coil seals) for this purpose.

On IAEA request, a study of the application of *SILab* ultrasonic seals to replace ARC seals for Cernavoda began in 2005. *SILab* ultrasonic seals present, as main advantage, stability against time and radiation. Being purely static pieces of stainless steel they will last the life time of the stacking frames and remain stable as identity. Only the reading equipment needs to be maintained.

2. Basics of ultrasonic seals

A seal has to provide evidence of any access to the content of the sealed item, whether authorized or unauthorized. It is usually attached to the lid of a container with the aim of ensuring that any opening will be indicated.

The internal structure of the ultrasonic seal comprises a unique non-reproducible identity and a frangible element (integrity) which breaks when an attempt is made to remove the seal from the sealed item [1].

The reading device consists of a transducer which generates an ultrasonic signal and senses the reflected signal. The transducer rotates above the sealing bolt recording the ultrasonic echoes reflected over a complete revolution.

The seal is designed to replace one of the standard bolts/nuts of the container lid, or to be installed on ad-hoc devices. It is possible to verify, when inspected, whether or not such a sealing bolt has been unscrewed or removed for opening.

When the seal is used in replacement of a bolt or a nut, the body of the seal has the same mechanical properties

	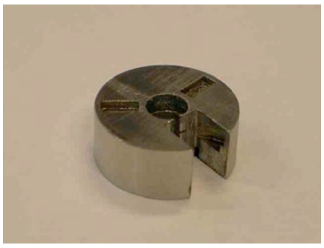		
DISCS WITH RANDOM ANGULAR INCISIONS	STACK OF DISCS (UNIQUE IDENTITY)	INTEGRITY FEATURE	ULTRASONIC CORE: IDENTITY AND INTEGRITY FEATURES BRAZED TOGETHER

Photo 1: Core of ultrasonic seals.

as a standard bolt/nut (thread and applied torque) and is designed for each specific application.

The core of the ultrasonic seal (photo 1 to the very right) is a cylindrical assembly containing its unique identity and an integrity feature which breaks when opened. This assembly is radiation resistant and particularly reliable even under very harsh environmental conditions.

The identification feature is an assembly of several discs randomly stamped (photo 1 to the very left), which are stacked in a random disposition and brazed together to form a univocal identity (second from left, photo 1). Brazing paste is put in several parts of the stack in a quantity that will adequately braze the disks, but not fill all the holes. This is done by heating them up to 1000°C for several minutes in the furnace. As the diffusion of the brazing follows a random process, it is not possible to predict the identities that will be produced.

Photo 2: Custom seals designs.

The integrity is controlled by a thin metal rod which breaks when torsion or traction is applied to it (third in photo 1). The parts providing identity and integrity are then brazed together to form the core of the ultrasonic seals (photo 1 to the very right).

This core is then welded into the top of the seal. The bodies of the seals are designed according to each application (photo 2).

Once produced, all identities are checked individually.

The seals are read using an ultrasonic device, consisting of a transducer generating a high frequency ultrasonic pulse. The sound energy propagates through the materials and when there is a discontinuity in the wave path, a part of the energy is reflected back from the surface. The reflected wave signal is transformed into an electrical signal by the transducer and is analyzed by the analysis device (figure 1). Signal travel time can be directly related to the distance that the signal has traveled. Information about the reflector location, its size and orientation, and other features can also be gained from the signal.

In order to have a complete fingerprint of each seal, this transducer is then rotated upon the seal. In each position of the transducer the echo is then recorded. Figure 2 can be seen as intensity of the echo as a function of the angular position of the transducer. The X axis covered a complete revolution (360°).

On inspections, after a complete reading, a mathematical correlation [2] with the reference reading is calculated. The reference reading is a previous reading made by an au-

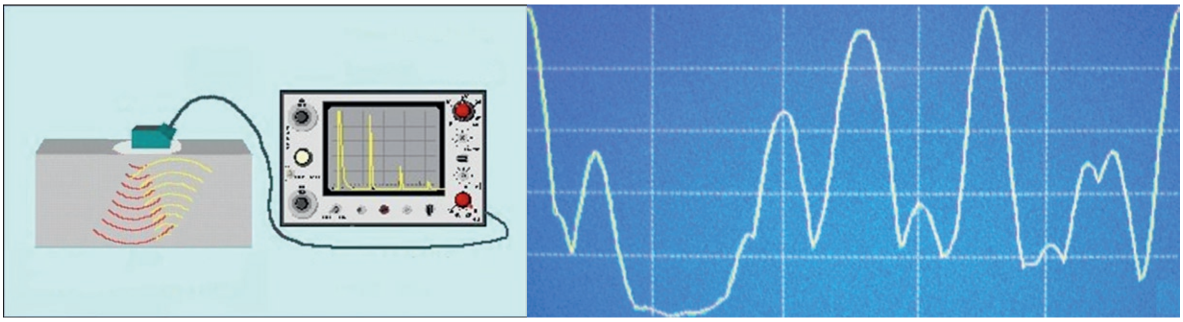

Figure 1 : Principle of ultrasonic reading and fingerprint of a seal.

thorized inspector (of IAEA or EURATOM). The seal is considered as "Identified" if the correlation between the two readings is higher than 0.90. Then an analysis of the integrity area (red area figure 2) will determine the "Broken" or "Unbroken" status.

The threshold of 0.90 was set according to the possibility to produce "twins". As seen previously, the fabrication process of the identities is based on the random diffusion of the brazing paste into the disk assembly. Preparing identical assemblies and brazing them in the same fabrication batch lead to slight differences between the identities produced, the so-called "twins". Experiences were done with IAEA and EURATOM Safeguard Department showing that even as manufacturer it is not possible to produce identical seals. The correlation between such identities is rather high (between 0.60 and 0.80). In consequence, it was decided to set the threshold for identification to 0.90.

The main advantages of these seals are that they are insensitive to radiation and they can last tens of years. Another advantage is that an inspector has an immediate answer as to the authenticity and status of the seal. In the case where these seals are used to protect material in long term storage, the only device that would need special maintenance is the reading head.

3. JRC ultrasonic seal for the underwater CANDU® spent fuel storage

A CANDU® reactor operates in continuous mode. New fuel is loaded and spent fuel is unloaded every day (up to 16 fuel bundles per day). The spent fuel is then carried to the spent fuel bay where it is placed in stacking frames. Once the frame is full, a frame cover and two seals are applied. The spent fuel will remain for typically 7 years in the spent fuel bay until it can be stored in dry storage. Hitherto, AECL Random Coil seals (ARC seals) were used to seal the stacking frames [3].

3.1. Specifications

The IAEA expressed its need to develop a seal that can be used in place of existing ARC seals with the following user

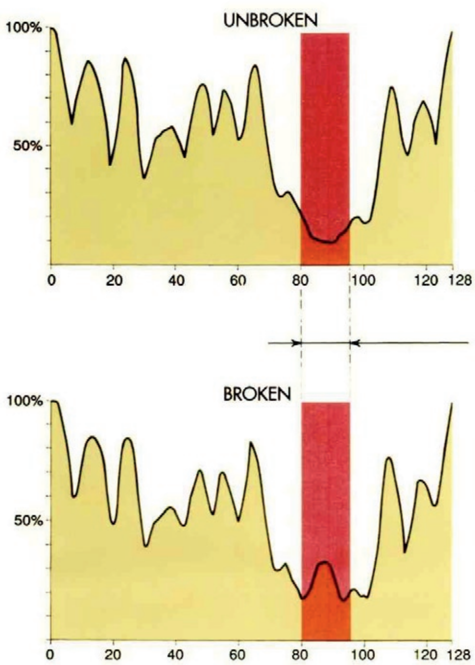

Figure 2: Unbroken versus Broken seal.

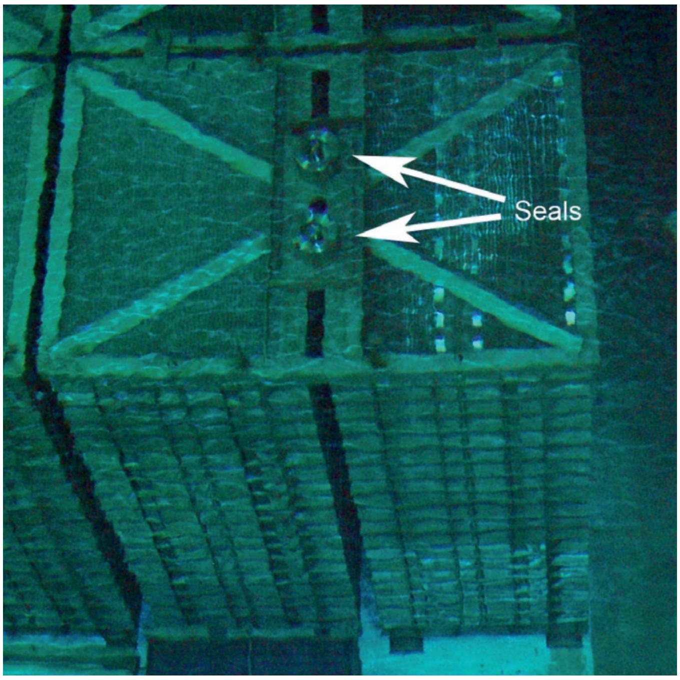

Photo 3: Candu® stack frame.

requirements. The seal must be read with no limitation of time between two readings, giving the same result. It must use the existing handling tools developed for the ARC seals and be compatible with the existing fixing interface (tie-rod).

When the frame cover is in place closing a stacking frame, two seals are attached by tightening them on two tie-rods. The tie-rods are tightened at the bottom of the structure of the bay.

IAEA provided an existing ARC seal [4] and mechanical drawings of the existing tools. Fruitful discussions with AECL and IAEA inspectors yielded the definition of the overall adaptations that were necessary.

Photo 3 shows the cover of the stack frame with its two seals already attached.

3.2. The JRC CANDU® Seal

The JCSS seal is based on the *SILab* ultrasonic core as described before.

There were very few modifications of the exterior of the JCSS seal when compared with the original AECL design (figure 3). Procedures for the handling and attachment of the seal were not changed.

- The cone angle was decreased from 15° to 8°. This allows better positioning of the reading head with respect to the upper part the seal.
- The distance between the hole, used to let water pass through the seal, and the centre of the seal was increased from 12 mm to 17 mm. This hole is also used to position reproducibly the reading head onto the seal.
- A groove is used in the AECL design to fix the location of the AECL reading head upon the seal. As the JCSS seal uses the hole for this locator, the groove no longer exists.

When the seal is attached, the integrity element must completely engage within the grip of the tie rod as shown in figure 4.

When the seal is removed, the integrity element is retained by the grip. The integrity element breaks from the upper restriction. It then falls into the tie rod where it remains. The identity feature remains unchanged [5].

3.3. The reading head

A new reading head is specifically designed for the reading of JCSS seals. The design allows checking the identity and integrity with a single measurement.

The reading head uses the same ultrasonic and motorisation modules as used by EURATOM in La Hague and

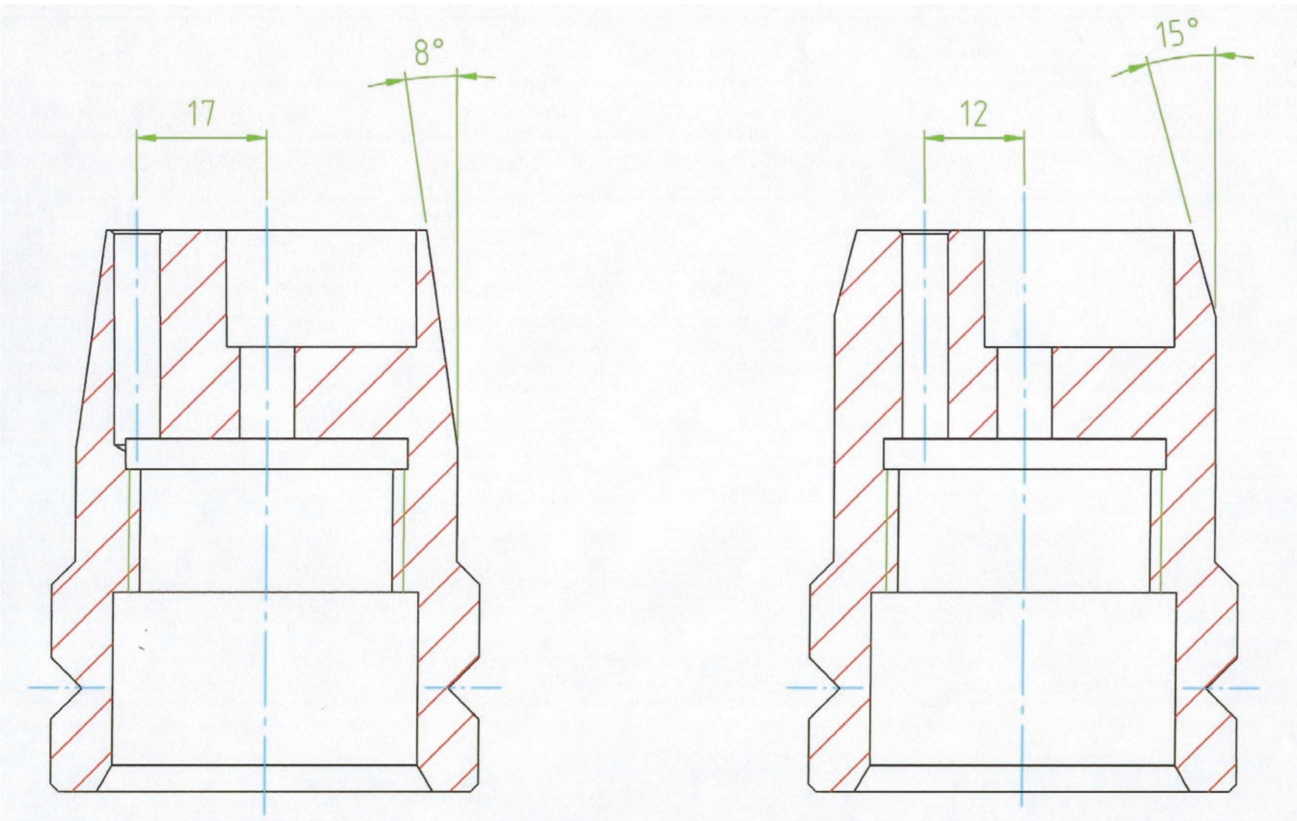

Figure 3: JRC design (left) versus AECL design (right).

