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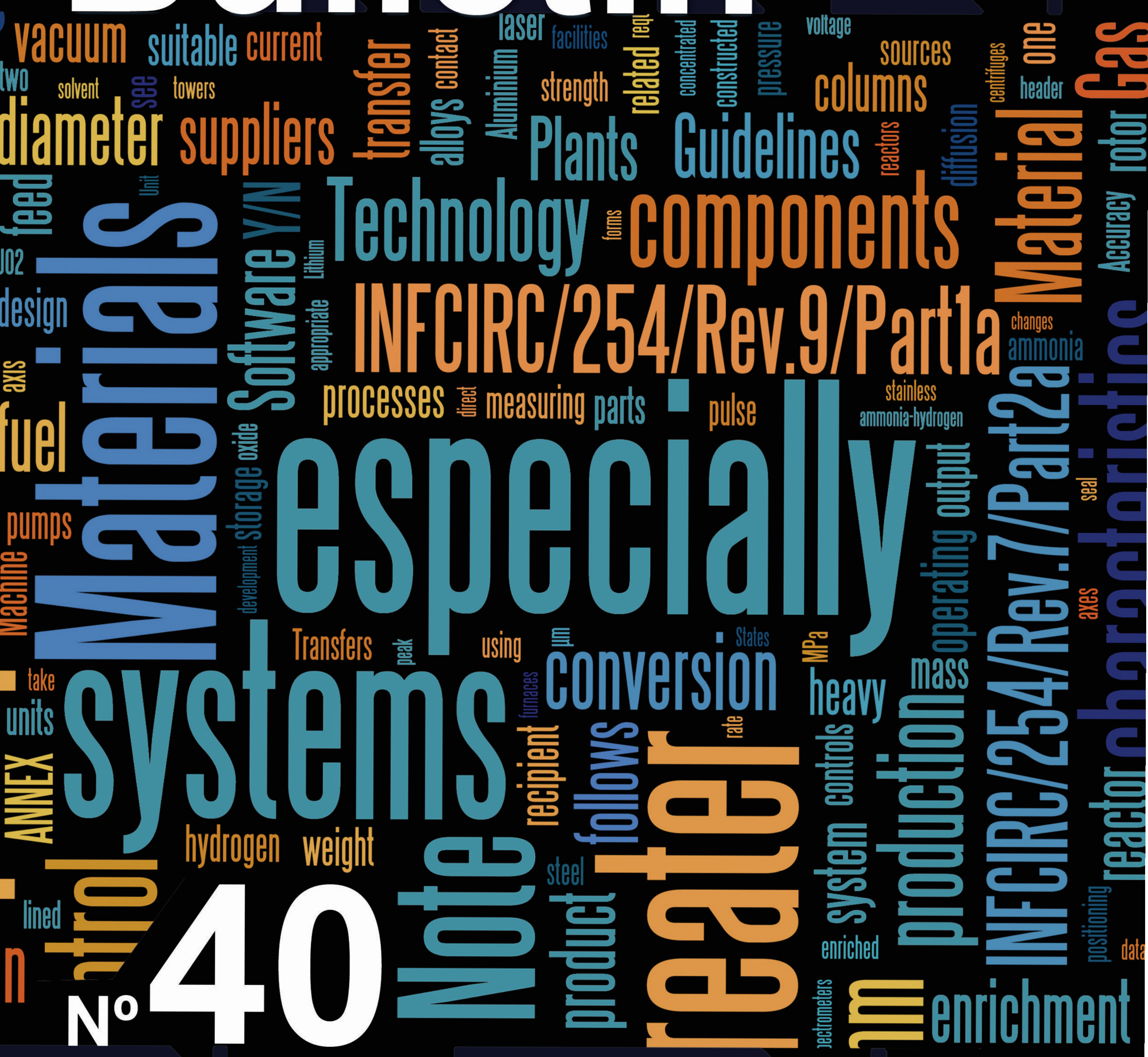
European Safeguards Research and Development Association

Bulletin



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Editorial

A Word from the ESARDA Editorial Committee

B. Autrusson
Chairman

Since 2006, the Editorial Committee publishes the regular Bulletin twice a year, in June and December. A special issue is published on demand, generally once a year. I take this opportunity to thank warmly the authors contributing to our association's reputation and sharing with others their experience and knowledge. I also thank my colleagues of the Editorial Committee for their prompt and exhaustive review work.

To continue on track, the Editorial Committee has taken early this year dispositions to ensure the efficiency of the publications. Submission of papers is encouraged throughout the year. However, in order to finalise the issues in time, the following agenda has been defined:

For the June Issue:

- April 1st is the limit for submitting a contribution to the peer-reviewed section;
- May 1st is the limit for all other kinds of contributions.

For the December Issue:

- October 1st is the limit for submitting a contribution to the peer-reviewed section;
- November 1st is the limit for all other kinds of contributions.

For the upcoming issues, the Editorial Committee intends to review and publish all the (accepted) contributions submitted before the deadline. We ask authors to submit their contributions as soon as they are ready. Extended versions of papers presented in ESARDA symposia are also welcome, and may be published in the Bulletin.

For this Bulletin n°40, two working groups reported on their activities. The authors focus in particular on the discussions occurring during their regular meetings and workshops, concluding that such manifestations are key moments for fruitful exchange.

The DA Working group has summarised the latest of their yearly workshops, dedicated to the measurement of minor isotopes in uranium. The workshop is a place to exchange views and information about current safeguards community needs. The paper presents some applicable mass spectrometric techniques and discusses the quality of measurement results for minor isotopes of uranium. The next workshop, to be held in 2009, will focus on impurity measurements in uranium.

The VTM Working Group organised a one-day seminar, wrapping up a discussion about the export control of dual use items in 2006. Experts from various national organisations in Europe and in the United States, as well as experts belonging to the nuclear industry, to research institutions, to the European Commission, and to the International Atomic Energy Agency (IAEA), participated and presented papers. Some of those papers are published in this Bulletin.

Additionally, a review of the Technical Assistance to the Commonwealth of Independent States – the TACIS support programme – is presented in this Bulletin, featuring the results of past collaboration, the follow-up programme being implemented and an overview of the JRC expertise that can be used in new nuclear safeguards and security programmes. Since 1994, nine projects have been implemented in three recipient countries (Russian Federation, Kazakhstan and Ukraine) within the Commonwealth of Independent States (CIS) by two of JRC's Institutes: the Institute for the Protection and Security of the Citizen (IPSC) – Ispra (Italy) and the Institute for Transuranium Elements (ITU) – Karlsruhe (Germany).

The ESARDA Bulletin publishes a variety of papers, covering both political and technical perspectives and discussing the interplay between the two. This diversity is valuable and constitutes much of the interest that a reader can have in the ESARDA Bulletin. Preserving this value is in the interest of the safeguards community. Therefore, the Editorial Committee encourages all safeguards experts and actors to report on their past or projected work.

ESARDA News

Announcement of a Workshop on Impurity Measurements in Uranium Samples

ESARDA Working Group on Destructive Analysis

Uranium materials hold much more information than what is normally exploited for safeguards evaluation purposes. The information inherent to the material arises from isotopic, from microstructural or from chemical properties of the sample. The chemical impurities in uranium samples may be native from the ore or process-inherited (either intentionally added or introduced as minor constituents of reagents or from the corrosion/abrasion of vessels and containers). As a consequence, the chemical impurities provide a wealth of information on the provenance of the material and the process it was subjected to. Reliable measurements of trace element concentrations in uranium and the interpretation of the data are the basis for exploiting this source of information.

The ESARDA Working Group on Standards and Techniques for Destructive Analysis (WG DA), in close collaboration with the IAEA, is organising a dedicated workshop on impurity measurements in uranium samples. The workshop will be held on 16 and 17 March 2009 at the Institute for Transuranium Elements (ITU) in Karlsruhe, Germany. The workshop aims to illuminate the relevance of impurity data for safeguards, non-proliferation, nuclear forensics and other applications. Safeguards authorities, fuel manufacturers and analytical laboratories are invited to participate in the workshop, to exchange views and experience in this area.

In particular the workshop will address:

- Needs and requirements of IAEA Safeguards
- Needs in other areas (e.g. fuel manufacturers, nuclear forensics)
- Methods and instrumentation used
- Instrument calibration and standards
- Sample preparation and contamination control
- Measurement performance, limits of detection and quantification
- Internal and external quality control
- Data evaluation techniques

As a result of the workshop, we expect recommendations on protocols for sample collection and sample preparation, on analytical methods, on data evaluation techniques and on methodologies for identification of characteristic impurities. Based on the discussions during the workshop, a set of performance recommendations for impurity measurements shall be elaborated, complementing the current set of International Target Values for Measurement Uncertainties of Nuclear Material for Safeguards.

More information can be obtained from K. Mayer (Klaus.Mayer@ec.europa.eu) or Y. Aregbe (Yetunde.Aregbe@ec.europa.eu).

5th 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 masters 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 non-proliferation system and how this sytem 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 in particular with 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, focussing 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 Organisations.

What is the methodology to verify: Nuclear material accountancy principles and statistics of 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 organisation

The course features a full five-days program with 1h lectures by experts in the field of nuclear safeguards, visits to five safeguards laboratories and some classroom exercises.

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://npns.jrc.it/frameset.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 31 December 2008. 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 charges.

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 3ECTS, 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 30th, 2009 at 8:30 till Friday, April 3rd, 2009 untill 18:00

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.

R. Berndt leads the nuclear measurements at the Performance lab in the JRC with large experience in gamma spectrometry.

B. Burrows joined the British Nuclear Group in 1975 for nuclear material management and recently changed to the UK Nuclear Decommissioning Authority.

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.

M. Franklin has been working in the JRC safeguards program since 1978 and is specialist in mathematical statistics.

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

D. Grenèche is assistant director of Research and Innovation (formerly COGEMA: Companie Générale des Matières Nucleaires) 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 safeguards unit at IPSC JRC Ispra.

M. Lesage is assistant director of Non-Proliferation and International Institutions in the International and Marketing Department of COGEMA (AREVA).

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 organisation.

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.

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).

Nuclear Safeguards and Nuclear Security Related TACIS Projects Implemented by the JRC

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Abstract

Following the breakdown of the former Soviet Union, the European Commission (EC) initiated a Technical Assistance to the Commonwealth of Independent States, the TACIS support programme. In the initial phase, essentially, nuclear safety projects were funded under the TACIS programme. From 1994, projects related to nuclear safeguards were included in the TACIS programme.

Since then, nine projects have been implemented in three recipient countries (Russian Federation, Kazakhstan and Ukraine) within the Commonwealth of Independent States (CIS) by two institutes: the Institute for the Protection and Security of the Citizen (IPSC) – Ispra (Italy) and the Institute for Transuranium Elements (ITU) – Karlsruhe (Germany).

After 10 years, the successful EC-CIS cooperation has evolved from a demand-driven to a discussion-driven relationship in areas of mutual interest and benefit. The new programme, taking into account new international threats, includes combating of illicit trafficking while sustaining past initiatives within an enlarged international cooperation. This new programme deploys 14 projects in 7 countries.

This paper presents the results of past collaboration, the follow-up programme being implemented and gives an overview of the JRC expertise which can be utilized in a new nuclear safeguards and security programme.

Keywords: nuclear safeguards, nuclear security, illicit trafficking.

1. Introduction

Following the breakdown of the Soviet Union, the international community realized the importance of nuclear safety and security issues in the Commonwealth of Independent States (CIS). The 1992 G7 summit in Munich decided to give the leadership to the European Union to address the corresponding problems. Upon the request of Member States, the European Commission (EC) created the TACIS (Technical Assistance to the Commonwealth of Independent States) programme. In a first step, projects tackled the most urgent problems related to safety of Soviet-design nuclear power plants. In September 1994, the EC decided to include in the TACIS programme projects for establishing improved accountancy and control of nuclear material and a more reliable safeguards system.

While the United States' safeguards support focused on the removal and physical protection of weapons grade material, the EC approach was centred on the civilian fuel cycle. The efforts were based on the following three pillars for a sustainable improvement of nuclear material accountancy and control:

- Training on safeguards methodology,
- Transfer of nuclear analytical capabilities,
- Development of instrumentation in cooperation with Russian industry.

In a further step, activities related to nuclear security were also developed. These essentially dealt with analytical capabilities for characterizing nuclear material intercepted from illicit trafficking. In their 1996 meeting in Moscow, the G-8 States expressed their will to combat illicit trafficking of nuclear material and initiated the foundation of the "Nuclear Smuggling International Technical Working Group" (ITWG). The JRC has been co-chairing this group (together with the Lawrence Livermore National Laboratory) since then, and actively contributed to its work. Also in the framework of the TACIS programme, increased attention was attributed to the issue of illicit trafficking. UN resolution 1540 (of April 2004), the Proliferation Security Initiative (PSI, launched in 2003) and the

Global Initiative to Combat Nuclear Terrorism (of July 2006), reaffirmed the considerable concern of the international community about the threats associated with proliferation issues and with illicit trafficking. The political will needs to be translated into concrete measures, some of which may be of an organizational nature while others will be of a technical nature. The development and implementation of the latter requires technical expertise and competence in this specific area.

2. JRC Competences

The Joint Research Centre is one of the 24 Directorates General of the European Commission; it is specifically dedicated to direct research European R&D. It consists of 7 thematic institutes hosted in 5 Member States. Two of them deal with safeguards and nuclear security, i.e., the Institute for the Protection and Security of the Citizen (IPSC) and the Institute for Transuranium Elements (ITU). Both institutes have more than three decades of experience in dealing with nuclear material and in all safeguards-related issues. They provide support: (1) to the Directorate General Transport and Energy (DG TREN) in implementing the Euratom Treaty; (2) to the IAEA for the Non-Proliferation Treaty; and (3) to the Directorate General for External Relations (DG RELEX) and to Europe Aid Co-operation Office (DG AidCo) through their participation in the TACIS programme.

The scientific support to the TACIS nuclear safety and security projects is based on:

- The recognition of JRC as a centre of excellence;
- The institutes' unique infrastructure and facilities for developing, applying and deploying up-to-date techniques and state-of-the-art methodologies; and
- The implementation of safeguards activities in a neutral way, i.e., independent of national or private interests.

In particular, the JRC is well recognized by the international scientific community for:

- the development of techniques, equipment and methodologies;
- on-site assistance;
- the provision of training; and
- the evaluation and qualification of safeguards equipment.

The specific competences of the JRC acquired in the safeguards area have been made available to a number of cooperation partners and customers. These scientific/technical competences have been transferred and applied to nuclear security issues, in particular to combating illicit trafficking. The two JRC institutes do have distinct and fairly specific competences that complement each other.

2.1. The Institute for the Protection and Security of the Citizen (IPSC)

The Institute for the Protection and Security of the Citizen (IPSC) is located in Ispra, close to Milan, Italy. The areas of expertise of the Nuclear Safeguards Unit of the IPSC are essentially in:

- Nuclear Material Accountancy and Control (NMAC), including relevant technologies such as mass and volume measurements, process monitoring and near real time accountancy;
- Non Destructive Assay (NDA) techniques;
- Containment and Surveillance techniques;
- Test and certification laboratory for safeguards and measurement equipment; and
- Corresponding training capabilities.

The Nuclear Safeguards Unit of the IPSC coordinates the JRC support implemented under the TACIS programme. Part of the support is directly deployed by IPSC based on its own competences and capabilities as described above.

2.2. The Institute for Transuranium Elements (ITU)

The Institute for Transuranium Elements (ITU) is located in Karlsruhe, Germany. ITU plays a pioneering role in fighting illicit trafficking of nuclear materials. The ITU has relevant expertise in:

- Radiochemical and Radiometric Measurement Techniques;
- Materials Science;
- Particle Analysis;
- Fuel Cycle Materials; and
- Corresponding training capabilities.

In particular, based on its technical infrastructure and modern analytical laboratories, the institute has established a new discipline in science available to support the investigation: nuclear forensics. Nuclear forensics may provide clues on the origin, the intended use, possible route and last legal owner of seized material.

Another possibility, to prevent not only diversion but the production of relevant nuclear material, is to detect undeclared facilities and/or activities. ITU has developed competences in the analysis of micrometer sized particles for this purpose.

The nuclear forensic capabilities of ITU are made available through collaboration agreements with requesting countries [1]. Nuclear material seized in a State can then be transported to ITU and is subjected to a thorough analysis, which is generally carried out with participation of an expert from the requesting country.

3. The Model Action Plan

After having gathered initial experience in nuclear forensic investigations in the first half of the 1990's, it was realized that a comprehensive approach needed to be developed, enabling credible nuclear forensics. ITU, as a co-chair of the International Technical Working Group on Nuclear Smuggling, took the initiative to develop a Model Action Plan within the ITWG. Today, the JRC strategy for nuclear security is based on the Model Action Plan. This plan provides an integrated and common response to illicit trafficking and makes use of a three steps approach (prevention, detection and response), including feedback and lessons learned to enhance the deficient situation at the origin of the incident (i.e., the place of theft or diversion of the nuclear or radioactive material).

3.1. Prevention

The very first step of the Model Action Plan concerns prevention of the diversion of nuclear materials. This is based historically on the implementation of physical protection and safeguards measures. The latter are mainly based on Nuclear Material Accountancy and Control, analytical techniques, containment and surveillance and a system of (independent) verifications. Consequently, all measures improving the physical protection and control of material will reduce the risk (or the likelihood) of theft or diversion. An IAEA document provides useful guidance in this respect [2].

3.2. Detection

Historically, illicit trafficking cases were mainly detected by intelligence, border control or, sometimes, by chance. Capabilities have been extended to the detection of radioactive materials in response to the potential threat of a Radiological Dispersive Device in a terrorist attack. The European Commission currently supports programmes to deploy equipment for detection, in particular considering the outside borders of the growing European Union. Upgrade (in terms of quality and quantity) of detection equipment at key points (border crossings, airports, seaports etc), and improved exchange of information between law enforcement and intelligence communities, will significantly increase the detection probability. The detection at borders is described in detail in an IAEA document [3].

3.3. Response

The response process is normally managed by the law enforcement services in close collaboration with radiation protection services. Measurements at the incident site are carried out to assess the radiological threat and to categorize the material. Experience has shown the usefulness of the support of a measurement expert support team (MEST), i.e., a team of measurement experts with mobile equipment, providing expert advice at the "crime scene". Once the material has been categorized as nuclear material, it needs to be transported to a safe and secure (and licensed) storage place. Nuclear forensic investigations may reveal information on the origin, the in-

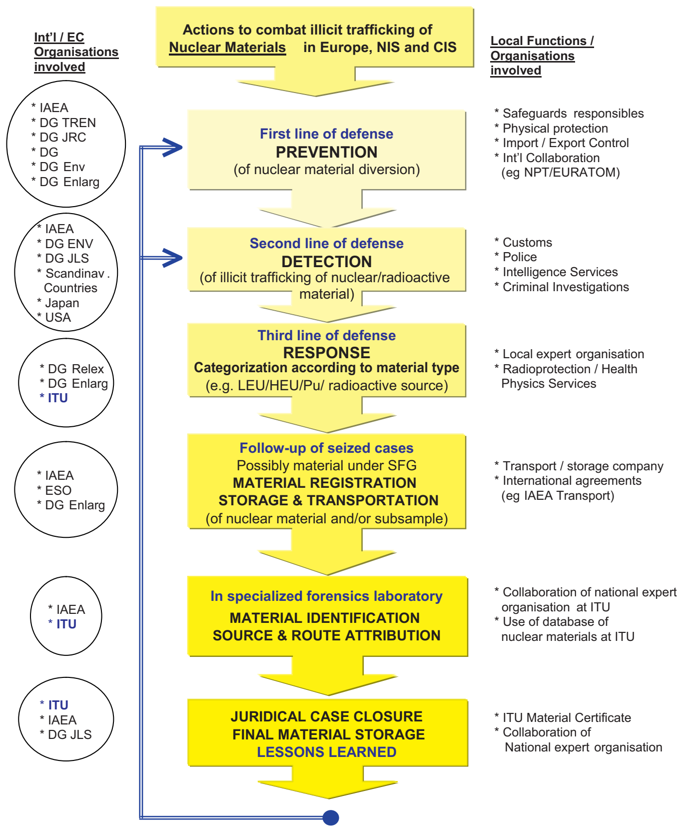

Figure 1: Schematic presentation of the Model Action Plan describing the main steps in combating illicit trafficking, the international organizations involved or cooperating with the newly independent states and the responsibilities to be taken over at each individual step

tended use, the last legal owner and possibly also on the smuggling route of the material. Preservation of evidence throughout the investigations (from the incident site to the laboratory) is a condition to reach credible conclusions. Also, the prosecution aspects need to be covered. Case closure is achieved with the relevant loop, providing feedback for necessary corrective actions at the origin of the material, i.e., strengthening prevention [4].

4. Focus on Prevention: the TACIS Support Programme 1994 – 2004

Since 1994, nine projects have been implemented in three beneficiary countries (Russian Federation, Kazakhstan, Ukraine) by two JRC Institutes: the Institute for Systems Information and Safety, ISIS, that was later renamed the Institute for the Protection and Security of the Citizen – IPSC- Ispra (Italy) and the Institute for Transuranium Elements – ITU – Karlsruhe (Germany).

A summary of each project with its main focus is listed below:

- IPPE: Support towards the creation of dedicated training centres for nuclear safeguards and Material Control and Accounting (MC&A):
    - Russian Methodological and Training Centre (RMTC) in Obninsk, in collaboration with US DoE;
    - Ural Siberian Methodological and Training Centre (UrSiMTC) in Snezhinsk;
- VNIIA: Establishment of a production strategy of instrumentation for the State System of Accountancy and Control (SSAC) of Nuclear Materials in Russia with the All Russia Research Institute of Automatics;
- VNIINM: Design and set up of three laboratories (nuclear forensic, analytical and metrological laboratory) at the A.A. Bochvar All Russian Institute of Inorganic Materials VNIIMN;
- REA: Pilot project on enhancement of the safeguards system at two nuclear power plants, Kursk and Kalinin, with Rosenergoatom;
- VNIITF: Modernization and enhancement of Nuclear Material Accountancy and Control (NMAC) at the Mayak RT-1 plant;
- INR: Pilot project on combating illicit trafficking of nuclear materials with the Institute for Nuclear Research in Kiev;
- ULBA: Enhancement of facilities' Mass/Volume, Containment/Surveillance and Training at Ulba Metallurgical Plant (UMP);
- ULBA: Enhancement of safeguards at the Ulba fabrication plant, the Almaty VVER reactor and the Kurchatov reactor in Kazakhstan.

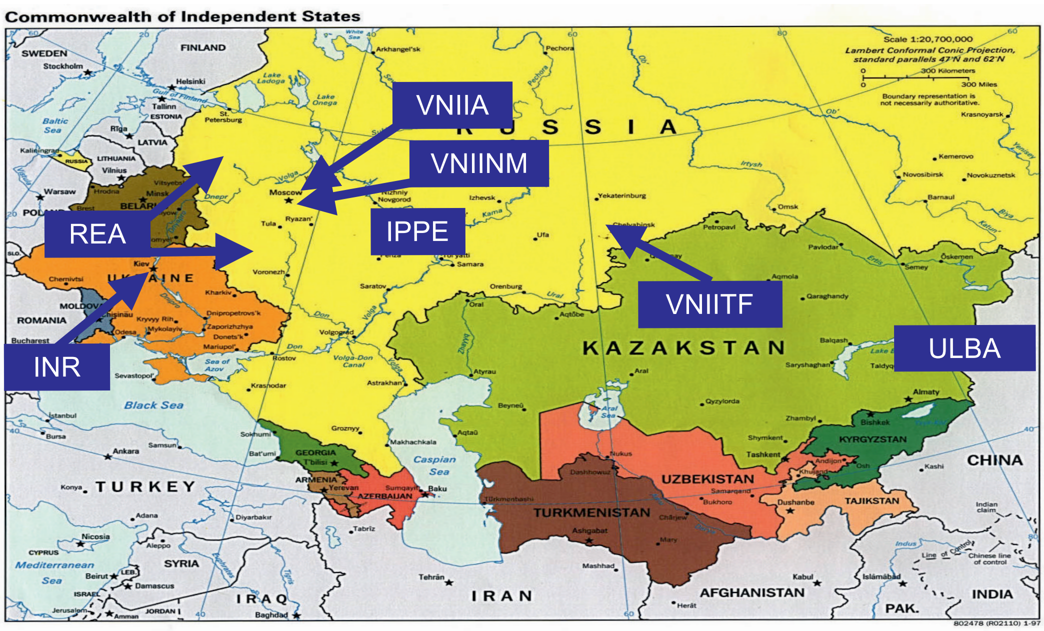

Figure 2: Geographic distribution of the TACIS projects towards nuclear material accountancy and control in the CIS countries during the period 1994 to 2004. Acronyms: REA: Rosenergoatom (Russia); INR: Institute for Nuclear Research (Kiev, Ukraine); VNIIA: All Russia Research Institute for Automatics (Moscow); VNIINM: All Russia Research Institute for Inorganic Materials (Moscow); IPPE: Institute for Power Physics and Engineering (Obninsk); NVIITF: All Russia Research Institute of Technical Physics (Snezhinsk); Ulba: Ulba Metallurgical Plant (Kazakhstan).