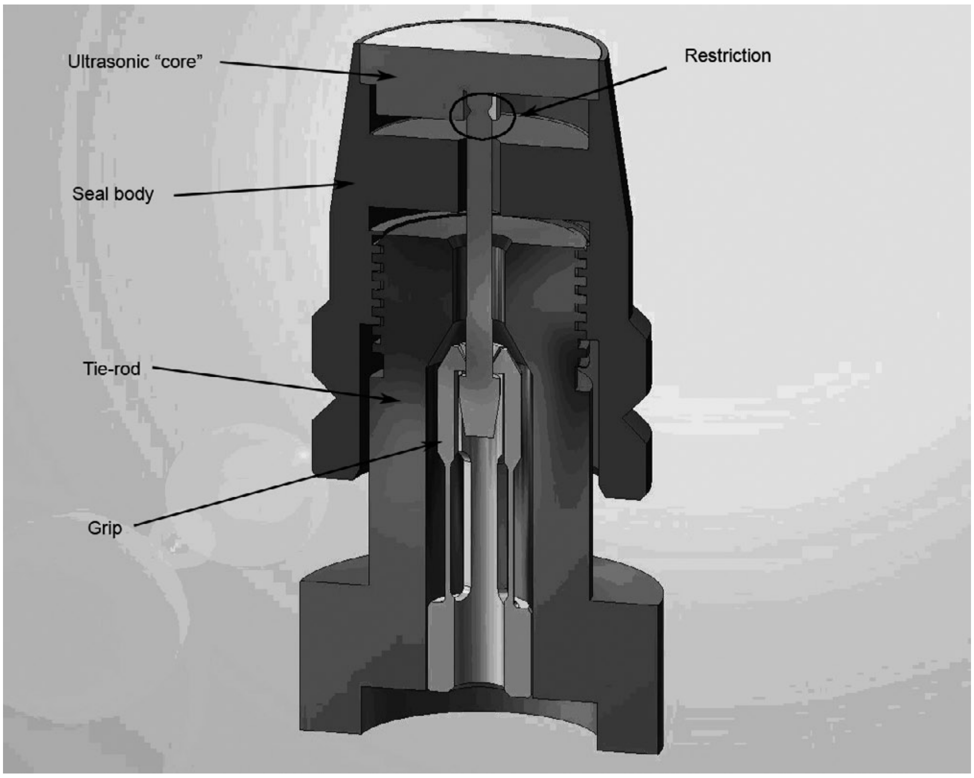

Figure 4: Seal applied in the tie-rod.

Sellafield. The overall geometry has been adapted to the specific shape of JCSS seals. The newly designed reading head has been successfully tested in the equivalent of 20 meters of water.

The mechanical interface on the top is identical to AECL reading heads to use the same tools for the handling.

Photo 4: JCSS Reading Head.

The reading head uses the cone shape of the seal to centre itself on the seal.

The hole on top of the seal is used to position the reading head. A pin of precise diameter will enter in this hole when the reading head is in the correct angular position. For reading, the inspector places the reading head on the seal and rotates it until the pin is engaged. This is an easy operation even with a tool shaft length of several meters.

When a broken seal is read the reading system will detect the absence of the integrity feature but will still be able to check the identity.

3.4. The software

The inspection software was conceived to facilitate "on-site" inspections [6]. The first menu level contains only the functions an inspector requires in the pond area. These functions include seal reference, attachment, detachment and verification (comparison with the reference). Management functions are accessible from a second menu level.

The management menu enables the inspector to look at single measurements, compare two measurements and look at the status of all applied seals.

When measuring seals, the relevant parameters are displayed. These parameters are also saved with the measurement and shown when an existing measurement is displayed.

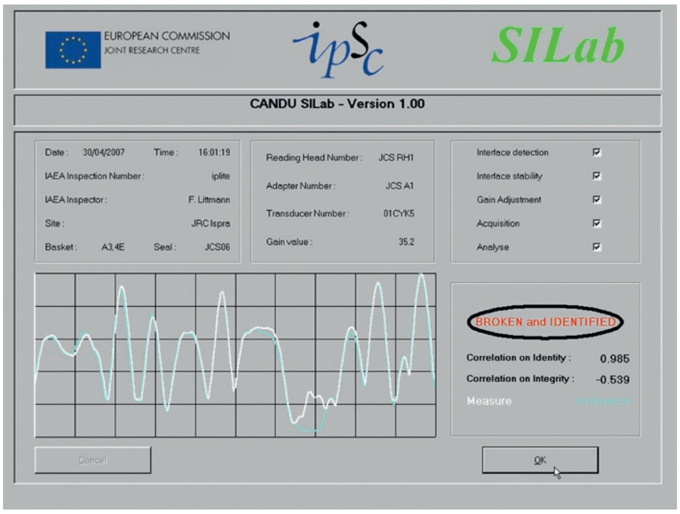

Photo 5: Reading screen of the Candu® software.

After any acquisition, the reading is compared to the reference reading by calculating the correlation coefficient. The result of the comparison is indicated together with the correlation coefficient. The status of the seal is indicated in green, if the seal is both identified and intact. Any anomaly such as "broken" seal is indicated in red (see Photo 5). During a detachment, when the seal is expected to be found broken, the status "BROKEN and IDENTIFIED" is normal, it will then be displayed in green.

The curves (both reference and measured) are shown. The correlation coefficients between the reference and the newly acquired measurement are also shown.

Every stacking frame is sealed with two seals. By convention a stacking frame is identified by its position in a coordinate grid. The seal locations are identified by the stacking frame identifier and the letters E or W, designating that the seal is installed on the East or West side of the frame. As there is no indication of East and West in the bay, it is possible to misidentify where a seal is attached. The software takes this into account. When a seal is found as "Unidentified" in a given position, the software checks the correlation with the seal in the other position to verify the problem was not caused by misidentifying the seal location.

The software automatically prevents an inspector from placing a new seal on a frame that has already been sealed. In cases where seals have been removed from a stacking frame, the software will ask for confirmation before authorising the re-sealing of the frame. This may happen when the fuel bundles have been transferred to dry storage.

3.5. Costs

The final costs of the seals is around 600 € each, when produced in small quantity (50 typically). The main part of the seals (the ultrasonic core) is produced individually and requires manual operations of a specialized technician.

The cost of the acquisition system (reading heads, acquisition system and computer) is 20.000 €. Only one system is useful by controlled area.

4. JCSS development

The development of the JCSS started in mid 2005. The objective was to develop a substitute for the ARC sealing system with the necessity to reuse all the tools already in use used at Cernavoda (Romania), and the substitute should not require frequent inspections.

4.1. Mechanical study of the seal itself

The first part of the JCSS study regards the seal itself. The overall dimensions of the seal are two to three times the dimensions of the ultrasonic seals previously developed at JRC. This has led to different mechanical concepts for the ultrasonic core.

A first attempt was to design an ultrasonic identity that covers all the upper part of the seal itself. This created two

Photo 6: Seal identity using large disks.

Photo 7: Smaller identity.

main problems. First of all, the disks used for the identity had to be flat in order to be brazed. This required having thick disks, with the consequence that the cavities were bigger and easier to reproduce. The second problem was also a consequence of the overall dimensions of the disks; they required more time to reach the temperature required for the brazing process. This longer time makes that some components of the brazing paste will have evaporated before the brazing being effective, leading to badly brazed identities. Such identities can be damaged with shocks.

Photo 6 shows such identities.

A second type of identity was designed that covers only part of the top of the seal, from the center to the side. This permits to have smaller disks and identities. The time required to have all pieces at the brazing temperature is compatible with the volatility of the components of the brazing paste. Photo 7 shows a first design of the different elements of these identities.

This configuration still presents a problem, adding the integrity link to the upper part of the identity (the so-called "delay line") creates a discontinuity in the identity that makes difficult the measure of the integrity. The ultrasonic beam has a diameter on the top surface of the seal that is equal or bigger than the diameter of the integrity link. This results in a low signal, and so possible errors in detecting the signal of a broken seal, but also in easy replacement of the integrity link by malicious people (no mechanical continuity required, only a welding point is OK). The solution consists in integrating the integrity link and the delay line in a unique piece by machining a single steel bar. Photo 8 shows the two configurations. Left is the integrity link that is added to the delay line, right is the unique piece (with already the identity disks brazed).

This seal design phase ended toward in February 2006 when a first batch of seals was supplied to the IAEA for field tests in Cernavoda (Romania). From this date on, no major modifications were made on the seal design, nor on the ultrasonic core, just a few on the mechanical fitting of the seal onto the tie-rod thread.

4.2. Manufacture of the JCSS seals

For these seals, the cores of the seal are realized in a single step brazing process.

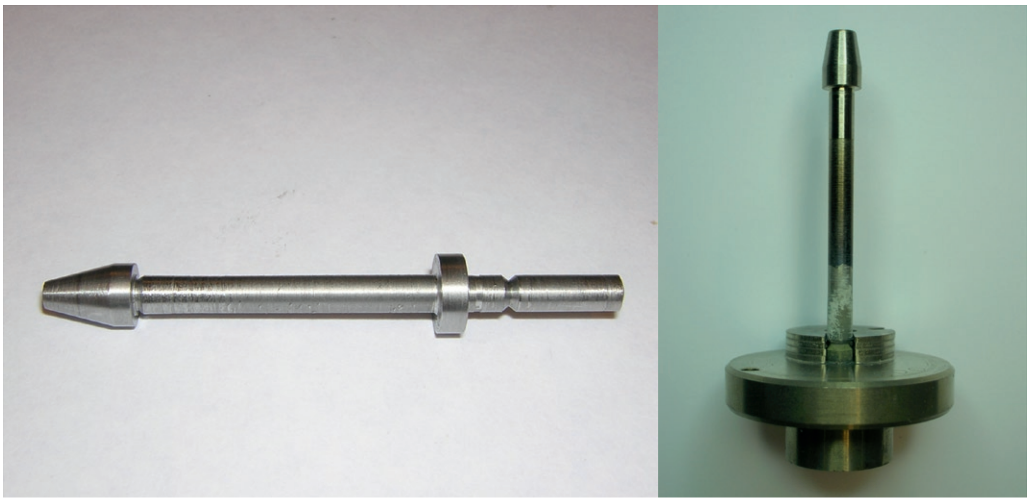

Photo 8: Two solutions for the integrity link.

Photo 9: Heating of an identity (left) and final identity + integrity (right).

Photo 10: Rough body of a seal (left), welded identity of top a rough seal (center) and final machining of the seal (right).

The identities disks are stacked in a random disposition on the integrity piece. Brazing paste is put in several parts of the stack in a quantity that will adequately bind the disks, but not fill all the holes. This assembly is then heated up to 1000°C for several minutes in the furnace.

Once produced, all identities are checked individually. As the diffusion of the brazing follows a random process, it is not possible to predict the identities that will be produced.

The bodies of the seals are machined in two steps. A first partial machining is done to rough out the seal body. Then the identities are welded on these bodies and the final machining of the seals can be done (cone shape).

4.3. Field test on the first batch of seals, February – June 2006

The first batch of seals was delivered to the IAEA in February 2006. They were read at IAEA head-quarters in Vienna and then installed at Cernavoda (Romania) in March 2006. The first verification of these seals was accomplished in June 2006.

Special software was developed for these tests. The correlations between Vienna readings and Cernavoda's yielded very good results (correlation higher than 0.9). The same reading head was used for both readings. Special test software was used for these tests.

A seal was then broken and read again. Photo 11 shows the response of the test system:

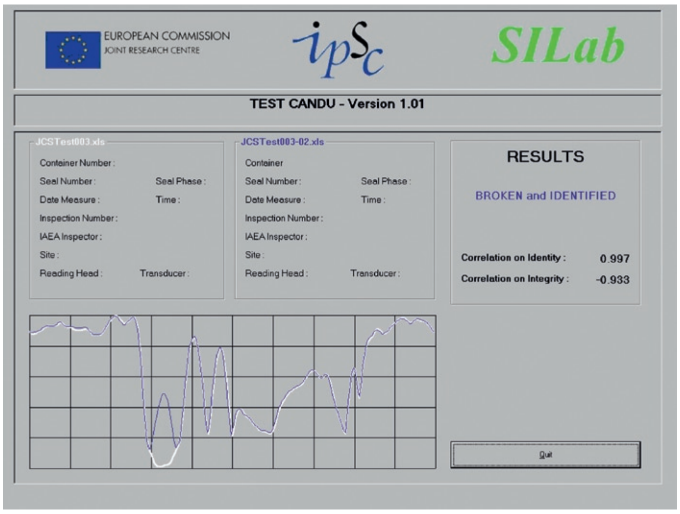

Photo 11: Reading of a broken seal in Cernavoda.

Note: The test software compares two readings without considering the type of readings (reference, attachment, verification or detachment). For this reason, the status is shown in blue.

4.4. IAEA tests in Cernavoda, June 2006 - September 2007

A second batch of 8 seals was supplied in June 2006. A few minor design modifications were made to improve the fitting onto the tie-rod and facilitate the use of the seals.

The seals were read the first time at Ispra with a new reading head. They were then read again in Cernavoda with a second reading head. The correlations between the two readings were all greater than 0.98. This demonstrates that the reading heads can be interchanged.

The June 2006 tests were done with both teams, SILab's and IAEA's. From that date on and for more than one year, the system was used by IAEA inspectors only.

During this year of field tests, the inspectors attached the 8 seals and read them several times using the test software.

4.5. IAEA tests in Cernavoda, October 2007 – December 2008

In parallel with the Vulnerability Assessment (VA) done by Sandia National Laboratories (see next chapter), the IAEA decided to substitute half of the ARC seals with JRC seals.

As the stack cover is secured with two seals, and as it is not possible to access the content of the stack without removing the two seals, it remains safe, from a safeguards point of view to substitute one of the two ARC seals with a JCSS one. The continuity of knowledge is assured by the remaining ARC seal on each stack. This gives also the opportunity to have quickly a return of experience from the inspectors on the use of the system and to propose improvements that could be tested by Sandia during the VA.

In September 2007, the system was presented at Vienna HQ and a training was made for the inspectors who could be involved in Cernavoda operations. This presentation and training yielded several potential improvements that were taken into account in the inspection software (version 1.01) before the ARC seal substitution campaign.

This campaign was done in October 2007 and more than 30 seals were substituted at that time.

Following this campaign, the IAEA made several inspections at Cernavoda, performing attachments, verifications and detachments of seals. Each new stack was sealed with an ARC seal and a JCSS one. Only minor bugs were found and corrected in software version 1.02 available since January 2009.

4.6. Vulnerability Assessment

A batch of fifty seals was produced to support a Vulnerability Assessment. The IAEA requires a Third Party Vulnerability Assessment before a new type of seal can be authorized for safeguards use. A new reading head and inspection software were also produced for this assessment.