5. Focus on Detection and Response: the TACIS Support Programme 2005 – 2012

The new programme proposal is larger, in terms of budget as well as in geographic distribution. On the one side it aims at completing previous projects, reinforcing and sustaining past activities. More importantly, it addresses new challenges with the same objectives: the dissemination of a safety culture, by the transfer of know-how and knowledge and the enforcement of nuclear security.

12 projects within eight countries (1. Russian Federation, 2. Ukraine, 3. Georgia, 4. Armenia, 5. Azerbaijan, 6. Moldavia, 7. Belarus, and 8. Kazakhstan) will be implemented by the two institutes, IPSC and ITU.

The new series of projects continues to deal with safeguards issues, controlling and tracking nuclear material by improving the NMAC of the fuel cycle to prevent diversion. But, as mentioned before, it also addresses new challenges, in particular, the upgrade of detection capabilities and the development and implementation of proper response mechanisms in accordance with international standards. Obviously, illicit trafficking is a border crossing problem; hence, it calls for a coordinated international response. A corresponding multi-country project involving Russia, Ukraine, Moldova, Georgia and Azerbaijan for combating illicit trafficking has been set up.

These projects are listed below:

- Improvement of accountancy and control of hold-up and waste in RT-1 plant at Mayak;
- Establishment of a testing laboratory at VNIIA for certification of NMAC instruments;
- Development and introduction of modern sealing devices at Minatom's enterprises;
- Analytical and metrological support to NMAC;
- Implementation of measures to combat illicit trafficking of radioactive and nuclear material – a multi-country project dedicated to the Russian Federation, Ukraine, Republic of Moldova (see above: Moldavia), Georgia, Azerbaijan;
- Containment/Surveillance system for RBMK spent fuel storage at Kursk NPP;
- Ukrainian border crossing station (measures to fight against illicit trafficking of nuclear and radioactive materials);
- Armenian border crossing station (measures to fight against illicit trafficking of nuclear and radioactive materials);
- Adaptation and commissioning of a computerized NMA system in the Armenian NPP Medzamor;

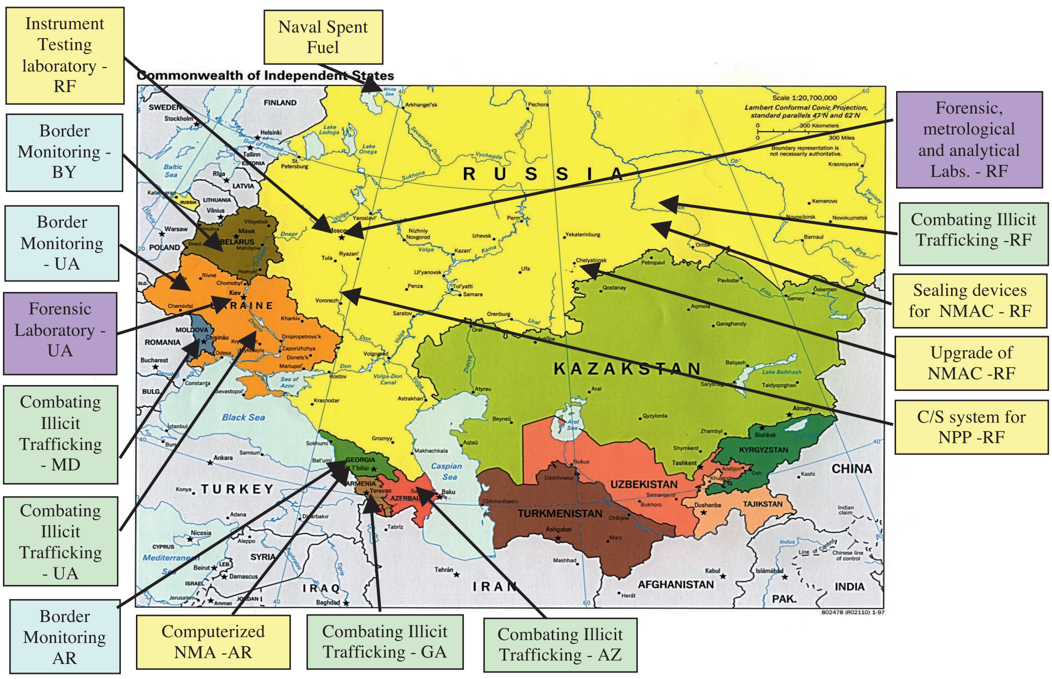

Figure 3: Geographic distribution of the TACIS projects towards nuclear material accountancy and control (indicated in yellow boxes), fight against illicit trafficking in the CIS countries (indicated in green boxes), border monitoring activities (indicated in blue boxes) and nuclear forensic analysis capabilities (indicated in violet boxes) during the period 2005 to 2012.

- Enhancement of the capability for analysis of seized nuclear materials and radioactive substances by the main expert organization of Ukraine;
- Automated data analysis and interpretation for Near Real Time Accountancy at the Ulba Metallurgical Plant; and
- Sustainability of UrSiMTC.

In all projects, enhancement of safety and security is achieved by delivery of equipment and through training. In the illicit trafficking projects, additional support is provided for implementing the Model Action Plan, for performing demonstration exercises and by establishing joint-analysis agreements for nuclear forensic support (to States not having their own nuclear forensic capability).

6. JRC Capabilities in Nuclear Security

The geopolitical situation brought increased attention to security aspects, in particular those associated with the proliferation and acquisition of weapons of mass destruction by both State and non-State actors. New threats by terrorist groups that may utilize nuclear or radioactive material for so-called dirty bombs also call for enhanced control measures [5].

Traditional safeguards activities supported by the JRC are being confirmed and extended in the proposal for the next framework programme, 2005 – 2012. In particular, R&D in automated and portable Destructive and Non-Destructive Assay (DA and NDA) techniques to support safeguards inspections will continue. New systems of Containment and Surveillance (C/S) will be investigated and classical Mass and Volume (M/V) measurement techniques will evolve to an integrated system dedicated to Near Real Time Accountancy, (NRTA) to enhance the first line of defence, i.e., detection of nuclear material diversion. Moreover, the technical capabilities for identification of clandestine nuclear activities are being upgraded by more sensitive measurement techniques (e.g., capable of analyzing sub-micrometer sized uranium particles), by open source information evaluation techniques and by satellite imagery. Finally, combating illicit trafficking and nuclear forensics will continue and evolve, taking into account the risk associated with radioactive sources and deploying detection systems to the outer borders of a future enlarged Europe.

The JRC is also active in dissemination of information, i.e., sharing its experience with the scientific community. This is achieved by a comprehensive training programme [6] covering awareness training, the concept of the Model Action Plan, first responders training, and training for measurement experts, as well as training in nuclear forensics. The training is encompassed by a series of exercises, partly practical, partly table-top. Joint training actions, at national and regional levels, are normally organized in co-operation or co-ordination between the three main organizations (IAEA, US DoE Second Line of Defence (SLD) Program and JRC).

National end-users are trained in analytical techniques and in procedures related to the equipment provided under the TACIS projects. This training is provided at JRC premises by laboratory experts specialized in the corresponding techniques, both NDA and DA.

7. International Collaboration

In 2003, the European Council decided to fund the first Joint Action (JA) to be implemented by the International Atomic Energy Agency (IAEA) in the frame of its programme against the proliferation of weapons of mass destruction. Three JAs are ongoing. The first JA targeted the Balkans, Central Asia and Caucasus areas, the second one focused on the Middle East and Africa, while the third one extended to south-eastern Europe. A fourth one, submitted to the Council and published on April 14, 2008, will complete the European effort with an overall financial contribution to the IAEA's nuclear security funds of almost €22 M. The JA aims to assess the situation in individual countries and, based on the results, it will support the enhancement of nuclear security in a selected country by:

- Developing the necessary infrastructure including legal and regulatory framework;
- Improving physical protection;
- Reducing threats for other radioactive materials by, e.g., identification, control and safe storage of orphan sources;
- Increasing the capabilities to detect and respond to illicit trafficking of nuclear and radioactive materials at borders.

The International Technical Working Group (ITWG) provides an international forum for practitioners in nuclear forensics to advance this new discipline in science. Furthermore, it serves as a platform for the interaction of law enforcement and customs agencies, regulatory bodies and nuclear forensics laboratories in order to assure information exchange and interdisciplinary, inter-agency collaboration throughout the entire response process. At present, more than 20 States are represented in the ITWG, and international organizations (IAEA, Europol, Interpol, World Customs Organization etc.) contribute to the activities of the group.

A number of donor States operate support programmes in the area of combating illicit trafficking of nuclear materials. In order to use efficiently the funds available and to avoid duplication of efforts in the recipient countries, the main actors agreed to establish an intensive and regular exchange of information. A strong focus was set on detection of nuclear and radioactive materials at borders and, in autumn 2005, a dedicated Border Monitoring Working Group (BMWG) was established under the auspices of the IAEA. Besides the IAEA, the US Second Line of Defence, the European Commission (represented by the Joint Research Centre, DG RELEX, DG AidCo) and the Council of the European Union are members of the Group. The BMWG coordinates activities in the field with an integrated approach by country, identifying in particular the recipient institution of the support and possible harmonization of the technical assistance (including equipment and training).

8. Conclusions

Over three decades the JRC has built up significant experience in measuring and controlling nuclear material through its involvement in the safeguards area. This expertise has been made available and transferred to CIS countries through dedicated projects carried out in the framework of the TACIS programme. The JRC is determined to continue its cooperation with CIS countries and is committed to pursue the TACIS Support Programme, as illustrated by a series of new projects with an increased budget. While past activities essentially dealt with traditional safeguards issues, more recent projects are being conducted in a more global, nuclear security oriented context. Evolving from a demand-driven to discussion-driven relationship with our CIS partners, a clear strategic paper on NMAC issues, with a clear vision of goals and corresponding needs has to be issued to anticipate and orientate future support programme tasks and cooperation activities.

Finally, the JRC is seeking to co-ordinate its efforts with other ongoing international activities (ISTC, US DoE, support of the Donor's States, etc…), to avoid duplication with other international projects in the CIS.

Acknowledgement

The authors explicitly wish to acknowledge the contributions from Marc Cuypers and Sergio Guardini to the conception and implementation of the JRC's TACIS projects from 1994 to their retirement in 2001 and 2004, respectively.

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Peer reviewed section

Database Tool for Storage and Evaluation of Radiation Profiles Related to the Dry Storage of CANDU-type Spent Fuel

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Abstract

IAEA safeguards are applied to dry storage of irradiated CANDU bundles in several countries. Before the casks are sealed, radiation traces are measured along the irradiated fuel stack to support verification of the loading and make provision for possible re-verification as necessary.

A database for the storage and evaluation of "fingerprints" (DSEF) has been developed to secure the measurement data over long periods of time and enable their easy retrieval to compare baseline radiation profiles with more recent measurements, thus supporting verifying the absence of retrieval of nuclear material from the casks.

DSEF is a distributed application allowing stand-alone operation in the field before synchronization with data in the central database.

DSEF incorporates advanced evaluation features aimed at recognizing the number of fuel baskets or modules loaded in the casks and assessing the similarity of radiation profiles taken at different times. It aids the Inspector by proposing a decision regarding the successful verification of a declaration for cask loading.

To recognize the presence of modules and baskets DSEF implements physical models of the various CANDU storage designs (MACSTOR and Silo). Using the physical model of the propagation of gamma rays from the baskets to the detector, DSEF rebuilds a theoretical gamma or neutron emission pattern consistent with the experimental data. Then the number of baskets involved in the theoretical gamma emission pattern is counted and compared to the declared number of loaded baskets.

To fulfill the radiation profile comparison goal, DSEF algorithms correct the data for the radioactive decay, and the differences of data taking into account parameters like the motion speed of the probe, the efficiency of the detector or the dead time.

In addition to the data evaluation features and performances, the paper describes in detail the software architecture and its integration in the IAEA Safeguards IT system.

Keywords: pattern matching; CANDU storage; radiation profile; monitoring.

1. Introduction

The International Atomic Energy Agency (IAEA) Department of Safeguards monitors CANDU[1] spent fuel bundles stored in a modular air-cooled arrangement (MACSTOR[2]), in silos or in dry storage containers (DSC[3]). Amongst other measures, the IAEA records radiation profiles on the CANDU dry storage arrangements to verify the initial loading of the casks and also as provisions for further analysis to restore continuity of knowledge as necessary.

MACSTOR and silos have verification tubes allowing vertical scans of the stored nuclear material to record gamma and neutron spectra. DSC have verification tubes allowing only gamma profiling.

The IAEA Division of Technical Support initiated a project to provide the Divisions of Operation with a software solution aiming at securing and evaluating the radiation profiles taken in the field by the IAEA Inspectors.

A contract was awarded to EURIWARE for the development of the Database for Storage and Evaluation of Fingerprints (DSEF). The Division of Technical support developed the user requirements while the Division of Information Management gave guidelines for smooth integration in the IAEA information system.

1 Canadian Deuterium Uranium Reactor
2 Modular Air-Cooled Storage
3 Dry Storage Container

The main purposes of the contract were:

- to design and to implement a database to store neutron or gamma spectra generated by various kinds of equipment;
- to design and implement comparison algorithms supporting the similarity assessment of the measured data taken at different times;
- to design and implement methods to verify the number of baskets loaded into dry storage casks based on the analysis of the radiation traces.

The concepts underlying the development of DSEF were:

- to establish a unique tool for securing and processing the radiation profiles taken by the IAEA;
- to allow a use of the database in standalone mode on inspectors' laptops while all data could be secured in a centralized database;
- to ensure maintainability of the application;
- to incorporate data evaluation features focusing on radiation traces taken on CANDU fuel in dry storage while allowing to store any other radiation traces.

This article focuses on the description of the methods and algorithms developed for processing the data. Some screenshots are also given for the description of the software. Modeling of DSC-type storage arrangements is not presented, as no information is available to support the development of a model-based approach.

*In the remaining part of this paper, the word **"spectrum"** defines the SPACE distribution of the signal and not ENERGY distribution of gamma detection.*

2. Problem definition

2.1. Measurement conditions

Different parameters may influence the measurement for a given cask:

- the collimated probe can be adjusted differently between two measurement campaigns,
- the probe speed may change,
- the measurement can be made either in downward or upward directions,
- the probe or its electronic part may be exchanged between two campaigns,
- the dwell time may be different and for a given probe speed the channel number is different,
- the probe may be partly blocked during the motion within the measurement tube.

These measurement conditions require the implementation of different kinds of algorithms such as:

- Merging data to produce signal versus location data by knowing the dwell time, the motion speed and scan direction or by merging radiation data file with location data file,
- Dead time correction by applying an average dead time correction or a point dead time correction when the dead time value is known for each measurement point,
- Smoothing by applying a moving average over a selected number of channels,
- Scan speed correction in case of positioning signal recorded with radiation traces, to assume that the probe motion is steady along the radiation trace,
- Cross calibration of detectors used for each measurement,
- Normalization if the cross calibration cannot be performed.

2.2. Comparison of measurement results and reference data base

The DSEF application has to compare a new measurement with a reference measurement taken at the end of all nuclear materials movements. The new measurement and the comparison report must be stored in the database for further utilization.

The comparison result must have a high confidence level and it must yield a statement of change or no change. Furthermore, the comparison may have to be performed with a measurement taken over 300 channels and one taken over 6,000 channels. Other issues to be taken into account are the decreasing efficiency due to diode ageing and different rising slopes from different measurements. Moreover, we may have to compare reference data acquired in downward direction with measurement data acquired in upward direction.

This comparison can be performed by applying different kinds of algorithm such as:

- Offset correction by using signal inter-correlation. In this case, the offset value is determined by the maximum of the inter-correlation function between the reference signal and the measurement signal.
- Decay correction according to ^{137}Cs decay for gamma radiation and ^{244}Cm for neutrons.

- Similarity between the reference data and the measurement data can be given by the use of distance algorithms. The comparison between the result of the selected algorithm and a defined threshold allows determining if the two signals are similar or not. A level of confidence must be implemented for each diagnostic procedure.
- Automatic count of the number of baskets in a CANDU silo. This count can be based upon the gamma radiation signals.

The most difficult part of the DSEF implementation is the comparison between two measurements.

The main problem is to quantify the deviations between the reference and measurement data. If a threshold must be used, its value must take into account the background noise of the two measurements. Furthermore, singular deviations are more significant than more frequently occurring deviations.

2.3. Basket counting

Signal interpretation based on counting baskets appears to be very difficult. First of all, it is difficult to detect the upper basket due to bending of the measurement tube (see Figure 1). Another phenomenon is dependent on the heterogeneous distribution of activity between baskets which can hide a transition between two baskets. Finally, the concrete rebar disturbs the signal (addition of a noise with high magnitude).

Therefore, when plotting the measurement results, it was sometimes impossible, even for trained staff, to distinguish between individual baskets.

2.4. Problem redefinition

Analyzing different kinds of measurements leads us to a new way of treatment for silo and MACSTOR storage arrangements. For these two types of storage, spent fuel is stored in vertical baskets. However, the theoretical number of baskets is known. The idea is to first locate these baskets in the measurement plot, and, secondly, to analyze the characteristics of each basket, instead of performing a measurement analysis first. A comparison between two measurements will then be reduced to a comparison between the areas of found baskets.

The problem is, therefore, “to find a defined shape along a measurement plot”. Then, for silo and MACSTOR, the problem becomes a model identification problem with a fitting procedure.

The following questions have to be answered: What is a basket? How can we characterize it in such a way that we can match geometry with measurement result? A modeling effort was then necessary to validate the approach before starting development.

This modeling effort consisted in:

- Describing the geometry in a few parameters
- Validating this model with fine simulation
- Finding a “correlator” able to distinguish between inexplicable differences (e.g., lack of basket, removed material) and explicable differences (in case of collimation device problem).

However, for the DSC storages, the fuel bundles are not stored in vertically stacked baskets; so, it appears that only the comparison between the measurement plots is possible, since there is no invariant that can help.

3. Modeling for silo and MACSTOR

3.1. Basket shape definition

We look for a model of the shape that allows finding a spectrum-like measurement result.

The signal shape due to the presence of a basket can be modeled by a formula depending on:

- the active length of basket,
- the distance between the basket axis and the measurement tube,
- the total activity of the basket.

We need to model the activity measured by a probe moving along a vertical axis parallel to a basket containing radioactive material in bundles (see Figure 2). The axis of the verification tube is located within the concrete of the silo as shown in Figure 1. The verification tube is bent to avoid the direct beam during probe introduction. The bend is located in front of the first basket, making it sometimes difficult to “see” a gamma spectrum emitted from this basket.

The following simplified problem can be studied:

- the basket is equivalent with a cylinder in which the radioactive material is homogeneously distributed
- the space is completely transparent to radiations. We do not take into account the attenuation due to concrete and metallic structures.

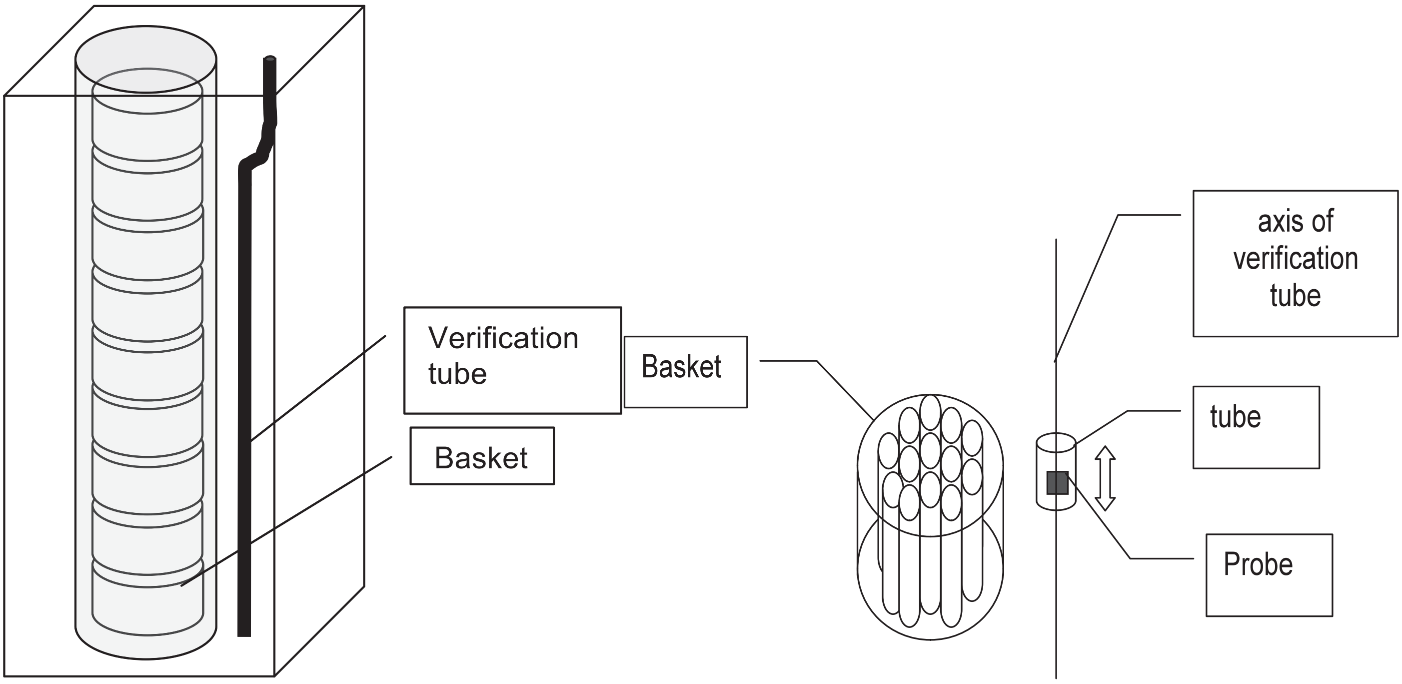

Figure 1: Geometrical model of a basket with a probe located in front of it.

Due to the symmetry, and in applying the Gauss theorem on a cylindrical surface concentric to the basket, the measured activity (as it is seen from the probe) is the same as if all the radioactive material was concentrated in an infinitely thin segment centred on the basket axis and with the same length as the basket (Figure 2).

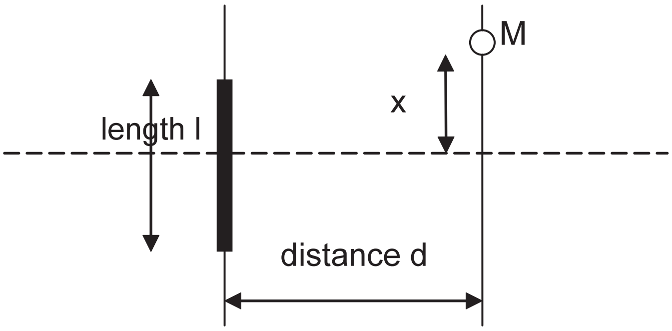

Figure 2: Equivalent geometry definition

3.2. Activity definition

Integration of radioactive segment points at the position of M gives the activity at M, *a(M):*

$$a(M) = A\frac{(ATAN(\frac{-l/2-x}{d}) - ATAN(\frac{l/2-x}{d}))}{l*d}$$

where A is the total segment activity.

After normalization at the point x = 0 the formula becomes:

$$a_N(M) = A\frac{(ATAN(\frac{-l/2-x}{d}) - ATAN(\frac{l/2-x}{d}))}{(ATAN(\frac{-l/2}{d}) - ATAN(\frac{l/2}{d}))}$$

An accurate simulation was made with MCNP[4] on current and actual geometry data.

The result is shown in Figure 3. Curves are fitting for *l* = 52,66 cm and *d* = 2,109 m.

The *l* and *d* values are determined in order to fit the curve calculated by the IAEA on the basis of a large amount of practical data, as accurately as possible.

The formula of the activity can be used considering that l and d are the «apparent length» and the «apparent distance» of a basket. The «apparent length» takes the solid angle of the collimation device into account. The same applies for the «apparent distance» d which encompasses the contribution of heterogeneous composition crossing the flow.

The «apparent distance» value, used in basket shape computing, will be considered as a parameter related to the storage characteristics.

The apparent length is the same for all baskets in a silo.