All seals were read once with our laboratory reading head and then a second time with the reading head produced for the VA. The correlations between these two sets of readings confirmed the results obtained from the second batch of seals. The median of these 50 correlations was 0.983. The measurements were made using the new inspection software (version 1.00 from August 2007).

The 50 seals, the reading system and the inspection software were supplied in August 2007 to the IAEA in Vienna. The kick-off meeting with Sandia National Laboratories was held in Ispra in January 2008. The software was upgraded following inspectors' requests in the meantime.

The results of the VA are not public, but in December 2008 the IAEA classified the JCSS sealing system in category A (Authorized for operation).

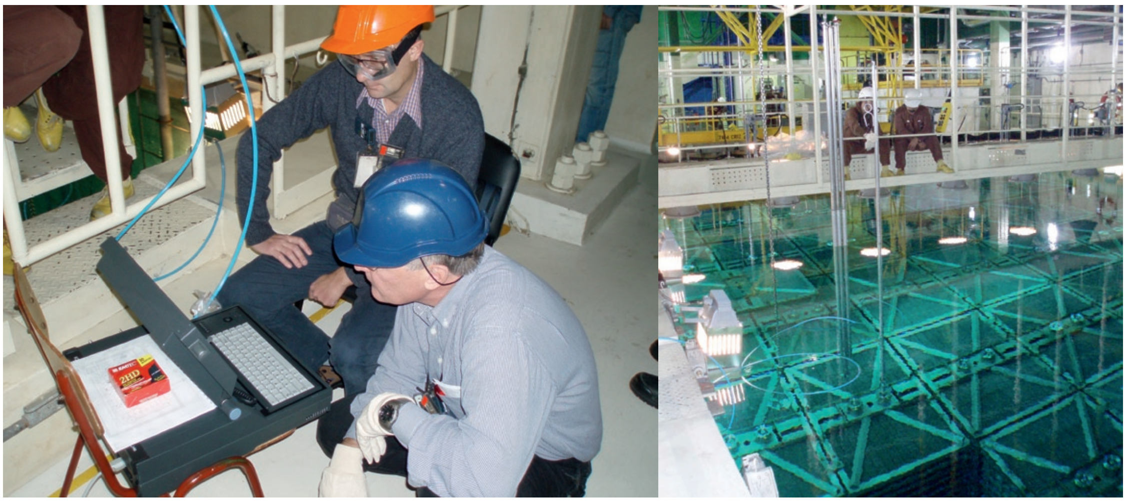

Photo 12: Substitution campaign in Cernavoda, October 2007.

4.7. Substitution campaign, January 2009

Following the classification of JCSS in category A, the substitution of the remaining ARC seals by JCSS ones was done in January 2009. The version 1.02 of the inspection software, correcting the bugs revealed by the inspectors was also installed at that time.

During the substitution campaign, all operations went smoothly and the continuity of knowledge in the spent fuel bay of Cernavoda unit 1 is now provided by the JCSS [7].

5. Other developments of JCSS sealing system

5.1. Cernavoda Unit 2

In 2007, the unit 2 of Cernavoda became operational. The first spent fuel bundles were withdrawn from the reactor core in late 2008 and are now stored in their respective spent fuel bay.

Tools, seals and sealing system were ordered by IAEA to start the sealing operations in 2009. The tools and the seals were delivered to the IAEA for Cernavoda unit 2 in January and February 2009 and the starting of operations is expected soon.

5.2. Kanupp (Pakistan)

Kanupp nuclear power plant in Karachi (Pakistan) is also a CANDU®-type reactor. IAEA investigated the sealing of the spent fuel bay. Up to now, there is no lid to close the spent fuel stacks. Together with Pakistani operators, a study of a system based on the JCSS was done. The designed system allows the closing and the sealing of these stacks.

Figure 5 shows the last proposed solution.

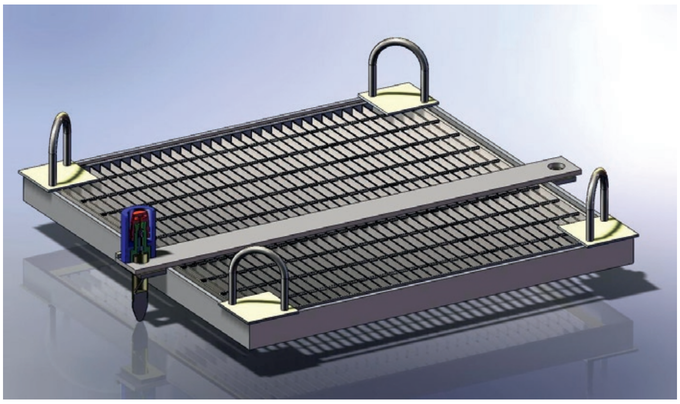

Figure 5: Proposed sealing system for Kanupp spent fuel bay.

The system consists in a grid that closes the top of the stack. On two opposite sides of the stacks are welded two supports that allow the centring of the grid on top of the stack and on which will be attached the seals. On the figure above, only one seal and its support is shown. Seals and reading equipments will be similar to JCSS developed for Cernavoda. The tools will be (slightly) adapted for the Pakistani configuration.

5.3. Constor® container sealing

Together with the Euratom Safeguards Directorate, an evolution of JCSS for the Constor® containers is also under development. These spent fuel containers are used in dry storage facilities. On their top a concrete lid is placed that acts as biological shielding. Continuity of knowledge can be assured if this concrete lid on top of the container can be sealed. There is a gap of air between the top of the steel container and the biological protection to allow dissipation of heat.

Figure 6 represents a proposed solution for this sealing.

In the steel lid of the container is fixed a small tie-rod that passes through the separator between the container steel lid and the concrete biological protection. The concrete lids are built with a specific insert in which the tie-rod will enter. Once the lid is in place, a JCSS seal (in red in the

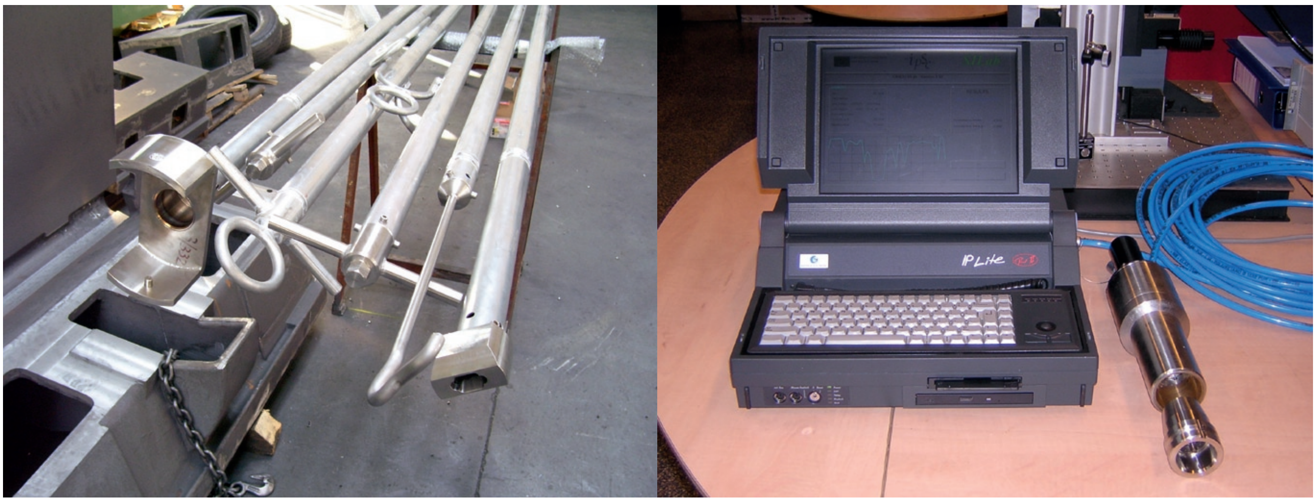

Photo 13: Tools and reading system for Cernavoda unit 2.

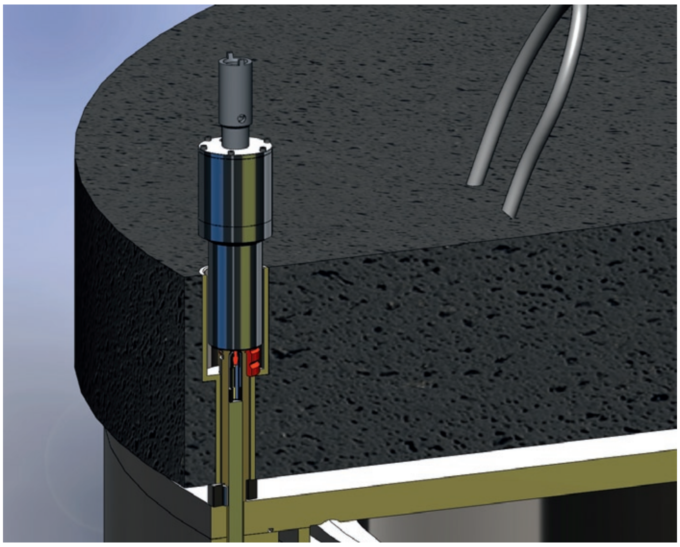

Figure 6: Sealing of Constor® containers (reading head in position above the seal)

above figure) can be applied on the tie-rod making impossible to hold the lid without withdrawing previously the seal.

The seal is based on the JCSS approved seal with only minor changes. The reading head will be adapted for the use in dry condition. Water will be necessary for the ultrasonic beam coupling, and so an external tin will bring a small quantity of water when required [8].

6. Conclusion

SILab developed in these last years a new seal concept (JCSS), based on ultrasonic detection of defects in stainless steel pieces, for the replacement of the ARC seals in the Cernavoda spent fuel bay (Romania). JCSS seals can withstand very high levels of radiation, have a long life time, and can be interrogated in-situ.

Several test campaigns were done to test the seal concept and its utilisation together with IAEA inspectors. A Third Party Vulnerability Assessment was also performed by an external laboratory. As a result of all these tests, IAEA decided in December 2008 to classify the JCSS as category A, authorized for operation.

The implementation of JCSS at Cernavoda unit 1 has been completed successfully in January 2009. Implementation at Cernavoda unit 2 is expected to start in 2010.

New developments of JCSS are ongoing, based on the same system: Kanupp spent fuel bay (Pakistan) and under dry storage conditions for Constor® containers.

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Quality Control in the OSL Rokkasho: Status after Four Years of Operation

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Abstract

This paper gives an overview and describes various components of the Quality System of the On-Site Laboratory (OSL) at the Rokkasho Reprocessing Plant (RRP). The Laboratory has been in active commissioning for four years. The quality of the raw data and of the analytical results are reviewed on a daily basis. Procedures are regularly updated according to the principle that the methods must be 'fit for purpose' and in particular meet the specified uncertainty limits. Calibration- and QC-sample documentation complement the documents on routine samples and on authentication. Recently, OSL intensified its participation in external QC programs, such as EQRAIN and Pu round-robin exercises, in line with its efforts to follow the principles of the ISO 9001 and 17025 standards. Improved methods (e.g. automated column separations, spectra evaluation software), ongoing training of staff members, improved information management, exchange of experts, advanced instruments and tailor-made tools have been developed, reflecting the highly dynamic nature of the work. Examples of processes and results are illustrated, without trying to cover all aspects of the quality management.

Keywords: Nuclear Safeguards; Nuclear Analytical Methods; Quality Control; Quality Assurance; On-Site Laboratory; Reprocessing Plant.

1. Introduction

As part of the safeguards (SG) approach to RRP, the OSL analyzes uranium and plutonium in inspection samples originating from various flow and inventory key measurement points (FKMP's and IKMP's). The sample types include dissolved spent fuel, product solutions, waste, as well as mixed U, Pu oxide (MOX) samples. The analytical activities at the OSL are shared between the Nuclear Material Control Center (NMCC) and the IAEA, because most of the equipment is installed for joint-use. This joint use of a laboratory is perhaps the most individual characteristic of the OSL-RRP, different from the two EURATOM-operated OSL's in Europe. The situation is an advantage and a challenge at the same time.

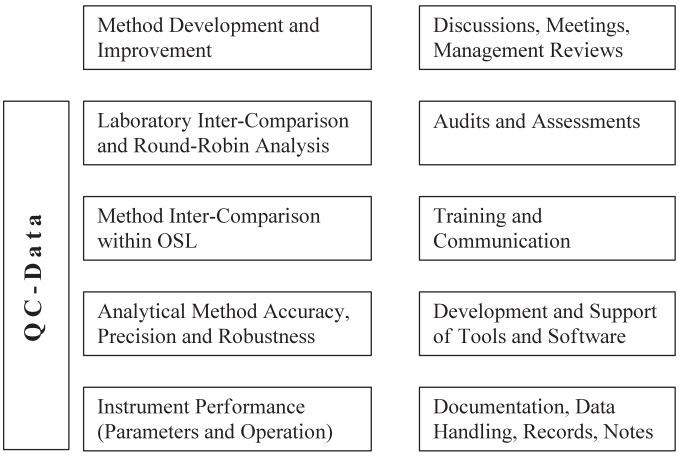
The routine analytical methods at OSL are hybrid K-edge densitometry (HKED), X-ray fluorescence analysis (XRF), high resolution gamma spectrometry (HRGS), isotope-dilution and thermal-ionization mass spectrometry (IDMS), density measurements, spectrophotometry, alpha spectrometry, and last but not least, weighing with high accuracy. They are accompanied by sample pre-treatment and treatment methods, such as solution transfer into evaporation-resistant jugs, dilution and archiving of samples, weight-control, dissolution of solid samples, column separation chemistry assisted by robots, transfer via pneumatic lines and others. The inspection samples are also distinguished by their treatment: in parallel (parallel samples) or jointly (common samples).

In 2008 during a test phase of RRP, the OSL analyzed for example 256 inspection samples (ca. 40% of the designed capacity) by HKED and density measurement. IDMS was applied to 116 samples during the same time period, consuming around 300 large sized dried spikes.

The Quality Control (QC) measures, as one important component of the Quality System, consist of common elements and of separate elements. The common elements are shared between NMCC and IAEA, while the separate elements are applied independently from each side. QC procedures are implemented and documented for the analytical methods, the instruments and for the sample treatment. They are reviewed and updated regularly.

2. Quality System overview

The most important components of the OSL Quality System (QS) are summarized in Scheme 1. Bearing in mind that the OSL is at an early stage and that experience is building up with time, many of the analysis processes are dynamic and evaluative in their nature and aimed at further strengthening the QS by cross-linking processes, e.g. making them multiple redundant.



Scheme 1: Important components of the OSL-QS.