4 Monte-Carlo N-Particles transport

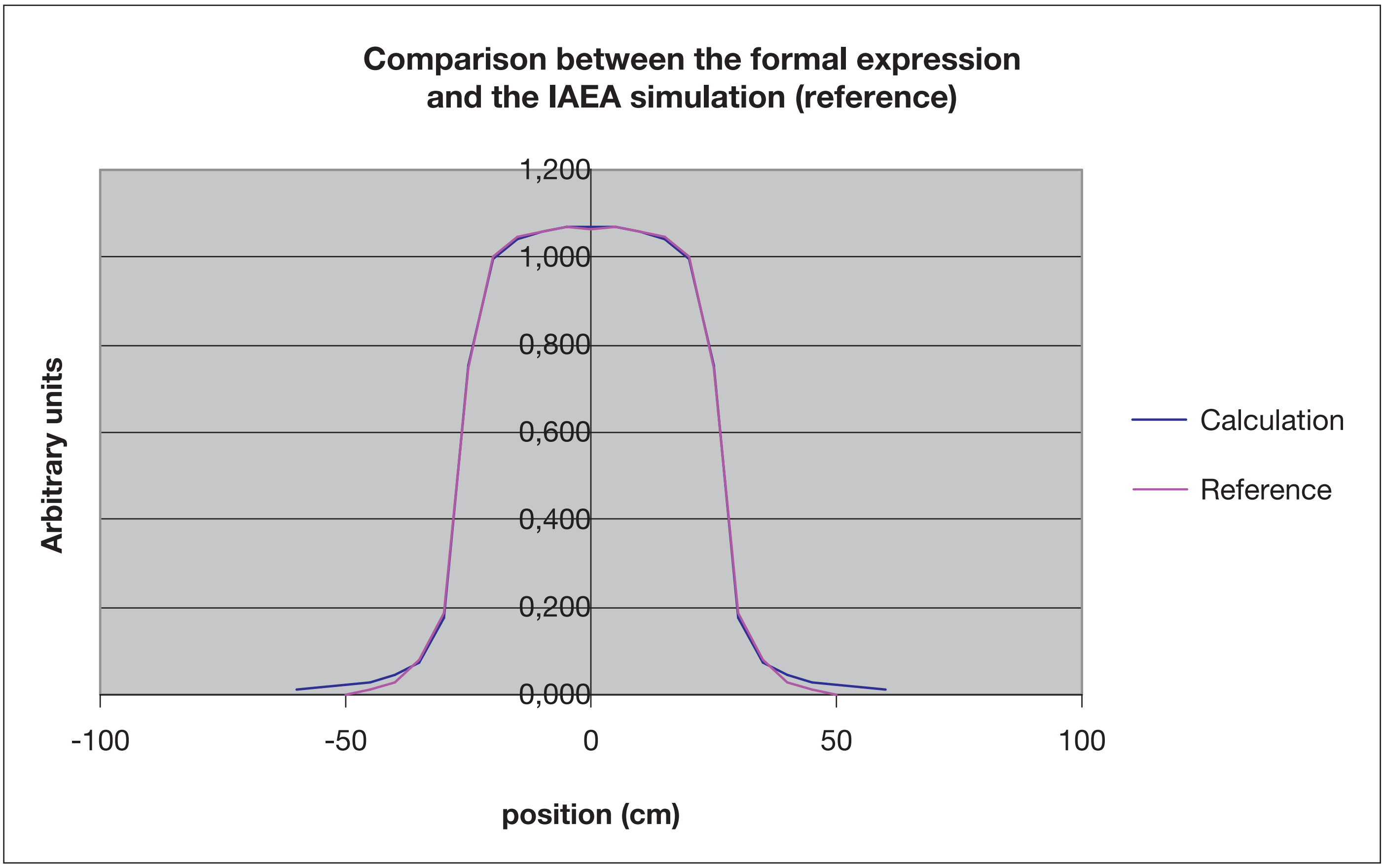

Figure 3: Basket model shape, matching the analytic model with MCNP simulation.

3.3. Fine-positioning of basket centre

For noisy measurements, the method may produce some error in basket positioning. The modeling effort studied the effect of small variations of the geometry parameter on the correlation peak location.

A basket shape can be seen as a summation of *n=9* (9 baskets are filling one silo) shapes with a noise. It can be described by:

$$S(x) = \sum_i A_i B(x,d,l,c_i) + N(x) \quad \textbf{(eq. 1)}$$

Where

- i is the shape number (the considered basket i= 1 to 9)
- A_i is the amplitude value of the model shape
- *B* is the model shape with unitary amplitude of a basket
- *l*, d are common values (fixed) for all baskets for apparent length and distance
- x is the channel number
- S(*x*) is the shape value at channel x
- c_i is the basket number "i" centre (fixed)
- N(x) is the noise at channel x

If we want to know how to detect bad positioning of the shape pattern, then the influence of the first order partial derivative must be evaluated. We, therefore, write the 1st order development into series of the activity around c_i, *d and l*.

$$S(x) = \sum_i A_i [B(x,d,l,c_i) + \frac{\partial B}{\partial c_i}(x,d,l,c_i)dc_i + \frac{\partial B}{\partial d}(x,d,l,c_i)dd + \frac{\partial B}{\partial l}(x,d,l,c_i)dl + O(2)] + N(x)$$

(eq. 2)

This set of linear equations is simpler to solve than the non linear model shape of equation (1). This assumption is valid, because we have geometric information about the silo or MACSTOR which renders a good estimate of c_i, *d and l*.

For a better understanding let us consider a Gaussian shaped basket model. Si can be defined by:

$$S_i(x) = e^{\frac{-(x-c_i)^2}{2\sigma_i^2}}$$

Consider two other Gaussians shifts to the right and left but still overlapping (partial derivative with respect to c_i), we get the following difference which is a resulting pattern. Moreover, if we have a variation in σi, then we also have a specific figure.

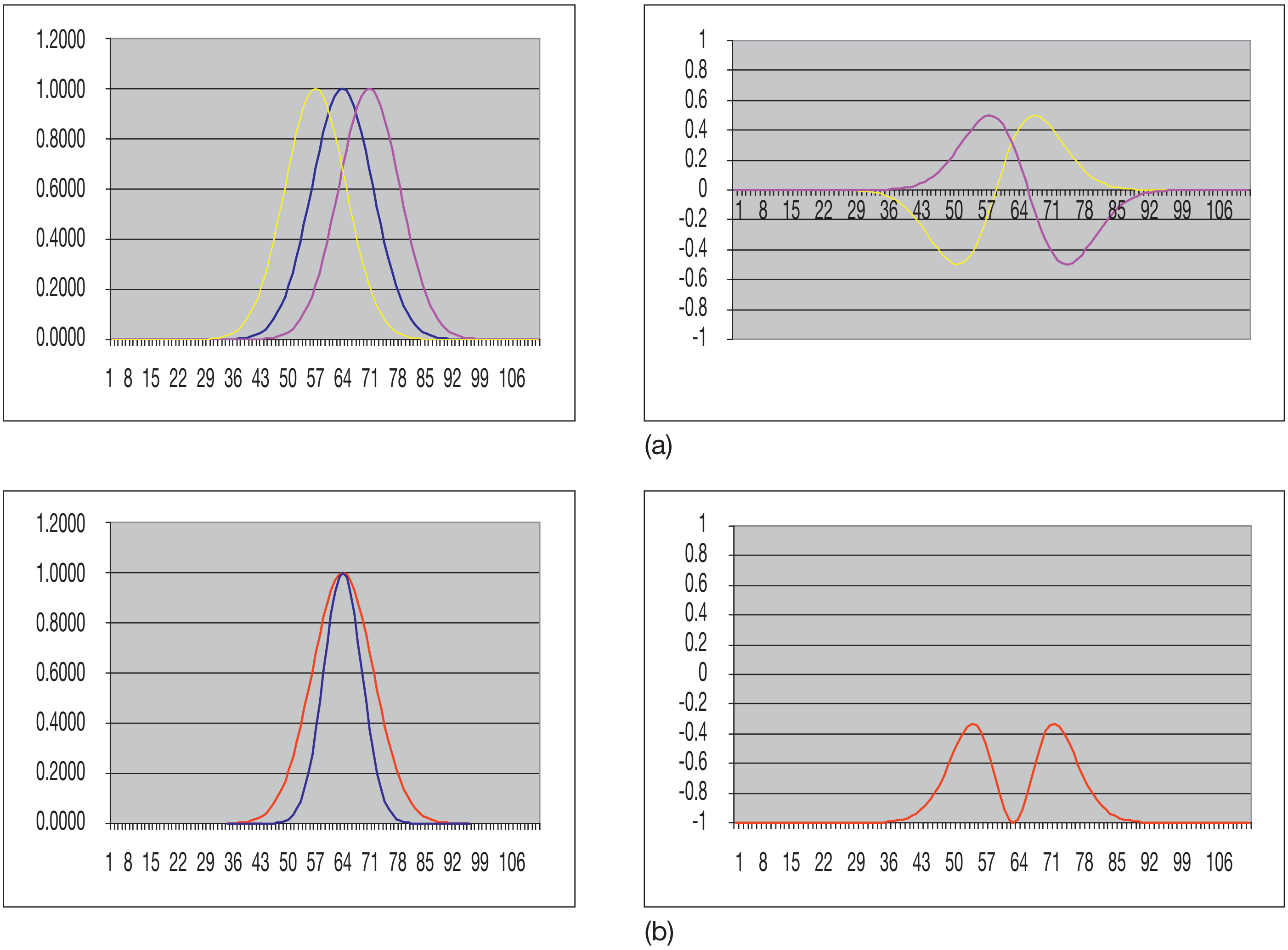

Figure 4: Partial Gaussian derivatives according to c_i in (a), according to σ_i in (b) and resulting difference between the centred Gaussian in blue and the others.

Fine-positioning of the basket centre and fine-tuning of the basket shape are based upon the development into series at first order.

The advantage of this linearization is that we can add the contribution of each basket at a given position.

The idea is then to estimate how much the parameters *(A_i, d, l, c_i)* must change for each basket to fit the measured values.

4. Theoretical solution for CANDU silo and MACSTOR

Based on the model here above and since we have to discriminate against inexplicable differences, the basket localization appears to be the first step of the fitting procedure. Indeed, once the localization is accurately defined, we can allocate areas-of-interest and channel number to the given basket.

Therefore, the spectral shape processing consists in:

- Spectral shape cleaning with respect to concrete rebar
- Locating the baskets
- Tuning the basket parameters
- Activity calculation
- Comparison.

4.1. Filtering spectral shape

As the measured spectral shape is distorted by the concrete rebar attenuation, the location of basket can be disturbed. To suppress the contribution of the concrete rebar, the measured spectral shape is first smoothed.

During the study two algorithms were tested to rub out the effect of the concrete rebar.

The first one is a HPF (filters out the high frequencies) filtering aiming at removing background noise, locating the rebar effects, removing the effect and smoothing residual irregularities.

The second one is simpler. It is a moving average method which gave good results as shown in Figure 5 below.

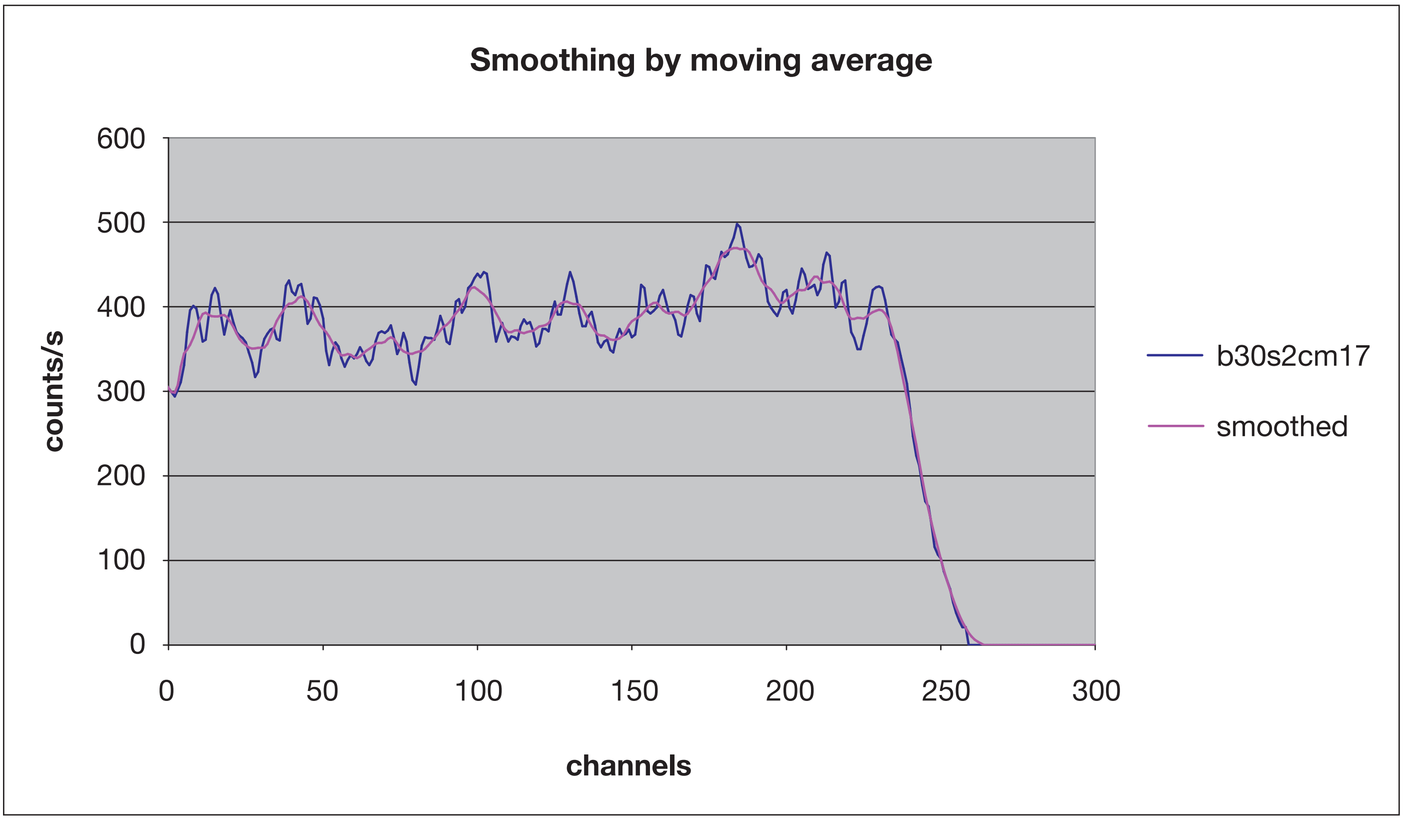

Figure 5: Smoothing signal with moving average.

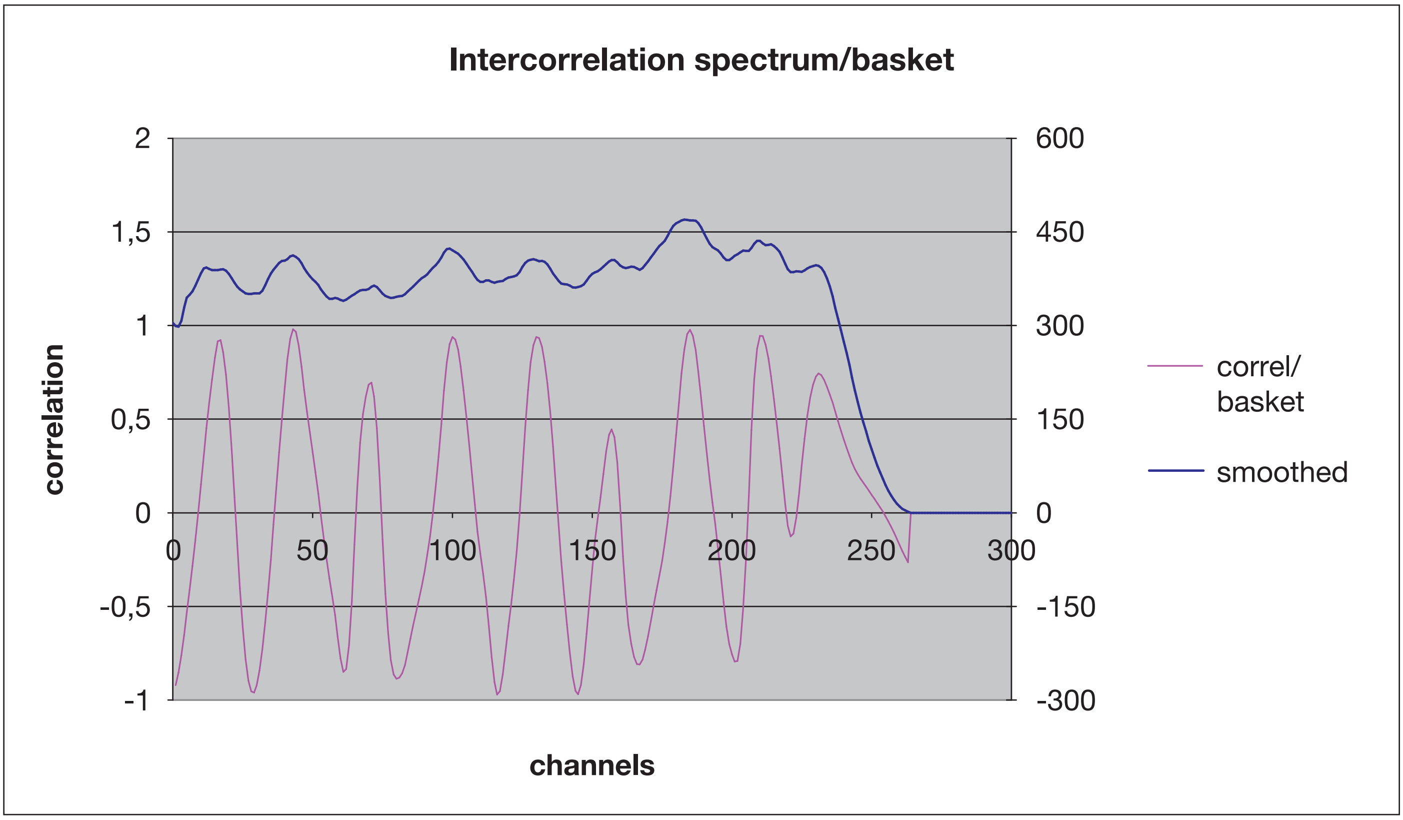

Figure 6: First location of basket centres with correlation.

4.2. Basket location

The basket positions are determined by computing a correlation between the basket shape and a window moving on the smoothed spectrum. The correlation result evolves between -1 and +1. This result does not depend on the analyzed signal amplitude. This detection renders very narrow peaks related to the basket centres (Figure 6).

If a basket with a very low activity is located between baskets with high activities, this basket may not be detected. If it is not detected, the found interval between the baskets is almost twice as large as other intervals.

Before continuing the signal processing, missing baskets must be added.

Intervals between baskets are not regular. So, if the probe is moving at constant speed or if the z position of channels is known, the found positions of baskets can be adjusted to show a regular interval between the baskets.

However, due to the bending of the verification tube, the last basket cannot be taken into account. Also, the first basket showing an asymmetric shape due to its position must not be taken into account in this step.

4.3. Parameter fine-tuning

During this step, a shape built from the addition of activities of each detected basket is created.

The initial raw shape is fitted to the best possible extent. The calculated activity is related to the basket but attenuated by the concrete rebar. The basket shape used in this step is computed with an apparent length based on the interval between the baskets.

Following the development at first order in equation (2), the contribution of all baskets at channel i depends on three parameters:

$$1)\quad A_i$$

$$2)\quad \frac{\partial B}{\partial c_i}$$

$$3)\quad \frac{\partial B}{\partial l}$$

The local variations of *d* and *l* have similar effects. That is why we kept only the variation of apparent length *l*, since it integrates the rebar contribution.

Therefore, for nine baskets in a silo or a MACSTOR, we have twenty seven (9x3) variables. If the measured spectral shape has *n* channels, we can write the linear form:

$$\underset{\dim n}{S} = \underset{\dim n \times 27}{A} \times \underset{\dim 27}{X}$$

with:

- S raw measured spectrum value for the *n* channels (the observations)

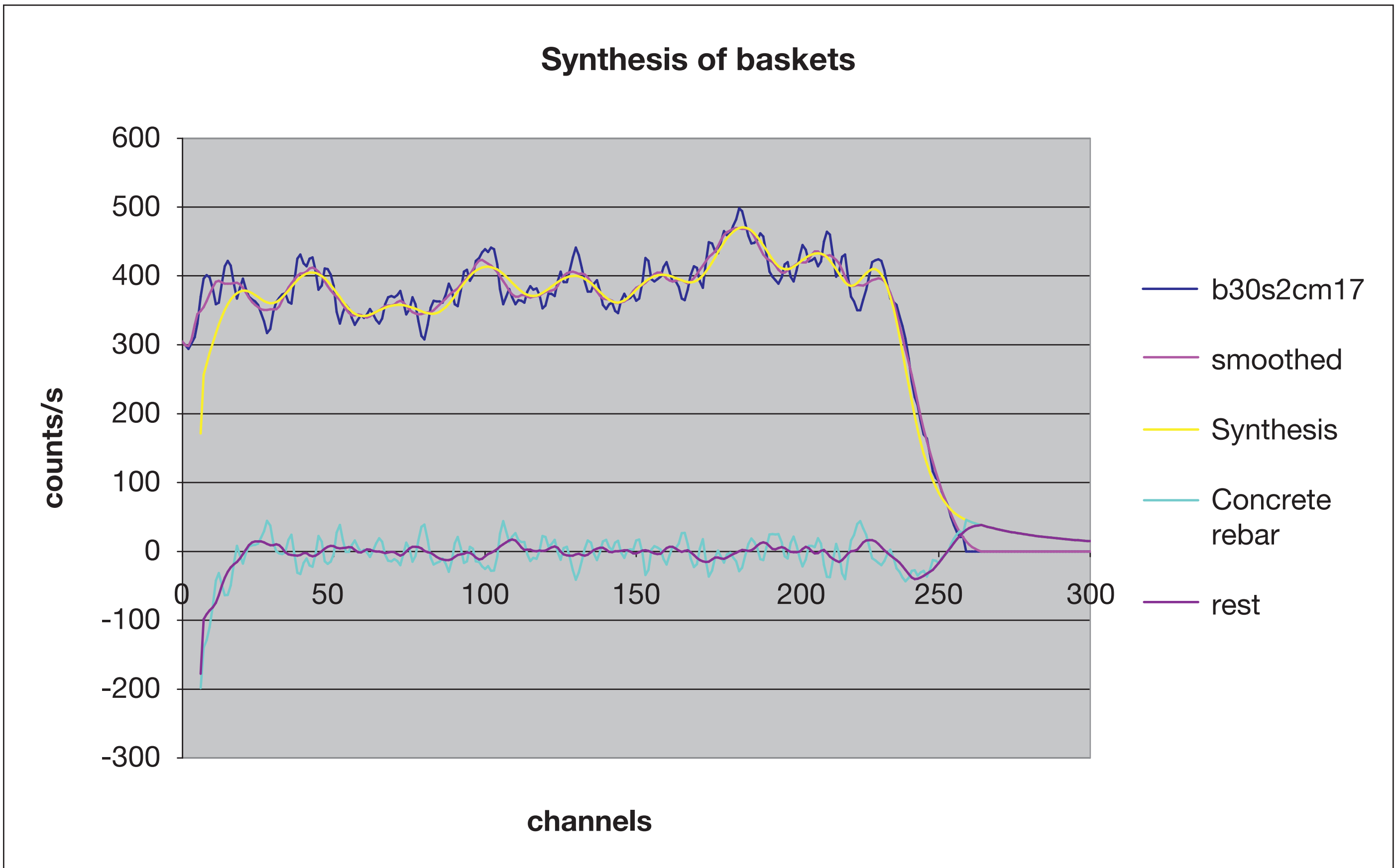

Figure 7: Resulting activities (Synthesis).

- X the vector of 27 unknown variables.
- A a matrix

The activities are found by solving this system with the method of least squares using the following equation:

$$X = (A^T A)^{-1} A^T S$$

After fine-tuning of parameters, the activities A_i are very accurate.

5. DSEF Software

5.1. Algorithm

For the MACSTOR or silo the algorithm provides:

- the number of baskets (with an uncertainty on the presence of the last basket)
- the precise activity of each basket. This activity is precise because it is based on the best possible measurements in the zone situated around the centre of the basket.
- the uncertainty on the activity (study to be completed):
  - o theoretical uncertainty = amplitude of background noise / number of channels for 1 basket
  - o estimate of uncertainty = mean square error on the basket channels.

Different measurements of the same silo with different collimators will give important deviations between the measured spectral shapes, but it will be possible to compare the activities with a good confidence level.

Comparison with reference data will be a comparison of scalars (Ai). The spectrum normalization must be done after basket area identification to avoid intermediate calculation with very small values.

If no baskets are found, then a spectrum comparison channel per channel is used.

5.2. Interfaces

The design of the DSEF application is based on the Unified Modeling Language (UML) with use cases method providing a very powerful tool to design the application with a description level that fits the end-user requirement without entering into IT considerations.

The first purpose of the DSEF application is to store measured data over an extended period of time. All stored data must be easily retrievable from the database. The measured data are stored in flat-files which can be ASCII or XML files, IEC1455File compliant such as GENIE2000 files, proprietary WinScanFile or WinMCSFile. The database, therefore, must store the description of each data set and record the corresponding file name.