Elements of the QS were set up to ensure the detection of errors, biases, equipment malfunctioning, to track results with respect to the control limits, to allow traceability, to follow the principles of ISO 9001 and 17025, and, among other important aspects, to guarantee the independence of both parties. There are separate and common elements of the QS at OSL as a jointly used laboratory. Among the common elements are, for example:

- Treatment of inspection samples which are designated as common samples, but followed by separate evaluation of the measurement raw data
- Shared QC samples and identical QC acceptance limits, for example for HKED, for the IDMS process, for TIMS, for density measurements and for α-spectrometry
- Calibrations, followed by validation are carried out jointly between NMCC and IAEA, if required with the support from experts in terms of support programs
- Calculation models, error propagation and physical constants are synchronized as applicable
- Computerized logbooks are shared
- Participation in external QC exercises, such as round-robin and inter-comparison campaigns are coordinated and realized in practice in a common mode, followed by separate evaluations, then joint discussion and reporting
- Regular technical meetings are organized with participation of JSGO, IAEA and NMCC, actions are derived and their status reviewed in subsequent meetings
- Large parts of the technical documentation are joint-use, such as instrument manuals
- The development of new tools to support the analytical methods are discussed/designed jointly

Many QC measures have two components, namely separate treatment/evaluation, followed by commonly agreed actions, e.g.:

- QC charts, derived from parameters of the shared instruments and of common QC samples are evaluated separately, then discussed jointly and corrective actions implemented jointly, if required
- Method inter-comparison results are evaluated separately
- Inspection samples in parallel mode are analyzed by each side independently. After final declaration by RRP for a sample, the IAEA compares its result with that of NMCC.

Separate elements of Quality Control include for example:

- The IAEA-own documentation system in accordance with the QMS of the Department of Safeguards
- Reporting of analytical results to the respective Inspectorate
- Data evaluation at the levels of the instruments, the methods and samples
- Strategies and new requirements are developed independently before joint discussions take place
- Team structure, responsibilities within the team and training are arranged independently but information is exchanged between both sides
- Corrective actions are discussed and consolidated within each team, before a joint discussion takes place
- NMC and IAEA track their parallel and common samples and the analytical information separately
- NMCC and IAEA plan internal and external audits separately, but inform each other about such events
- NMCC and IAEA have separate Quality Manuals.

Selected aspects of the Quality System are discussed in the subsequent sections.

3. Documentation

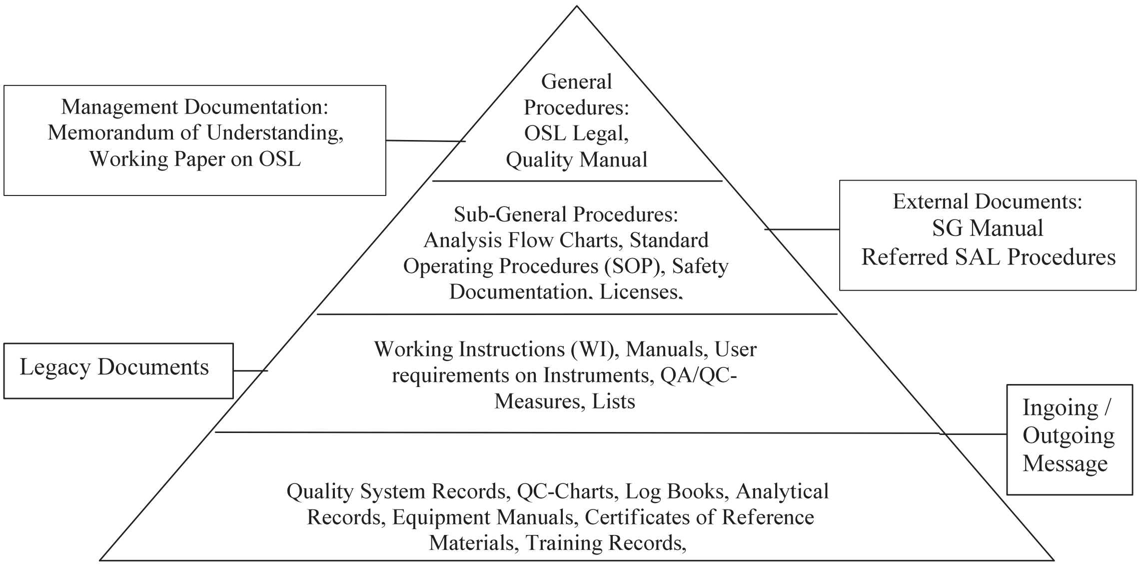
In terms of the Quality System (QS), the analytical core and auxiliary processes are documented at various levels, from general to specific, complemented by SG-specific procedures on authentication, continuity of knowledge and other aspects. Scheme 2 summarizes the levels in the documentation system.

The Quality System of the OSL is not static, but continuously improved and adapted to technical and strategic developments, reflecting dynamic interactions in the complex situation of the OSL in a large reprocessing plant. It is documented in:

(i) The Quality Manual of each side, which gives an overview of the Management System requirements as well as the technical requirements, referring to

(ii) a set of Standard Operating Procedures, Working Instructions and Process flow charts containing detailed procedures and instructions relevant to working of the Quality System,

(iii) Joint-use (IAEA and NMCC) documents, defined as 'OSL Joint Documents' such as instrument user requirements, manuals and QC procedures at the instrument level,



Scheme 2: Documentation system at OSL-RRP.

(iv) Quality System records (functional test reports, log books, records of analyses, certificates of reference materials, quality assurance records, quality standards, personnel records etc.), and associated documents. Comprehensive and up-to-date documentation is an important part of the Quality System, as outlined in the documentation policy. In that respect, the documentation structure (including the analytical data generated) on our server is currently reviewed for updates.

Three high-level joint documents constitute the basis for the operations at the OSL:

(a) The Memorandum of Understanding – The joint use of the OSL at the RRP, between the Ministry of Education, Culture, Sports, Science and Technology, the NMCC and the IAEA which provides a legal binding document

(b) The OSL-Working paper for the On-Site Laboratory at RRP that gathers the principles, working arrangements and expected performances of the OSL

(c) The Joint Notes of Operation that specifically describe all interfaces between the IAEA and the NMCC for the operations at the OSL.

4. Examples in instrument and method performances

The basis of quality control starts on the instrument level: The generated QC data reflect the state of health of the various instruments, such as the short- and long-term stability. Indicative instrument QC data are compared with the limits on every measurement day. The limits are derived from the international target values [1] and the experiences at other analytical laboratories.

4.1. Hybrid K-Edge Densitometry (HKED) and XRF analysis

In HKED, the count rates of the KED- and the X-ray detector during a QC measurement, reflect the stability of the X-ray tube, the detectors and of the sample positioning. The correction factors derived from the intensity of the $U_{k\alpha1}$ line (98.4 keV) in the XRF spectra of a QC–sample are used to normalize the XRF-result to the date of the latest calibration. Similarly, within a certain range, corrections for the high voltage and for the temperature are applied in order to normalize the measurement results to the reference values (150.00 kV, 298 K). Other HKED instrument parameters under routine monitoring are the resolution of the 88 keV peak of the ^{109}Cd sources at the detectors and the reference position of the sample changer.

The measurement results from QC-samples and reference materials are checked against the certified values. For example, OSL implemented a QC-procedure for HKED as recommended by Institute for Transuranium Elements (ITU) of the European Commission Joint Research Centre to measure a certified synthetic sample containing U and Pu in the same batch with an inspection sample. Figure 1 shows the intensity of the $U_{K\alpha1}$ line and the U/Pu-ratio of the QC-sample of one of our HKED-systems during 15 months after a calibration in February 2008. As the U/Pu ratio determination from XRF measurements in HKED mode is a relative method, it depends only indirectly on the count rate, which fluctuates significantly during the period shown in the Figure (1.5% standard deviation). The relative standard deviation of all U/Pu ratio results (two outliers removed) shown in the Figure 1 corresponds to 1.1%.

As additional QC samples, vitrified uranium (glass matrix) at concentrations between 50 and 500 g/L have recently been prepared by OSL staff and normalized during the latest calibration.

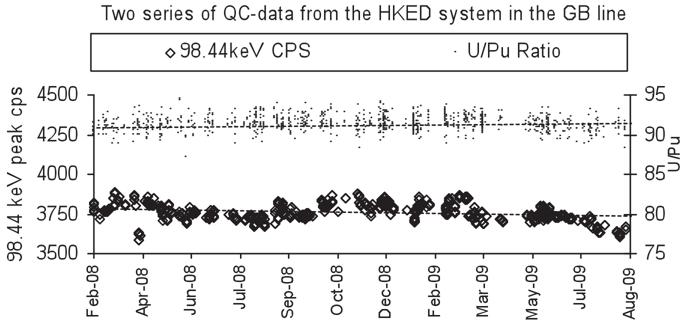


Figure 1: Measured $U_{K\alpha1}$ line count rate and U/Pu ratio (not normalized to compensate for the slight increase in count rate) of a QC-sample containing 214.8 g/L U and 2.34 g/L Pu, measured in triplicate for 1000s in HKED mode over the course of 15 months after a calibration in 2008. A 0.6% increase in sample concentration during the time occurred due to evaporation, but the effect is masked by the uncertainty of the count rate. One of the sources for the count rate variation is maintenance of the equipment.

In order to facilitate the updating of QC charts containing measurement results and instrument parameters, a data retrieval program was developed by Canberra Inc. (Japan) for the OSL.

Another recent improvement at OSL-RRP concerns QC evaluation engines for HKED measurements, which were developed, adapted for OSL and installed by ITU-JRC experts.

4.2. Thermal Ionization Mass Spectrometry

In thermal ionization mass spectrometry (TIMS) with total evaporation (TE) method, two filaments on each turret are routinely loaded with a CRM. The CRM's always used for this instrument/method quality control are NBL-010 and NBL-137. They are suitable with respect to the isotope ratios of the inspection samples received and spiked at OSL. NBL-144 is periodically employed to confirm the instrument stability over a wider range of isotope ratios and that the storage bottle with NBL-137 did not become contaminated. Blank filaments are measured periodically to check the cleanliness of the ion source.

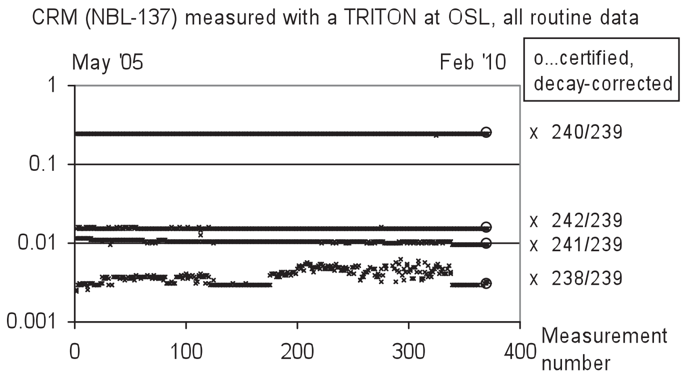


Figure 2: Isotope ratios of NBL CRM-137 measured by TIMS in TE mode at OSL.

Figure 2 shows the measured isotope ratios (atom ratios) of NBL-137 since 2006. One data point of the $^{240}Pu/^{239}Pu$ series is outside of the warning limit (WL). The warning limits are:

$WL_{NBL137:\ 240/239}$: + 0.15% = 1 times the certified uncertainty,
$WL_{NBL010:\ 235/238}$: + 0.3% = 3 times the certified uncertainty.
The decline of the ratio 241/239 in Figure 2 corresponds to the decay of ^{241}Pu. The circles at the end represent the isotope ratios expected from the decay-corrected certified values. The ratio 238/239 reflects a slight contamination of the ion source by uranium, accumulating after baking or exchanging the ion source.

4.3. Method uncertainty

4.3.1. HKED

One of the most important references on the precision of analytical methods are the International Target Values (ITV's) [1], revised in 2010 [2]. In K-edge densitometry (KED) at concentrations above 50 g/L, the limit of the random uncertainty component according to the ITV's corresponds to 0.2%. This compares with a standard deviation of 0.3% for KED-U in a glove-box (GB) environment, derived from calibration data and from IDMS-KED comparison. In the hot-cell (HC) line, the standard deviation of KED-U is slightly higher and corresponds to 0.4%. For KED-Pu, the observed standard deviation is 0.5% for both HKED-systems at OSL, derived from QC-samples and the calibration data, using data till June 2008. Since 2009, the X-ray tubes of the HKED analyzers were allowed to run continuously during the working week, which contributed to the reduction of the day-to-day variation of the HKED-results on QC- and inspection samples.

In this paper, the terms random and systematic uncertainty components are used in accordance with the ITV's [1, 2] which are binding for the OSL-RRP. They are useful for the purpose of evaluation of the operator accountancy measurement systems, as discussed recently [3].

In HKED mode (dissolver solutions, c_{Pu} 1 to 2 g/L), the limits for the random component are 0.2% and 0.6% for U and Pu, respectively. This compares with a standard deviation of 1.0% derived from calibration data and from QC-data of the HC HKED system at OSL in 2008/2009. An alternative approach to determine the random uncertainty by taking into account the contributing sources (Figure 3) gave a comparable result (< 1.3% in 2008). The evaluation of the latest calibration is still in progress. The development in 2009 of new evaluation algorithms of the KED and XRF spectra in terms of a Member State support program is expected to reduce time for measuring passive spectra and release time for the increasing of the count time in active X-ray mode that will contribute to the reduction of the random uncertainties of the measurement results.

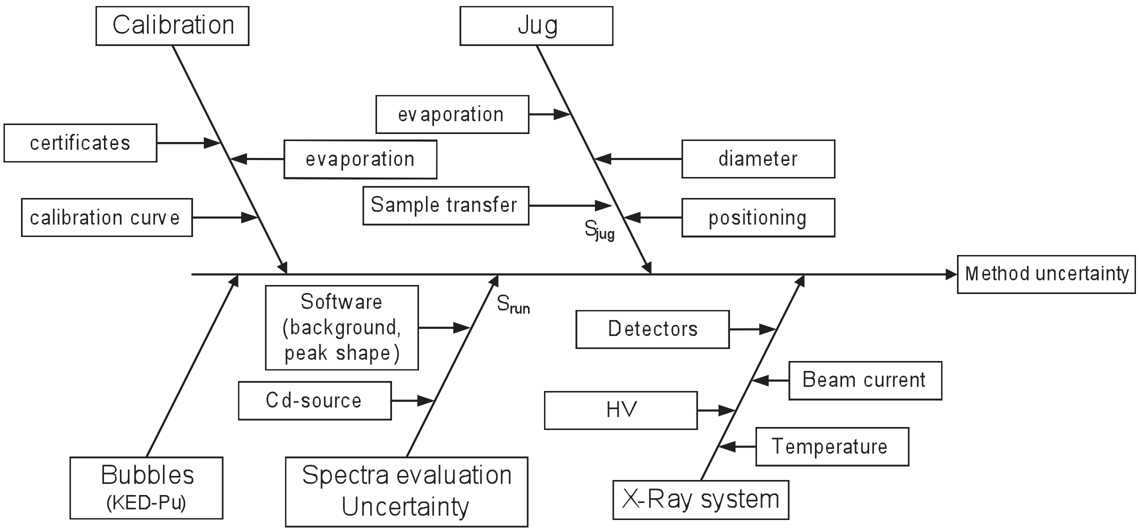


Figure 3: Sources of the random component of the HKED uncertainty.

4.3.2. IDMS

The random component of the uncertainty of a single IDMS plutonium result at OSL was derived from ANOVA analysis by the statistics of data accumulated between June 2008 and November 2009 is 0.18%, that of the average of two spikings per sample is 0.13%. The systematic uncertainty, derived from comparison of IDMS results between different laboratories, is estimated as 0.29%. These values are mainly derived from samples treated under glove box conditions. While the random component meets the criterion of the ITV, the systematic doesn't. There is another way to determine the systematic component, namely by comparing the analytical result with a certified value. In case of uranium, the limit set by the ITV (0.1%) was not exceeded (see Chapter 5.3).

Regarding the isotopic ratios, the standard deviations were derived by comparing results from OSL with another laboratory on 26 selected samples as follows: 0.09% ($^{238}Pu/^{239}Pu$), 0.03% ($^{240}Pu/^{239}Pu$), 0.11% ($^{241}Pu/^{239}Pu$), 0.06% ($^{242}Pu/^{239}Pu$). These values are below the limits defined by the ITV's.

5. Inter-comparison and round-robin exercises

5.1. Comparison between two methods

5.1.1. IDMS and KED comparison

The method of IDMS has lower uncertainties than KED and thus serves as quality control for KED. After a calibration of the HKED system, a validation is carried out. These validation samples are inspection samples with a range of Pu concentration between 100 and 300 g/L, characterized in OSL by IDMS. The spiking and the KED measurement are carried out on the same day so as to trace both results to the same sample composition. Nevertheless, radiolytic decomposition occurs during the KED-Pu measurement in concentrated inspection samples. In two cases (points 4 and 5), the KED result drifted during the triplicate measurements, which is interpreted in terms of gas bubbles growing in the path of the X-ray beam. This can be avoided by a repeat of the measurements after homogenization.

The random uncertainties determined from the analysis repetitions of the results are shown in Figure 4 together with the average results. With the exception of drifts, the method differences are within the ITV (0.3%) for the combined uncertainty components of both methods on this type of samples.

5.1.2. Case example on bias detection

In 2007, the KED count rate of the HC HKED instrument showed a sudden drift by 3% to a lower level. It was detected from the QC sample measurement on the same day as the inspection sample was analyzed and later confirmed by IDMS. 100% of the inspection samples since that day

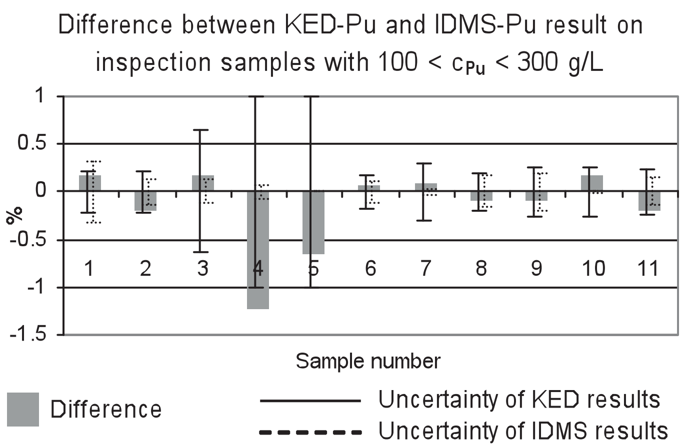


Figure 4: Comparison between KED-Pu and IDMS result (at least duplicate spiking) after KED calibration in October 2009. Points 4 and 5 reflect a drift of the KED result due to gaseous radiolysis products in the X-ray beam during measurement.

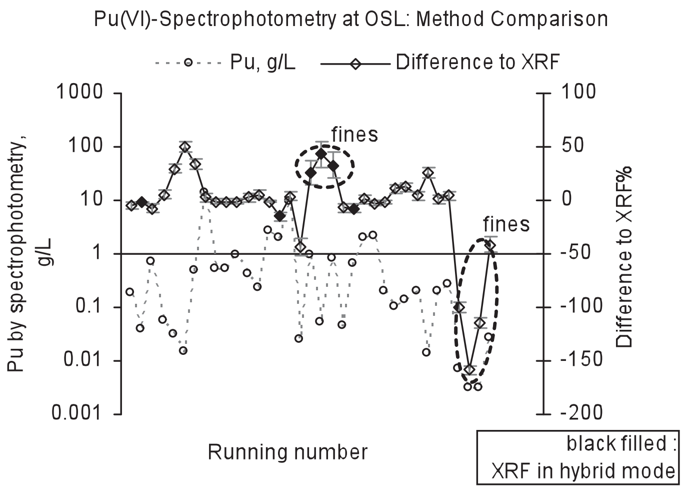


Figure 5: Differences between Pu(VI) spectrophotometry and XRF (standalone mode, except as indicated) for diluted samples.

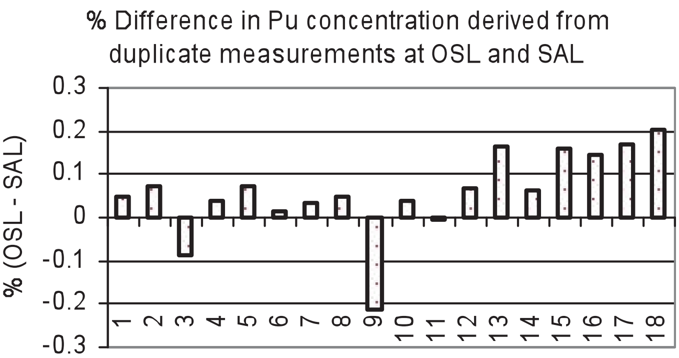


Figure 6: Comparison of results on loaded filaments after shipment from OSL to SAL.

were subjected to IDMS in parallel to HKED until the problem was resolved. Consequently, only the IDMS results were reported by the OSL to the Inspectorate. Eventually, that X-ray tube failed and was replaced, followed by a new HKED calibration. At that time, OSL switched back to routine HKED operating mode with ca. 20% of dissolver samples analyzed in parallel by IDMS for quality control.

5.1.3. Comparison between spectrophotometry and XRF results

Within the calibrated concentration levels and in the absence of solid particles that can interfere with the sample preparation for the spectrophotometry of Pu(VI), the differences between these two methods on low-level concentrations reach 10% at maximum. From this, a random uncertainty of the XRF method in standalone-mode is derived as 3% (sample type: diluted process solutions). The lower limit of the currently calibrated range in XRF stand-alone mode at OSL is 0.5 g/L. The XRF uncertainty increases at low concentrations due to counting statistics and the low XRF to background counts ratio.

Figure 5 shows that the relative difference between spectrophotometry and XRF results significantly increases to over 10% under the following conditions: (i) when the sample contains less than ca. 0.03 g/L Pu, and (ii) when the sample contains fines. It is concluded, that below 0.5 g/L Pu, spectrophotometry is more accurate than XRF, and that interfering particles (“fines”) must be removed prior to spectrophotometry, e.g. by decantation as currently applied. A modified XRF-method is under development in terms of a support program task to account for the matrix in particle-containing samples.

5.2. Data comparison between OSL and SAL on loaded filaments

As part of the quality control and authentication measures, sub-samples are sent from OSL to SAL-Seibersdorf, on average one shipment per year. Due to the radiation limits for transportation, the largest number of different sub-samples can be combined in one shipment by means of loaded TIMS-filaments. As a first exercise on off-site analysis, ca. 80 filaments (40 duplicates), loaded with spiked (IDA) and un-spiked (ISO) separated U- and Pu-fractions of inspection samples, were shipped in 2007 from OSL to the IAEA-SAL in Seibersdorf and measured by TIMS.

In Figure 6, the IDMS-Pu results as calculated from the raw data of this first shipment are compared with the results obtained at OSL on the same samples. It shows the relative difference for 18 Pu samples of different type. All results agree within 0.3%. The slightly positive average discrepancy originates from grown-in ^{241}Am during storage and transportation as seen in the raw data on isotope ratios. A low signal intensity of sample #9 (filaments bent during transport) contributed to the observed discrepancy there. The results confirmed that off-site shipment is an option to confirm the quality of OSL mass spectrometry results, a back-up analytical method, and an authentication measure.

5.3. Participation in round-robin analysis

In 2008/2009, OSL participated for the first time in the EQRAIN-U exercise organized by CETAMA (France). The purpose for OSL was the control of two main measurement methods at OSL: IDMS and KED. Internally within the OSL, we compared results of the two methods with each other in order to confirm the stability of the KED components and to determine the extent of the KED-U non-linearity correction at that high concentration. Inspection samples with such high uranium concentrations (around 400 g/L) are normally not received at OSL and were outside of the calibrated range of KED-U. Additionally, we diluted the EQRAIN samples in order to fall within the calibrated range of KED-U and statistically evaluated all results to derive the random component of the method uncertainty. At the same time, we compared KED-U results between the two systems installed in a glove box and in a hot cell, respectively. The largest absolute difference [OSL – certificate] was 0.05% (IDMS) and 0.17% (KED). These differences are smaller than

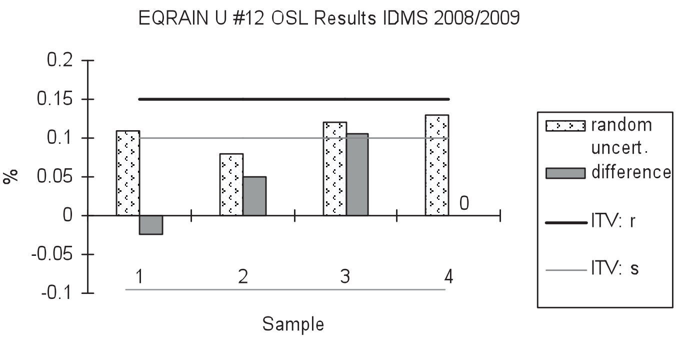


Figure 7: IDMS results of OSL during EQRAIN U round 12.

the maximum uncertainties allowed according to the ITV's and fall within the method uncertainties at OSL, for IDMS even within the uncertainty of the certificate.

Figure 7 summarizes the main results for IDMS: the difference between the average IDMS results (at least triplicate spiking) and the reference values, the random uncertainty within each series, and the ITV's. Overall, the participation in EQRAIN round 12 gave the OSL a good experience in treating external QC-samples and confirmed the approach implemented at OSL that IDMS serves as a accurate internal quality control of the HKED-systems, which are considered as the 'OSL-workhorses'.

In 2009/2010, OSL for the first time participates in the plutonium round robin exercise which is organized by NMCC Tokai-mura. One of the purposes is to confirm the random and systematic uncertainty components of IDMS-Pu under our conditions. The participation in external QC campaigns is also one of the requirements of the ISO 17025 standard, to which the OSL aims to comply.

5.4. Comparison with data provided by the operator

Based on experience gained during the starting phase of OSL and RRP, samples have been selected since 2008 by IAEA out of the regular inspection samples, for which the operator of RRP is requested to analyze them according to a method specified by us and to provide the detailed analytical results after the final operator declaration (OPD) has been released. The results are then evaluated by OSL and discussed in the OSL technical meetings on a monthly basis. Both laboratories, OSL and the operator analyze the selected samples by the same analytical method such as IDMS or KED and measure also the density. Without undermining the independency of the IAEA regarding sample data, the on-going comparison can discover a systematic bias and deficiencies of new equipment. Narrow QC limits, derived from the historic data of this inter-comparison, are applied as upper limit for OSL-OPD differences. For example, for comparing the results of density measurements on samples taken for both laboratories from one tank at the same time, our QC limit is 0.2% (corresponding to three sigma), compared with 1.1% derived from combining the declared uncertainties of the operator and of the ITV's (for OSL). The narrow limits are used in order to quickly discover any systematic errors and deficiencies of new laboratory equipment or of modified methods.

6. Training and external Support

Training is an important part of Quality Control Assurance at the OSL. In addition to internal training, each staff of the (IAEA)-OSL participates in external training on average once per year, either analytical method related or Safeguards-related. Training sessions were for example conducted at the LSS in LaHague, JRC-ITU, Thermo-Finnigan, LANL and SAL-Seibersdorf. New (IAEA)-OSL staff participates in an introductory training at SAL Seibersdorf. In parallel, experts from the European JRC and from national laboratories of IAEA member states and from manufacturers visit the OSL and train the staff, provide updates on new developments and technical support. Thus, new technical developments are accounted for. The consultation with external experts is important also for maintaining the performance of the instruments, such as HKED.

7. Improvements during the first years of operation

In the first years of operation at OSL after commissioning, many processes, procedures and methods were improved. This was necessary in order to adapt them from the original sources (e.g. other safeguards laboratories) to the specific conditions at the OSL-RRP. As key elements of the OSL quality system, procedures and user requirements of SAL-Seibersdorf and of SAL-Tokai were implemented. The experience from these and other safeguards analytical laboratories are beneficial at this early stage of the OSL. An example of an early improvement (beginning of 2007) at OSL was the separation chemistry for IDMS: It turned out that the Working Instruction required modifications to account for the specific conditions at the OSL-RRP. Thus, a bias in IDMS-Pu which was observed between April and October 2006, was traced to technical reasons and resolved.

The current status of all methods is regularly reviewed and improvements are applied on a continuous basis. For example, QC parameters were defined and warning/action limits derived, correction sheets for HKED based on QC-results were introduced, new HKED QC-samples (U-glass) were developed and are now in routine use. For TIMS the dynamic zoom system is now used for focusing the ion beam instead of moving the Faraday cups to avoid causing possible mechanical problems over the years. An important step towards information management was the establishment of a Laboratory Information Management System (LIMS) for the OSL and its databases, which is currently in the 3rd stage of development and integrates the various macros which were developed by (IAEA)-OSL staff during the first years to support the daily work such as calculation and tracking.