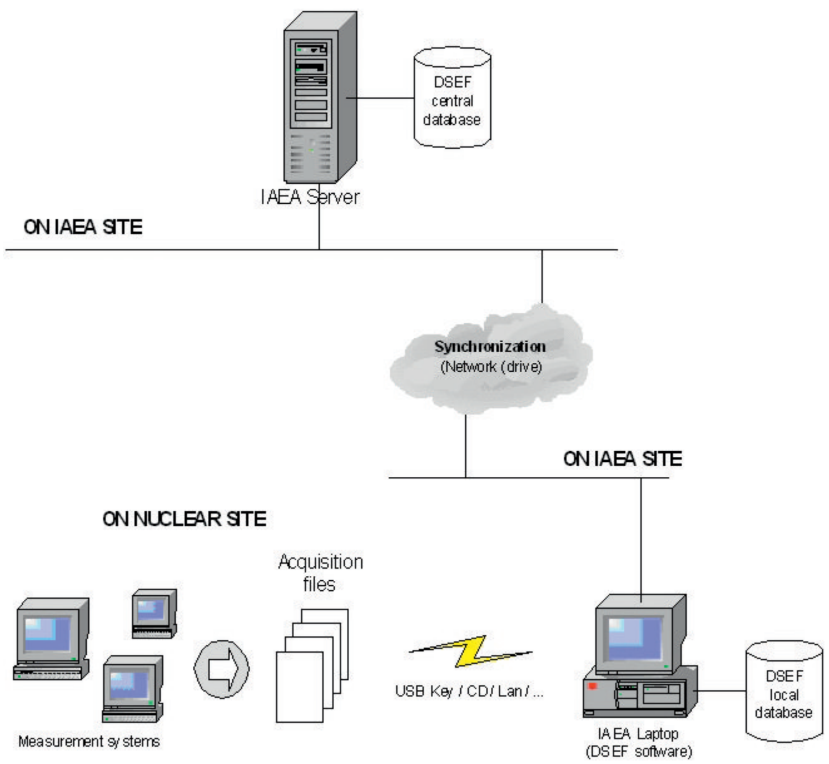

Figure 8: DSEF software architecture.

On-site inspections require a capability to run the application on a local database (i.e., running on a laptop). Obviously, this requires that the synchronization procedure can automatically download on-site measurement results into the DSEF system hosted on the Agency network (Figure 8).

The IAEA standard being based on Windows, the selected database is SQL Server 2005.

5.3. Using DSEF application

After having acquired new spectra, the inspector can see the result in DSEF. Then, a baseline selection is possible and a comparison can be executed against different baselines/reference data if necessary (see Figure 9).

On the right hand side of the screen indications are given to help inspectors to understand the situation. Algorithm 1 is the one explained here above, Algorithm 2 is a comparison channel per channel. We can see that, in the case where Algorithm 1 is selected (for silo and MACSTOR) we have indicators for each basket. In Figure 10 we can see a good matching for a given setting and in Figure 11 alarms on particular baskets.

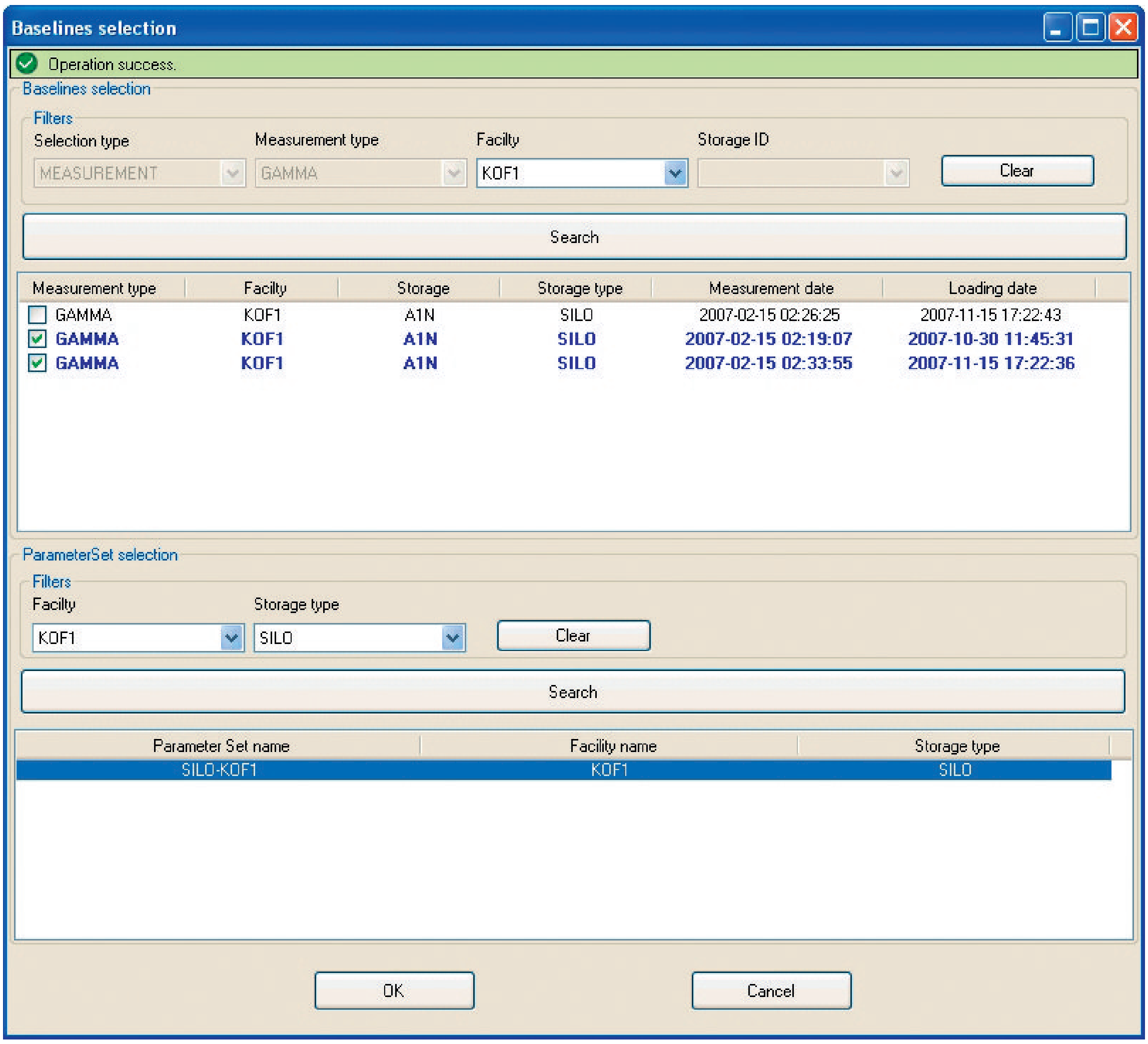

Figure 9: Selecting a baseline.

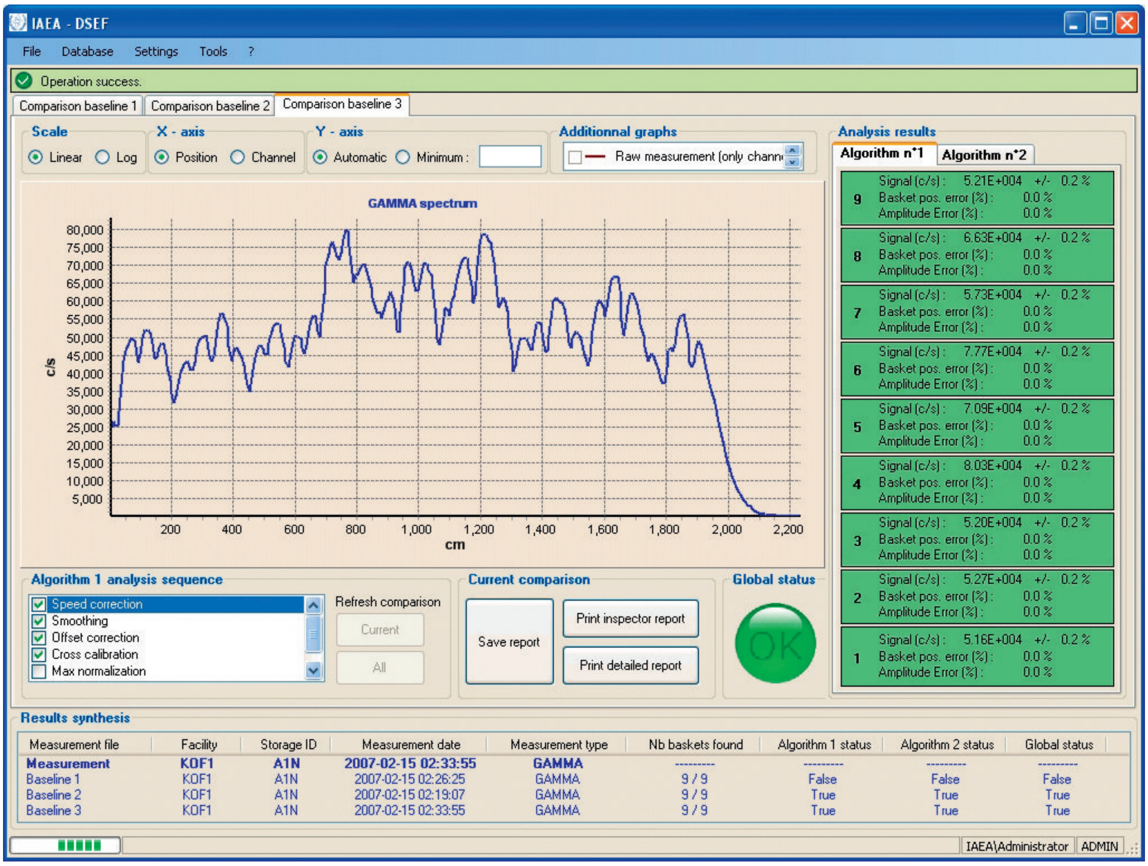

Figure 10: Successful comparisons with a baseline and with 9 baskets.

Figure 11: Matching error.

5.4 Testing correlation threshold

The algorithm sensitivity has been tested regarding correlation threshold, apparent length, apparent distance, and basket shape length. The screenshot below shows the case of a missing basket with a correlation threshold value of 0.9 (Figure 12).

The application has a set of threshold parameters to define a good configuration (Figure 13).

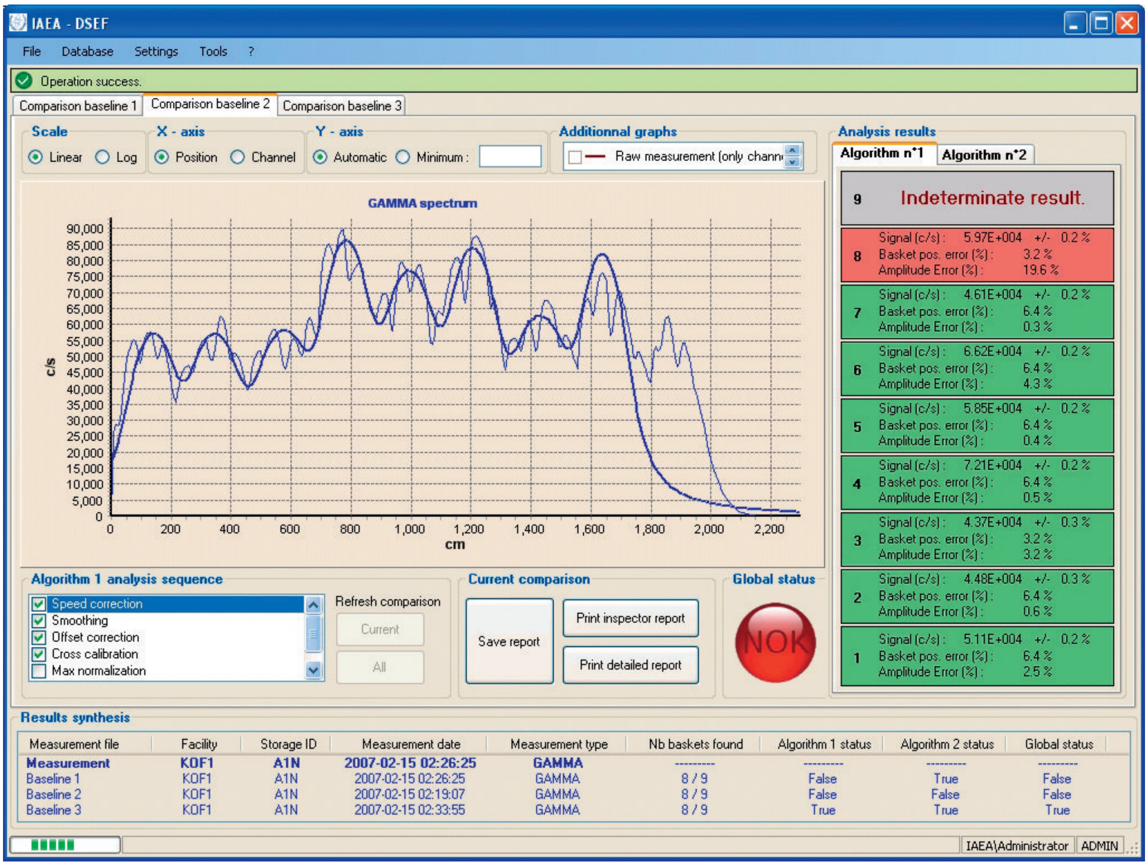

Figure 12: Wrong value for correlation threshold.