In another important aspect, the exchange of information and the communication between (IAEA)- and (NMCC)-OSL was also continuously improved. A system for the information-exchange was established, which includes regular meetings at various levels: The daily operations in the OSL are coordinated in a joint (NMCC and IAEA) morning meeting; the activities for the next week are planned in a weekly meeting. In the monthly meeting, held together with the Japan Safeguards Office (JSGO) and via videoconference with Vienna, the activities and performance results of OSL are reviewed and important developments, conclusions/ proposals and strategic plans are discussed. Actions are derived in the course of these discussions and subsequent meetings discuss the achieved progress on these actions. The annual meetings summarize achievements and performances of OSL and are a platform for strategic planning with external cooperation partners.

Acknowledgement

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[1] International Target Values for analytical methods for Safeguards, ITV-2000

[2] International Target Values for analytical methods for Safeguards, ITV-2010 (draft)

[3] Minutes of the Meeting: ESARDA Working Group on Techniques and Standards for Destructive Analysis, 4 March 2010 (Luxembourg)

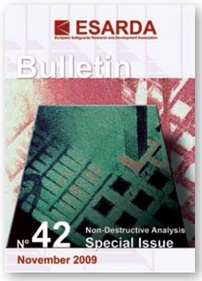
Working Groups activities

Report by the Working Group on Non Destructive Analysis

P. Peerani
Chairperson

The major achievement of the NDA working group is the special issue of the ESARDA Bulletin, number 42, November 2009. This issue was totally dedicated to two reports produced by the working group:

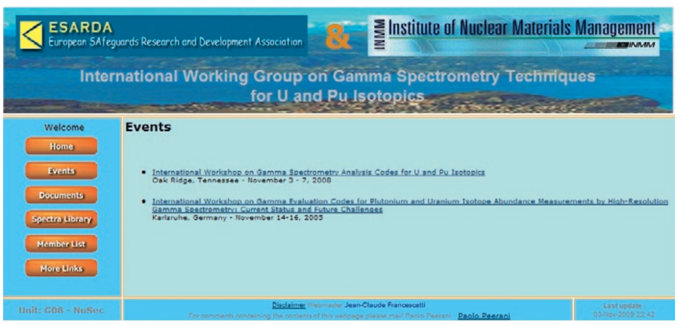
- the ESARDA Multiplicity Benchmark
- the Good Practice Guide for the use of modelling codes in Non Destructive Assay



A rationale and description of the two projects can be found on the Editorial of the Bulletin nr. 42.

Progress was made in the project on "Performance Values of NDA techniques for Waste Sentencing". At the beginning of the year, a questionnaire concerning the collection of performance values was distributed to a number of laboratories performing measurements on wastes. Up to now, 23 answers have been collected by the person responsible for the project, Jamie Rackham. This has already allowed drafting of a quite comprehensive collection of system performances, complementing the already compiled description of NDA techniques applied to various types of wastes. Now the data will be structured in a proper aggregate way in a table suitable for the document. The next version of the report will be distributed and discussed during the meeting at the 2010 ESARDA Annual Meeting.

Another important activity concerns the participation and support that ESARDA NDA-wg members provide to the IWG-GST. This working group, co-sponsored by ESARDA and INMM, gathers gamma spectrometry specialists both from Europe and America, with the purpose to undertake jointly problems related to isotopic measurements of U and Pu with special emphasis on code sustainability, standardisation and validation issues.



The website of the IWG-GST is hosted in a dedicated area of the ESARDA website and is accessible via a link that can be found on the webpage of the NDA working group; the access is controlled through a password.

The first project of the international working group was launched with an important contribution from the ESARDA NDA members. It concerns the development of a testing platform for gamma spectra evaluation codes. It will contain a collection of spectra that can be used by code developers to validate their new versions and by users to test and benchmark the performance of different codes.

The platform will contain different sections with different purposes:

- set of spectra acquired in ideal measurement conditions, mostly devoted to performance assessment of the accuracy of codes in "typical" range of application
- spectra acquired in non-ideal conditions to test the robustness of the analysis to harsh or bad conditions
- spectra acquired in unusual situations in order to test the extension of the application of codes outside the normal operational conditions

The architecture of the testing platform has been approved; the contents, structure and formats are described in a document that can be found on the website. Collection of spectra has started and NDA-wg specialists have agreed to share their libraries. Spectra from the ESARDA "U and Pu reference spectra library" will be also used.

Finally the NDA working group is contributing to the finalisation of the IAEA document "International Target Values 2010". The first draft from the IAEA has been discussed by the working group experts. Comments and recommendations are being collected and will be presented to the IAEA at a Coordinated Expert Meeting planned to be held in Vienna in March 2010.

Report by the Working Group on Training and Knowledge Management

G. Janssens-Maenhout
Chairperson

The ESARDA WG TKM aims and succeeds in stimulating students' interest in safeguards, non-proliferation and security by creating an overview from the legal basis to the implementation of safeguards, including inspection techniques ranging from neutron/gamma detectors and design information verification to environmental sampling, nuclear forensics and combating illicit trafficking.

A two-fold scientific-technical and political-juridical education and training is given by nuclear safeguards and non-proliferation experts from industry, safeguards authorities, regulatory bodies and research centres on a yearly basis, addressing the content as provided in the ESARDA syllabus. With the increasing demand for the course, the WG TKM actively looked for a repeat of its Ispra course at other places (2010: Cadarache, 2011: Stockholm).

In line with the mandate set under the Euratom Treaty (Article 9) "to establish an institution of university status", a close bilateral collaboration with the European Nuclear higher Education Network (ENEN) is maintained with: (1) support of ENEN to the ESARDA course for academic recognition with 3 ECTS[1] points and (2) support of the WG TKM to the ENEN in setting up a European Master in Nuclear Security.

The WG TKM strengthened its international network by actively participating and promoting the international initiative for Nuclear Safeguards and Security Education and Training (NuSaSET). The Institute for Nuclear Materials Management (INMM) is very supportive, and is in the process of establishing a sister Working Group. Common views of ESARDA WG TKM and the future INMM WG TKM were shared and presented at the annual meeting of the American Nuclear Society. Moreover, both engaged in synergy to the establishment of the NuSaSET International Working Group with "Working Procedures", "Content" and "logo".

[1] European Credit Transfer System

Report by the Working Group on Verification Technologies and Methodologies

M. Richard
Chairperson

Abstract

This article presents the history of the creation of the ESARDA Working Group on Verification Technologies and Methodologies (VTM WG). It gives an overview of the objectives, activities and products of the VTM WG as well as the prospects for the years to come.

1. History of the VTM WG

The need for ESARDA to establish a working group addressing the new verification issues raised during the nineties and the new tools to deal with had been identified by Dr. Gotthard Stein supported by some other members of ESARDA. Triggering events were, for instance, the IAEA safeguards crises in Iraq and DPRK, the adoption of new safeguards and non-proliferation instruments to give the IAEA, in connection with protocols additional to comprehensive safeguards agreements, the means to verify not only the correctness of a state's declaration but above all its completeness, and the emergence of new technical means such as environmental monitoring, remote monitoring, open sources information collection and evaluation, to detect undeclared nuclear activities.

Furthermore, the definition of new methodologies to be implemented for verification, the adoption of new disarmament treaties such as the Chemical Weapons Convention, the Comprehensive Test Ban Treaty, the Fissile Material Production Cut-Off Treaty, all the issues related to the former Soviet Union disarmament, the indefinite prolongation of the Non-Proliferation Treaty, the responses to give to the threats of the proliferation of Weapons of Mass Destruction and their means of delivery have been the main issues fuelling the reflexion on the evolution of ESARDA. This illustrates that the rationale for the creation of a Verification Technologies and Methodologies working group is deeply rooted in the history of ESARDA as reported by its current President Ms. Elina Martikka in her article on the forty years' anniversary of the association[1].

The idea of analysing the benefit of synergies with other verification regimes oriented towards the control and reduction of weapons of mass destruction touched an area which has already been addressed by ESARDA in several sessions of symposia, in particular during the ESARDA annual seminar on "Modern Verification Regimes : Similarities, Synergies and Challenges", held at Helsinki in May 1998[2]. Although each verification regime has its own specificity in the implementation of its regulations, the general methodologies present similarities, and some technologies could be used by different systems; important synergies can, therefore, be found and exploited. The discussions held during the Helsinki symposium showed the seeds of the future VTM working group. In 2000, pointing out that the international safeguards and non-proliferation context had dramatically changed since the last evolution of ESARDA, a new reflexion group was set up to allow ESARDA to cope with the new issues. The Reflection Group recommended[3] that ESARDA should give further consideration to the role it can play in helping to keep its members abreast of safeguards-related developments in the wider subject of nuclear non-proliferation. For the possible extension of the interest of ESARDA, a clear distinction is to be made between verification regimes dealing with the nuclear area and verification regimes dealing with non-nuclear areas (i.e., chemical and biological).

To meet this recommendation and to fulfil the need, Dr Gotthard Stein (Forschungszentrum Jülich) created the Verification Technologies and Methodologies Working Group (VTM WG) in 2002 with the help of some other ESARDA members. He was the first Chairman giving the WG its specific work approach and composition of participating experts. The VTM WG held its first meeting at JRC/Ispra in February 2003, in order to draft its Terms of Reference and set up a programme of work and discuss issues of interest.

At least, the ultimate objective of the VTM WG is to help to understand and to, set up what Dr. Gotthard Stein called ***"the big picture"*** which means have a global overview of the international context or the situation of a specific country or a region regarding proliferation taking into account all the information available to build the picture.

1 40 YEARS OF ESARDA: SAFEGUARDS MADE TO ORDER, Elina Martikka, President of ESARDA, STUK - Radiation and Nuclear Safety Authority, Finland.

2 Seminar on Modern Verification regimes: Similarities, Synergies and Challenges. Proceedings of the ESARDA annual seminar, Helsinki, Finland, 12-14 May 1998.

3 REPORT OF THE ESARDA REFLECTION GROUP 2000, M. Cuypers, JRC, Ispra On behalf of the Reflection Group. ESARDA BULLETIN, NO. 31.

2. Mission and objectives

The mission of the ***ESARDA Working Group on Verification Technologies and Methodologies*** stems from the acknowledgement by ESARDA members of the need for a forum where to discuss verification issues of multinational instruments. The VTM WG aims at providing the safeguards community with expert advice on modern verification technologies and methodologies and to act as a forum for the exchange of relevant information in this area. To this end the VTM WG was charged with the following tasks :

- Identify, evaluate and promote verification technologies and methodologies which can be applied in specific verification areas (both nuclear and non-nuclear).
- Assess science and modern technology and identify possible new verification technologies and methodologies.
- Identify and promote research areas for new verification technologies and methodologies and support the creation and realization of research networks.
- Stimulate discussions and communications between different verification institutions in Europe and elsewhere.
- Offer a forum for experts in different verification regimes to meet and exchange ideas on a regular basis.

Figure: Poster on the VTM objectives and activities.

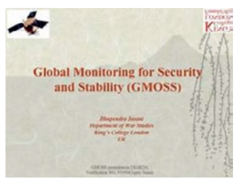
- Encourage the private sector in the development and commercialization of verification technologies and methodologies.

3. Topics addressed

The topics addressed in the VTM WG cover a wide range of verification issues resulting from nuclear and non-nuclear regimes and treaties, leading to research and development of innovative verification technologies, analysing synergies between verification regimes and implementing advanced verification technologies and approaches. It constitutes the workload of the VTM WG and determines the agenda of the meetings. Since its inception in 2002, the VTM WG has addressed topics related to safeguards implementation, non-proliferation, nuclear security, disarmament and treaty verification, technologies/detection equipment, R&D and how to use it, methods of implementation/inspection, verification & monitoring, legal and institutional aspects as illustrated below (inter alia): :

- IAEA safeguards implementation and strengthening
- Research and development of innovative verification technologies
- Synergies between verification regimes: Nuclear, chemical, biological, missiles, conventional weapons
- Implementation of advanced verification technologies and approaches
- Chemical Weapons Convention Verification Regime
- Environmental Monitoring: Verification under the Kyoto Protocol
- Environmental Monitoring: Environment and Wide Area Monitoring
- Comprehensive Test Ban Treaty Monitoring & Verification System

- Nuclear Forensics: Illicit trafficking/bulk analysis
- EU Security: Non-proliferation of weapons of mass destruction (WMD)
- Export Control and Dual Use items issues
- Information driven safeguards: Role of information collection, analysis and integration for International Verification.
- Satellite Imagery and International Security/Remote Monitoring: GMOSS LIMES & GMES, Seismic Monitoring



- Exploring the potential of Novel Technologies for IAEA Safeguards

- Exploring new laser technologies and laser measurements for safeguards
- Proliferation Resistance: Future nuclear systems GEN IV, INPRO, safeguardability
- Preventing the spread of WMD. Expertise from former Soviet military scientists: Discussion of ISTC – STCU issues
- Nuclear disarmament verification: Cut-Off Treaty, excess material disposition, Trilateral Initiative

The VTM WG operates as a transverse working group: The topics which are addressed are strongly linked to those addressed in other ESARDA Working Groups such as Destructive Analysis (DA), Non Destructive Analysis (NDA), Containment/Surveillance (C/S), Implementation of Safeguards (IS), the Nuclear Material Accountancy and Audit Focus Group (NMACAG).

4. Highlights of recent years activities

The VTM WG is involved in the participation and management of meetings in several frameworks:

- First, the VTM WG is actively participating in and contributing to the life of ESARDA, in particular, with paper presentations during the annual conferences and symposia, bringing support to the Steering Committee and Editorial Committee.

  In particular, the VTM WG is fully involved, along with the other WGs and the ESARDA Presidency, in the reflection on ways and means of the possible evolution of ESARDA, in order to address the new international and European non-proliferation and security challenges.

Figure: 1st meeting of the ESARDA Reflexion Group RG2010 JRC Brussels, 21st January 2010.

Figure: 29th ESARDA Annual Meeting Aix en Provence, 2007.

Figure: IS, C/S and IPSC members relaxe after the VTM meeting, ISPRA, 10 November 2009.

- Second, the internal meetings. The VTM WG meets at least twice a year, i.e., during the annual ESARDA meeting in spring and in fall often in coordination with the C/S and IS working groups allowing to have good exchanges on topics of common interest[4].
- Third, several meetings or sessions have been organised to deal with specific subjects such as:
  - Satellite imagery in collaboration with GMES or LIMES (EUSC/Torrejon, October 2009) project members
  - Export Control in cooperation with JRC/Ispra/IPSC and DG-TRADE and the US DOE (Ispra, 2006 and 2008)

4 Presentations made during the VTM internal or specific meetings could be found in the restricted access section of the ESARDA web site either at: http://esarda2.jrc.it/about/organisation/working_groups.html, or at https://circa.europa.eu/Members/irc/securejrc/jrc_esarda/home

– Environmental monitoring (Luxembourg, May 2008) in cooperation with IGSE[5] (*Regina Hagen*, iGSE Coordinator, and *Martin Kalinowski*, Chair)

- Fourth, in cooperation with the International Safeguards Division of the INMM[6] and the local correspondent, the VTM WG organises the joint INMM symposium, gathering about 120 experts and dealing with legal and technical non-proliferation and security issues:

  – In 2003 at Como (Italy) with the JRC

  – In 2005 at Santa Fe (USA) with the US Safeguards Support Programme

  – In 2008 at Tokyo (Japan) with the Japanese and Korean INMM chapters

  – In 2011 in France

- Fifth, active contributions to the INMM Annual Meetings.

5. Prospects and objectives of the VTM WG for 2010 and beyond

For the year 2010, the prospects of the VTM working group and its members, regarding the IAEA, will be to support the safeguards objectives of early detection of non-compliance and the implementation of the information-driven safeguards; regarding the EU external security policy, to support the EU strategy against WMD proliferation through instruments such as the Instrument for Stability, the CBRN task force, the GMES; as far as possible to support the definition & implementation of non-proliferation and disarmament treaties, in particular, the 2010 Non-Proliferation Treaty Review Conference; the inception of the negotiation of a Fissile Material Production Cut-off Treaty; the preparation of the entry into force of the CTBT and the preparation of On Site Inspections. As for the environmental treaty a post-Kyoto reflection will be conducted.

Regarding domestic ESARDA activities, the VTM WG as a transverse working group will work to develop coordination with other ESARDA WG through the organisation of sessions of common interests and definition of joint projects and with EU think tanks (Vertic, IPFM, Insap and others) and INMM.

An important internal objective will be also to update the ESARDA web site VTM WG page as a tool of communication between members and archives of past events. But the objective of utmost importance is to actively contribute to the work of the 2010 Reflection Group (RG) on the evolution of ESARDA.

The issue of the management of the membership has also to be tackled in line with the future outcome of the ESARDA RG 2010: How to mobilise the members for a common project and maintain the links between them as the origin of the members of the VTM WG is rather wide ranging from a large span of laboratories, academics and institutions either national, European, non-European or individual, and the issues addressed are also rather wide ranging as described in section III.

Regarding the participation of the VTM WG in seminars and conferences, the programme is the ESARDA Luxembourg symposium, the INMM Annual Meeting and, on the top of the agenda, the Quadrennial November IAEA Symposium on International Safeguards: Preparing for Future Verification Challenges[7].

6. Organisation and management

The VTM WG has a management team: Michel Richard (current chair), Dr. Gotthard Stein (current vice-chair and former chair), Louis-Victor Bril (secretary), and Prof. Rudolf Avenhaus. Due to the wide scope of issues addressed by the VTM WG and the range of its various activities, the members of the group come from a large span of institutions in Europe and abroad (United States, Japan, Canada, Australia, Russia and others): laboratories & research centres, universities, industry, international organisations (such as the IAEA), European institutions, national regulatory authorities and administrations, think-tanks and Non-Governmental Organisations. The complexity of the VTM WG issues made it necessary to create the following subgroups:

- Environmental Monitoring (chair: Dr. Martin Kalinowski)
- Satellite Imagery (chair: Dr. Bhupendra Jasani)
- A subgroup is also foreseen on Novel Technologies and Approaches for IAEA Safeguards, as an important part of the work of the WG was dedicated to other definitions and the use of novel technologies for the detection of undeclared activities, as defined by the IAEA with the support of the Novel Technology Unit of the Safeguards Department, headed by Dr. Julian Whichello.

Following the proposal by Dr Whichello, the ESARDA Executive Board decided to create a fully independent, new transverseworking group dedicated to Novel Approaches and Technologies, additional to the existing working groups.

The VTM WG keeps close links with other governmental and non-governmental institutions, in particular, with INMM. Individual working group members volunteer to prepare discussions and working papers, subgroups have been established, conferences and meetings with special

[5] iGS: independent Group of Scientific Experts on the detection of clandestine nuclear weapons-usable materials production

[6] INMM: International Nuclear Material Management.

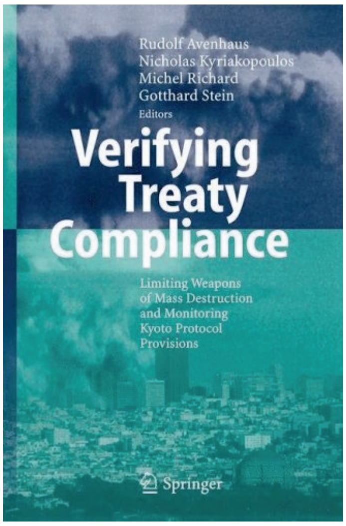
[7] Vienna, Austria, 1–5 November 2010. Organized by the International Atomic Energy Agency in cooperation with European Safeguards Research and Development Association (ESARDA) and the Institute of Nuclear Materials Management (INMM)

topics are performed. An important goal is to publish the results of major activities.

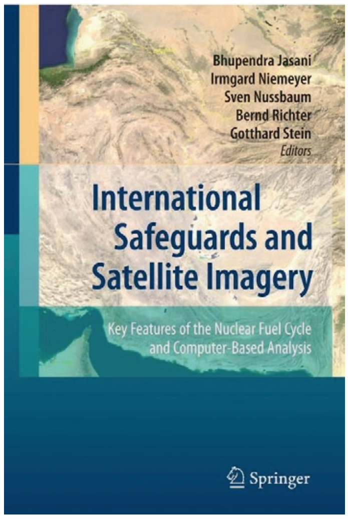
7. Publication and articles

The VTM WG has issued two books:

- Verifying Treaty Compliance: Limiting Weapons of Mass Destruction and Monitoring Kyoto Protocol Provisions, by (eds.) Rudolf Avenhaus, Nicholas Kyriakopoulos, Michel Richard and Gotthard Stein, Springer, July 2006.



- International Safeguards and Satellite Imagery: Key Features of the Nuclear Fuel Cycle and Computer-based Analysis, by (eds.) Bhupendra Jasani, Irmgard Niemeyer, Sven Nussbaum, Bernd Richter and Gotthard Stein, Springer, August 2008.



A further book publication is planned for the complex field of proliferation resistance.

The VTM WG members make presentations at the INMM and ESARDA Annual Meetings and publish articles in the ESARDA Bulletin, in the Journal of the INMM, and in other scientific journals.

Report by the Working Group on Containment and Surveillance

J.G.M. Gonçalves
Chairperson

1. General information

The ESARDA Working Group on Containment and Surveillance has 18 members and observers from R&D establishments, safeguards equipment manufacturers, safeguards inspectorates, plant operators, regulatory agencies, and ministries. The following ESARDA organisations are represented:

- European Commission (Euratom/DG ENERGY, DG JRC),
- Finnish nuclear regulatory authority
- Swedish nuclear regulatory authority
- IRSN – France's Institute for Radiation Protection, Safety and Security
- AREVA
- German nuclear operators (GNS, VGB)
- Jülich Research Centre
- United Kingdom Safeguards Organisation
- Sellafield Safeguards Department

The C/S Working Group includes regular observers from the following organisations:

- IAEA – International Atomic Energy Agency,
- ABACC – Argentine-Brazilian Safeguards Authority
- ASNO – Australia Safeguards and Non-Proliferation Office
- CNSC – Canadian Nuclear Safety Commission
- US Sandia National Laboratories

In 2009, the working group met twice, a meeting in May in Vilnius, Lithuania, and a meeting in November at JRC, Ispra, Italy. The following topics were addressed:

- Performance and assurance of C/S instrumentation
- Guidelines for sealing, identification, and containment verification systems
- Enhanced Data Authentication
- XCam: IAEA's New Generation Surveillance System
- Interface between the EOSS electronic seal and video surveillance
- Trial of 3D laser scanning equipment in France
- Remote Data Transmission system (jointly operated TREN and IAEA)
- Technical Sheet on Laser Based Design Information Verification

Further to the discussions, a technical visit to JRC's Surveillance laboratories was organised in November as part of the November meeting.

Recurrent activities include: general information exchange, discussions on current R & D projects, maintaining a web based compendium on C/S instrumentation, support of ESARDA Editorial Committee, Training and Knowledge Management (TKM) Working Group and, more recently, the ESARDA Reflection Group 2010.

It can be stated that C/S Working Group members normally use the regular meetings to introduce new projects and developments or make early presentations on the first results and updates. During these presentations new ideas can be tested and qualified technical and application feedback is received. Later, members submit papers to other international professional fora, such as the ESARDA or IAEA Symposia or the INMM Annual Meetings. Indeed, six papers, previously discussed in the working group, were presented to the 2009 ESARDA Annual Meeting at Vilnius, and a further five papers presented to the 50th Annual Meeting of the INMM, Tucson, USA. Working group members published articles in the ESARDA Bulletin No. 41 and 43.

2. Progress and highlights of the C/S Working Group in 2009

2.1. Performance and assurance of C/S instrumentation

This topic, which occupied the working group for several years, came to a milestone with a publication by Richter et al, of the main results at the 2009 ESARDA Annual Meeting at Vilnius. Two further articles were published in the ESARDA Bulletin No. 41, June 2009. Due to its interest, the Working Group decided to keep this topic open and continue the discussions on an ad-hoc basis.

2.2. Enhanced Data Authentication System (EDAS)

The EDAS concept enables the sharing of data from sensors (or instruments) owned by a plant operator for Safeguards purposes (as additional information with potential safeguards relevance). EDAS collects the data as close as

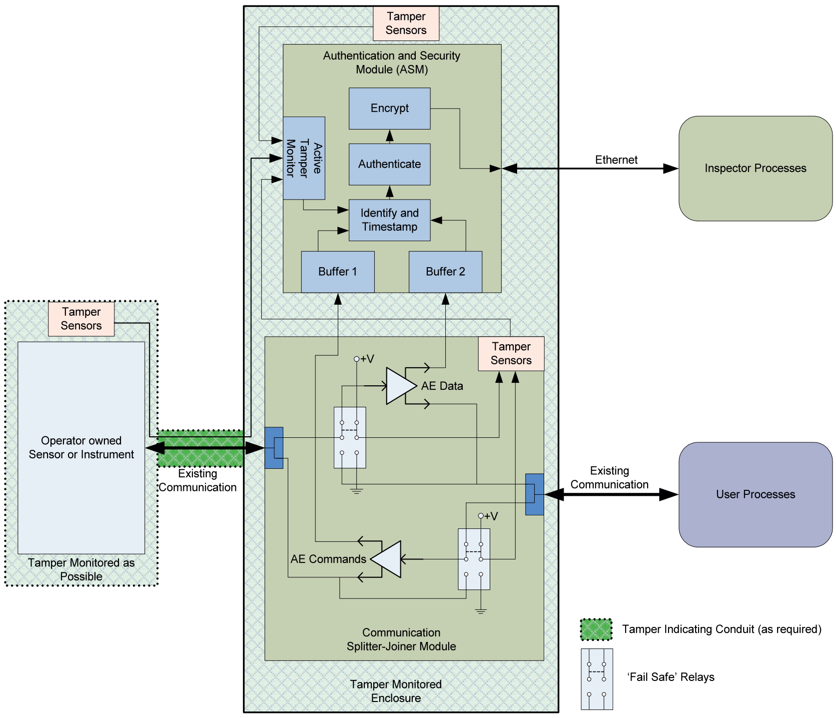


Figure: General Architecture of the Enhanced Data Authentication System – EDAS.

possible to the sensor and provides data authentication and encryption such that Safeguards authorities have confidence in the origin and integrity of the data received.

EDAS is designed as a device to be inserted between the operator's instrument and the operator's process system, so as to monitor all communications (i.e., data and commands), and to register them with additional authentication and encryption. By design, the EDAS does not influence or interfere with the operator process. Subsequent updates on EDAS are expected in 2010.

2.3. Guidelines for sealing, identification, and containment verification systems

This study will lead to a guideline document to be used by developers. Requirements should be regularly updated, considering the progress to be made in terms of Safeguards methodologies as well as the technological evolution. Further, this document will be also useful as a pedagogical document for operators and for newcomers in safeguards. It is foreseen that the study will finish in 2010, with subsequent publication at the ESARDA Bulletin.

2.4. XCam: IAEA's New Generation Surveillance System

XCAM is the new name for the IAEA Next Generation Surveillance System. Its design goals include:

- Integration of the surveillance camera and the security critical components into one tamper-indicating, electronically sealed assembly
- Advanced data security (authentication and encryption)
- Short Picture Taking Interval (PTI)

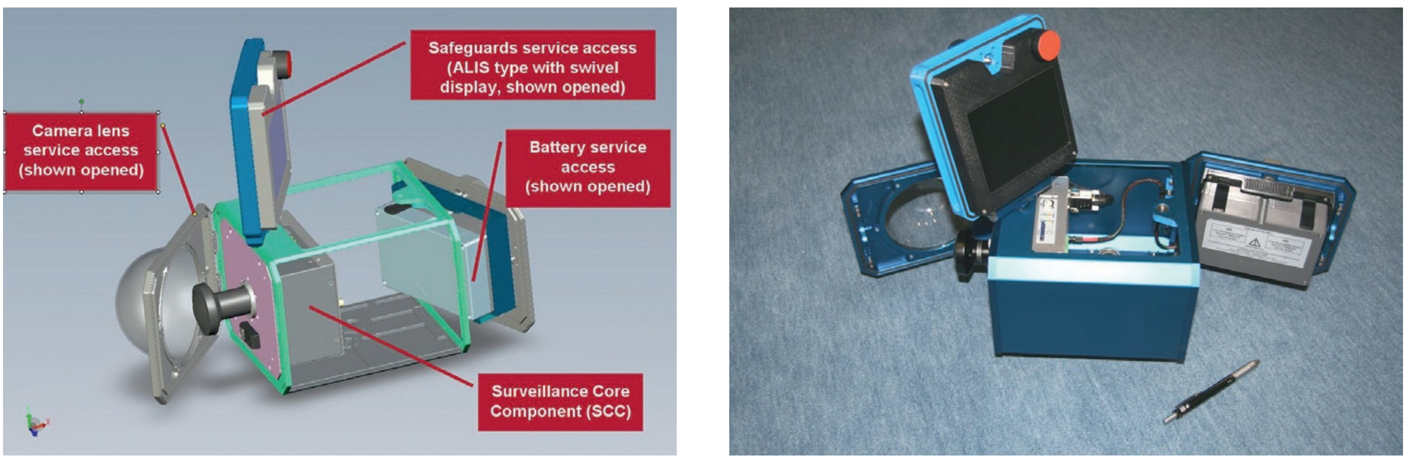


Figure: XCAM: exploded view and existing prototype (courtesy of IAEA).

- Support for high resolution and colour images
- Support for modern TCP/IP networking over Ethernet and possible co-existence with current surveillance equipment (backward compatibility)
- Modular, fully scalable system to allow simpler installation, maintenance and spare parts logistics
- Low power consumption
- High reliability under harsh environmental conditions
- Commercial-Of-The-Shelf (COTS) and non-proprietary components where possible (extended life cycle management)
- Designed to be easily implemented as Joint-Use-Equipment (JUE)

The first XCAM prototypes became available in 2009, and the IAEA has started the required vulnerability assessment studies. The XCAM development is scheduled to be completed by mid 2010. Regular updates to the C/S Working Group on the progress of the XCAM development and its authorization for IAEA safeguards use are expected throughout 2010.

2.5. Trial of 3D laser scanning equipment in France

A presentation on the use of 3D laser scanning at an installation in France was originally made at the Integrated Safeguards Working Group. A later discussion on the same topic at the C/S working group focussed on the technical aspects of the verification system used.

The purpose of these trials was evaluating the capabilities of 3D laser scanning in detecting whether containers had been moved inside a nuclear material storage. Ultimately, the scope is to ensure that containers had been handled in accordance with declaration of the operator.

The initial conclusion is that it seems feasible to use the 3D laser scanning system to confirming the movement of containers (or its absence) in the storage area.

2.6. Visit to JRC-IPSC surveillance laboratory

During this visit it was possible to demonstrate the following sensors and applications:

- 3D Surveillance: a solid state, 30 frames per second, camera capable of providing a 3D image of a scene under surveillance
- L2IS (Laser Item Identification System) Unit: a 3D triangulation laser based system for the unique identification and authentication of UF6 drums
- 3DLR (3D Laser Ranger Finder for Design Information Verification) and 3DLVS (3D Laser-based Verification System): two 3D time-of-flight laser based systems for the accurate modelling of complex scenes "as-built" and subsequent detection of changes
- Laser based 3D System for grid verification: a 3D triangulation laser based system aiming at verifying the physical integrity of separation grids inside the ventilation ducts of a nuclear product residue store.
- OVS – Outdoor Verification System: a 3D time-of-flight laser based system for the accurate modelling of outdoor scenes and buildings "as-built" and subsequent detection of changes.

3. Activities foreseen in 2010

In 2010 the working group is scheduled to meet twice. The following topics are scheduled to be discussed:

- Guidelines on sealing, identification Techniques
- Enhanced Data Authentication System
- XCam: IAEA's New Generation Surveillance System
- Data Security: key management
- Geological Repositories facilities: Continuity of Knowledge
- Interface between safeguards, safety, and security
- Review of Surveillance Data

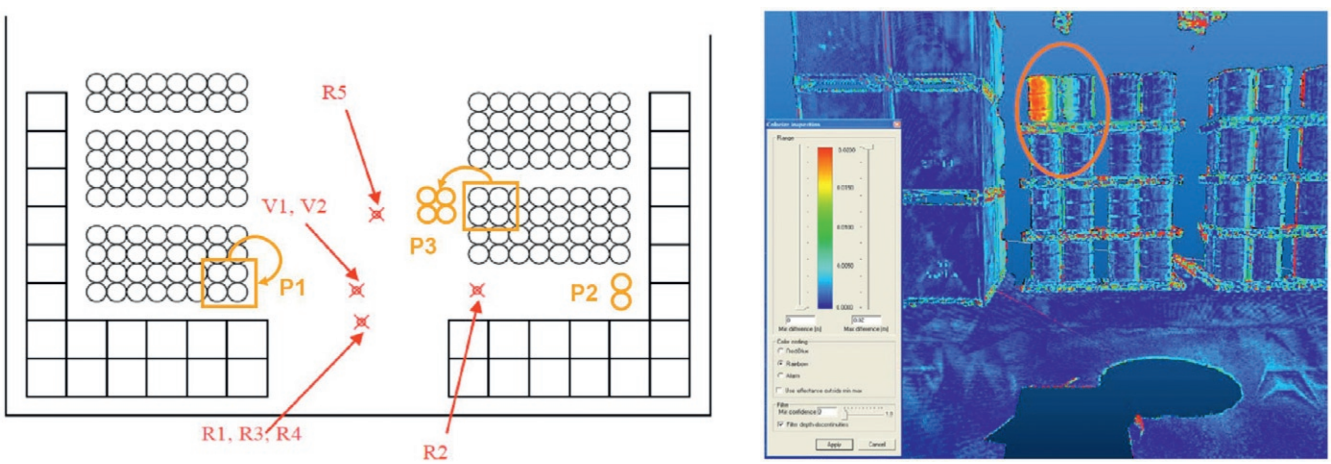


Figure: Description of the container changes made by the operator (unknown to the verification team) and detection of a group of containers put back in, allegedly, the 'same' place.

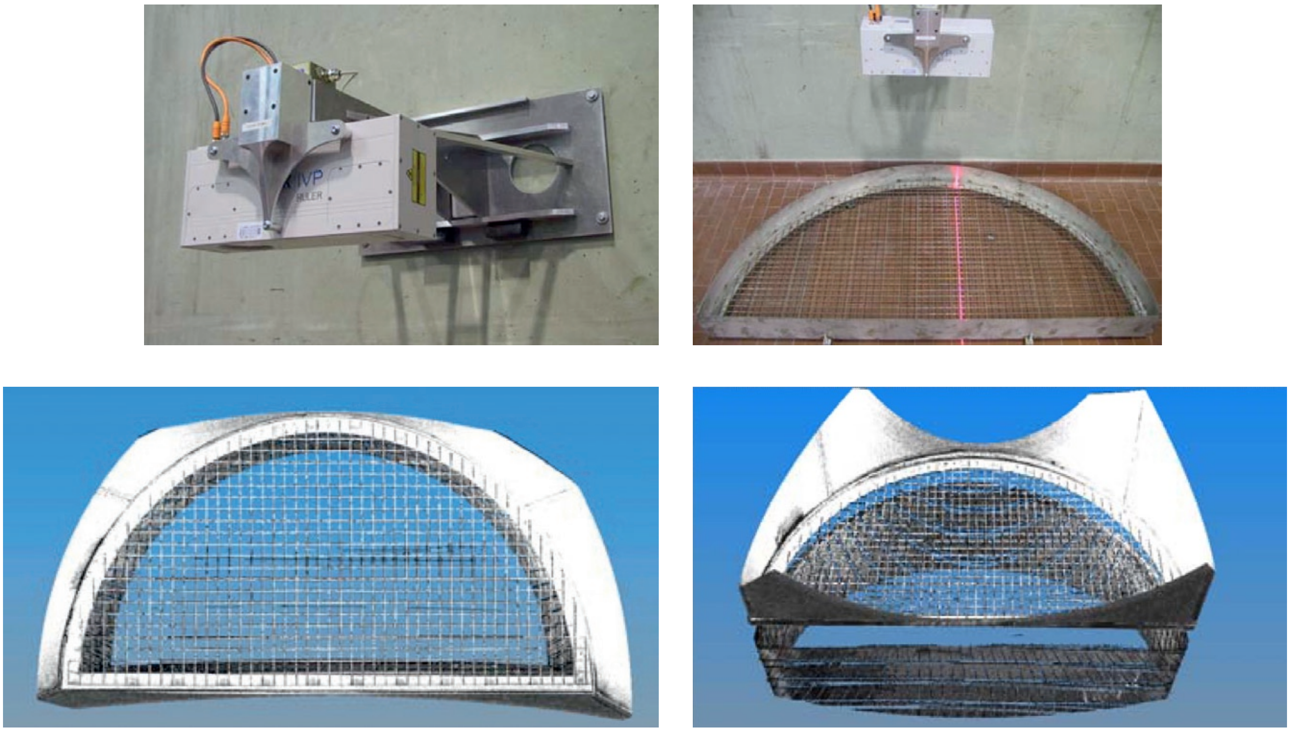


Figure: 3D Laser based System for the verification of the integrity of separation grids.

- Remote system control
- New developments in sealing technologies
- Performance of C/S instrumentation.

The working group will continue contributing to the production of technical material to the ESARDA web site, in particular, Technical Sheets. Three technical sheets are scheduled to be published in the future:

- 3D laser based design information verification (still in 2010)
- cap-and-wire seals
- optical surveillance techniques.

The working group is discussing with other ESARDA working groups (e.g., NDA and IS Implementation of Safeguards) the opportunity to hold joint meetings to discuss topics of common interest. This may happen already in the second half of 2010.

Report by the Working Group on Standards and Techniques for Destructive Analysis

K. Mayer
Chairperson

Non-proliferation, nuclear safeguards and nuclear security remain high on the political agenda as underlined in the recent nuclear security summit in Washington. The technical challenges associated with the verification of treaty compliance are also reflected in the work program of the ESARDA WGDA. Moreover, questions related to nuclear security receive increased attention and new, investigative analytical techniques are being implemented. The information revealed through these advanced analytical techniques, enables checking the consistency of material inherent parameters with declared operations and processes. The WGDA engaged in 2009 in a couple of activities addressing the application of advanced analytical techniques.

Chemical impurities are a candidate set of parameters that could provide information on the history of nuclear material. Impurity patterns are studied for nuclear forensics purposes and measurements of trace elements in uranium are being investigated as tool in nuclear safeguards. In a dedicated workshop (hosted at ITU Karlsruhe, 17-19 March 2009), the group addressed the challenges and opportunities associated with the measurement of chemical impurities in uranium. Experts from different scientific communities (nuclear industry, environmental science, safeguards and nuclear forensics) exchanged their experience in the field in order to formulate the needs and requirements, to identify measurement challenges and to identify evaluation challenges. The group recommended issuing a best practice document for impurity measurements, encouraged laboratories to report uncertainties and detection limits when providing results, invited CETAMA and IRMM to give consideration to an interlaboratory comparison and to consider the production of an appropriate set of reference materials. Apart from the challenges related to the actual measurement, the group recognized also the discuss methodologies for data evaluation, including the use of statistical tools and the respective data pre-processing. A detailed report on the observations and conclusions of the workshop was published in the ESARDA Bulletin (December 2009).

Target Values for uncertainty components in the measurement of nuclear material for accountancy and verification purposes was a major product of the group. The IAEA had taken over the concept in the early 1990’s and released “International Target Values 1993” (jointly with ESARDA, INMM and other expert groups). A revised version of the ITV’s was published in 2000 and after a decade, an update appeared necessary. In the past year, the WGDA started reviewing a draft document on International Target Values (ITV’s) 2010 as prepared by the IAEA. A dedicated workshop was held in early March 2010 in Luxemburg and addressed the individual values provided for different method/material combinations as well as the overall presentation of the tables. In particular the consistency with the GUM approach (ISO Guide for the expression of Uncertainty in Measurement) was discussed. The points elaborated by the group were presented at the Consultants Group Meeting on ITV’s in Vienna, which was hosted by the IAEA.

The group prepared a review of the “Action Plan and Success Indicators”, which defines a multi-annual work program for the WGDA. The document was finalized during the internal meeting in Luxembourg in early May this year.

Overall, the WGDA has progressed very well along the lines defined in the latest update of its Action Plan (2007) and released the deliverables as indicated in the success indicators.

From 'Integrated Safeguards' to 'Implementation of Safeguards'

A. Rezniczek
Chairperson

The ESARDA Integrated Safeguards working group (IS WG) was founded in the year 2000 to cope with the challenges arising in the context of the implementation of the IAEA Additional Protocol (AP) in European Union Member States. The AP is now in force in the EU since more than 6 years and it's successful implementation and application was one of the prerequisites for the transition of IAEA safeguards to the 'Integrated Safeguards' (IS) scheme. The IAEA defines IS as *'the optimum combination of all safeguards measures available to the IAEA under comprehensive safeguards agreements and additional protocols to achieve maximum effectiveness and efficiency in meeting the IAEA's safeguards obligations…'*.

At the end of 2009, the IAEA and the European Commission reached agreement to implement IS in all non-nuclear weapon States of the EU with significant nuclear activities. This achievement also represents an important milestone for the work of the ESARDA Integrated Safeguards working group and was a good reason for a retrospection that the WG conducted in the autumn meeting 2009.

In 2009, the IS WG held two meetings, one in April in Stockholm and one in November in Ispra. The main topics, besides our customary round table information exchange, were in Stockholm presentations and discussions on how states were preparing for the introduction of Integrated Safeguards (IS), e. g. how to cope with short notice inspections or unannounced inspections, and presentations on IS concepts for final disposal facilities. In our meeting in Ispra we had, among others, topical presentations on trials of 3D laser scanning equipment and on the development of guidelines for designers to facilitating the implementation of IAEA safeguards. As the main activity we reviewed the country specific IS concepts and the WG achievements in the preparation for the implementation of Integrated Safeguards.

As a common opinion it was stated that the most important reason for now 10 years of successful work lays in the WG's function to serve as an independent forum for the exchange of information and views, for open discussion aiming at the understanding of the intentions of the provisions of the AP and IS. Over the ten years of its existence, the WG was always growing. The composition of the WG ensures a broad range of practical expertise in all aspects of safeguards implementation and since the ESARDA WGs do not have any political mandate, discussion could be passionate and take place without constrains owed to political courtesy. The intensive information exchange and the presentations given led to a deep insight in and better understanding of the specific circumstances in the different countries that had to be taken into account for the implementation of IS. The WG members thus got a complete picture of the safeguards realities in many EU Member States and learned how specific problems are dealt with in other countries. This was a good basis to develop harmonised solutions to common problems.

The status now reached with the introduction of IS in all relevant EU Member States is in our view a big milestone but not the final aim of the WG. Among the expectations expressed by the WG members for the future of the working group was to continue with the collection and evaluation of IS accomplishments, to continue with considerations on the further development of IS concepts, e. g. the transition from a State Level perspective to a Community Level perspective and to broaden the scope of the WG to cover not just IS but also other safeguards implementation issues.

These aspects were taken into account by the ESARDA Executive Board in its meeting in January 2010. The Board decided to rename the Integrated Safeguards Working Group to "**Implementation of Safeguards**" WG and thus enlarge the area of activities for the WG while preserving the established acronym IS WG. Another decision taken by the Board was to shift some tasks of two working groups that will terminate their regular activities to our IS WG. These two working groups are the Working Group on Fuel Fabrication Plants (FFP) and the Nuclear Material Accountancy and Audit Focus Group (NMAC AG) and our IS WG will cover those activities where the broad range of practical expertise in safeguards implementation matters as represented in the IS WG will be required. As a consequence, the IS WG has to rework their terms of references in the near future.

The cover illustrates Edgar Schein’s model of culture.

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