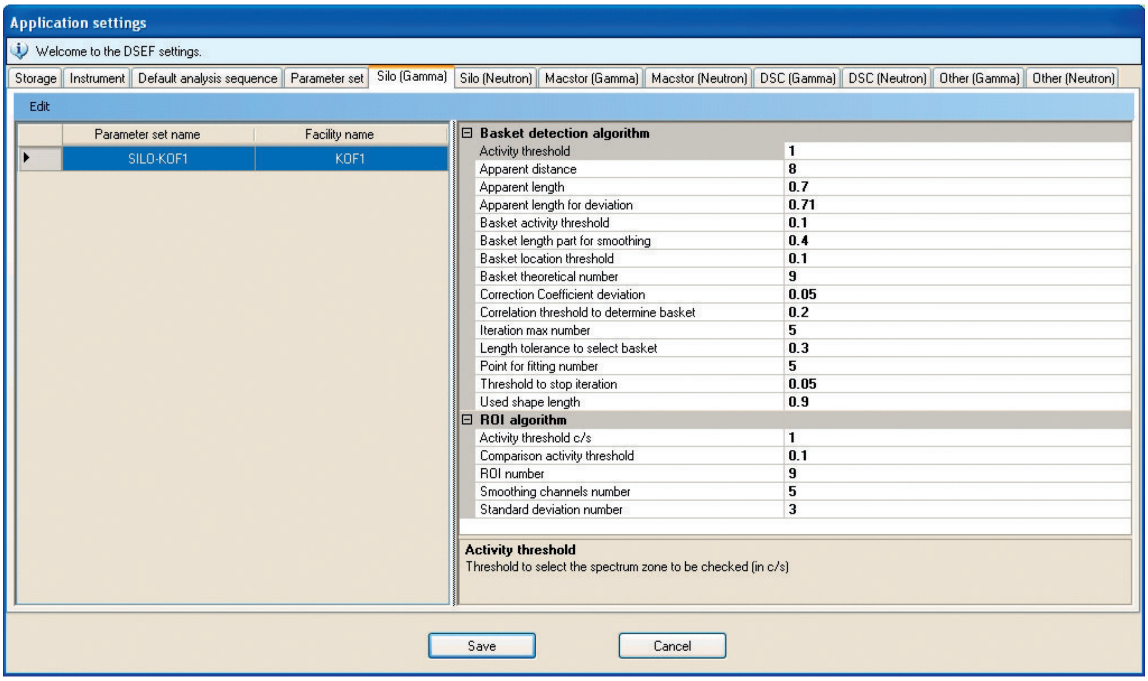

Figure 13: Threshold lists.

6. Conclusion

This paper shows how we can take advantage of the prior knowledge about the geometry to improve algorithm. During the study we redefined the problem definition in another way. The decision of looking for basket positioning before spectra matching was of great help.

Moreover, this approach produces consistency control capabilities, since we can control the validity of results and we can raise an alarm in case of anomaly on:

- the spaces between concrete rebar (if we calculate their position)
- the basket numbers and on the spaces between the baskets
- the consistency in comparison with the speed of motion of the probe (measurement with respect to t)
- the consistency in comparison with the basket width (measurement with respect to z).

The developed application allows working on a laptop PC, i.e., local database downloaded from the reference server and automatically synchronizing data, once the inspector is back at his or her office at IAEA headquarters or regional office. The application is, therefore, very practical and adapted for in-field conditions encountered by inspectors.

DSEF provides the Department of Safeguards of the IAEA with a reliable tool to secure specific inspection data as a second line of defense to resolve possible failures of containment surveillance measures applied at CANDU spent fuel dry storage. Additionally, data evaluation algorithms, as described in that paper, are implemented in DSEF to facilitate the data processing towards the goal of prompt resolution of anomalies or initial verification after loading of the CANDU casks.

Acknowledgement

This work has been carried out under a service contract IAEA 2005-2841-1. We would like to acknowledge the support from the IAEA, in particular, in the Division of Technical Support and Mr. Becar in the Division of Information Management.

A Versatile Simulation Code for Alpha Spectrometry: Development of the Graphical User Interface and Applications

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Abstract

A graphical user interface for the alpha-spectrometric simulation package AASI is introduced. The package calculates the alpha particle energy spectrum in different measurement geometries and for various source types. AASI is able to take into account the coincidences between the alpha particles, electrons and photons. Typical applications include quality control, training, and, for example, direct alpha spectrometry from aerosol samples or swipe samples.

Keywords: Alpha spectrometry; Monte Carlo simulation; environmental surveillance.

1. Introduction

High-resolution alpha spectrometry with semiconductor detectors is a widely used method in environmental and occupational radiation surveillance. However, a pronounced energy loss of the alpha particles in matter poses stringent demands for the characteristics of the source and the detection system since the energy loss causes peak tailing and may, in unfavorable cases, fully prevent the nuclide identification. Simulations are an option to study the alpha particle behavior for the measurement setup in question. Simulated data may even be used to facilitate spectrum unfolding when challenging samples, like swipes, are analysed.

Existing Monte Carlo simulation packages may not be convenient for an occasional user since their use, as a result of versatility with respect to the measurement geometry, particle types and interactions taken into account in the computation, often requires programming skills. In the previous article [1] we introduced a simulation package known as AASI which can be used to study energy spectra in alpha spectrometry. The code calculates the alpha particle energy loss in different measurement geometries and for various source types. Here we introduce a graphical user interface (GUI) for the AASI package. The GUI facilitates the use of AASI since no programming skills are required. Quick demonstrations of various factors that affect the alpha spectra are possible, making AASI ideal for a wide range of applications.

2. Graphical User Interface

The graphical user interface generates the input files required by AASI and facilitates presentation of the simulation results. Management of other information, such as nuclide and stopping power data, is also performed in the GUI. Java programming language is used so that the execution of the code is possible in many common operating systems. To familiarise a new user to AASI, illustrative examples are included in the distribution.

The GUI is composed of the following components (see top of Figure 1):

- Properties of the detector are given in the detector page
- Radionuclides present in the source and the source matrix properties are determined in the source page
- The materials between source and detector are characterized in the absorbing layers page
- Alpha-electron and alpha-photon coincidences are treated in the coincidences and backscattering page
- Execution of the simulations is controlled in the calculations page
- Simulated alpha particle energy spectrum is shown in the plot page

In addition to detector dimensions, materials of the active volume and the dead layer, the detector page includes information on the detector response to monoenergetic alpha particles. The response function is a convolution of a Gaussian peak, characterised by the full-width at half-maximum (FWHM), and a double-exponential low-energy tail which is characterised by the curve steepness and the relative areas under the exponential curves. For more details see [1].

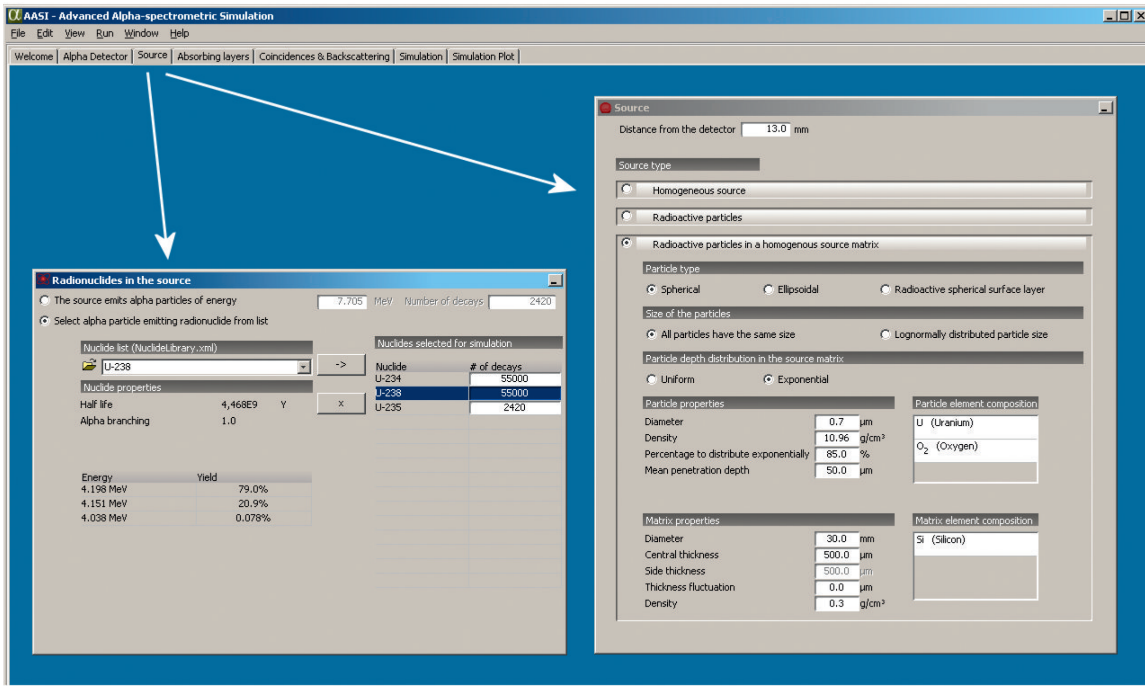

Figure 1: An example of a screen snapshot of the source page. On the left window, the radionuclides and the number of decays used in the simulations are selected. Source type and characteristics are selected on the right window.

Radionuclides present in the source are selected from a dropdown list (left window in Figure 1). The decay data are read in from a special nuclide library based on the ENSDF database [2]. The library is prepared in XML format to facilitate data amendments. The user may also set a specified energy for the alpha particles. Three types of sources may be used in simulations (right window in Figure 1):

1) Homogeneous source, which is a cylinder with user-defined diameter, thickness, density and material composition. The source thickness may be subjected to random variations, or the surface of the source may be defined to be paraboloid.
2) Radioactive particles may be homogenous or the alpha-particle emitting material may be on the surface of the particles. Particles are characterised by their shape, size distribution, density and material composition.
3) Radioactive particles may be embedded in a homogenous source matrix, e.g. in an air filter. Particle characteristics and their depth distribution in the source matrix in addition to matrix properties must be given.

In the absorbing layers page the material layers between the source and the detector are given. The layers are characterised by their composition, density and thickness. User-defined composition of the layers can be saved and restored which allows their flexible use in different simulations.

The coincidence phenomena are important, for example, in unfolding the spectra generated by nuclides which have alpha particle energies close to each other. Coincidences of the alpha particles with electrons and low-energy photons may be taken into account in the simulations [3]. Properties of the source backing material are relevant especially in the case of alpha-electron coincidences.

In addition to the simulations of the alpha-particle energy spectrum, the geometrical detection efficiency may be determined in the calculation page. Calculation of the efficiency is necessary, for example, in direct alpha spectrometry where tracer nuclides cannot be used for activity determination.

Plotting the simulated alpha particle energy spectrum is of vital importance when simulated spectra are compared to those obtained by measurements or previous simulations. This facilitates to investigate the influence of a pre-selected parameter, such as particle size or sample thickness, to the generated alpha spectra. Measured spectra, in various formats, can be imported to the plotting tool.

3. Applications

The AASI computer code can be used in different applications. Simulations are demonstrated first in the case when radioactive particles are sampled using swiping. Another example is the role of simulations to predict the alpha particle energy spectrum when radioactive particles containing transuranium elements are deposited on an air filter. Nuclide composition is assumed to be the same as that of reactor fuel. The third example refers to the use of AASI in studies where the influence of coincidence phenomena is under investigation.

3.1. Swipe samples

A swipe sample from a metallic and surface-oxidized piece composed of natural uranium was taken using the IAEA swipe sample kit. The sample was placed as such into a vacuum chamber of an alpha spectrometer at a distance of 13 mm from the detector, resulting in an alpha particle energy spectrum presented in Figure 2. Almost identical energy spectrum is obtained if the source parameter values presented in Figure 1 are used in the simulations (for the sake of clarity the number of decays in the simulations are assumed to be ten-fold higher).

Although the measured source was far from ideal, i.e. no radiochemical sample manipulation was performed, clear peaks of ^{238}U and ^{234}U were detected. Peak shapes near the nominal alpha energies are round-edged owing to the thickness of the source material (UO_2 particles of 0.7 µm in diameter are assumed in the simulation). A great deal of the particles is penetrated to the swipe material causing notable peak tailing extending below 1 MeV in registered alpha particle energy. Because of the tailing the activity of ^{235}U should be 20% or more of the activity of the other U-isotopes to be clearly distinguished in the spectrum. The peak tailing might be reduced considerably by selecting the swipe material and the swiping technique to be more practicable for direct alpha spectrometry [4].

3.2. Direct alpha spectrometry from air samples

This example highlights the use of simulations for example in emergency preparedness and training. Pöllänen and Siiskonen [5,6] used simulations to investigate the direct alpha spectrometry in the case of air samples and concluded that the method is feasible for rapid measurements. However, in a severe nuclear reactor accident the presence of numerous alpha particle emitting radionuclides in air

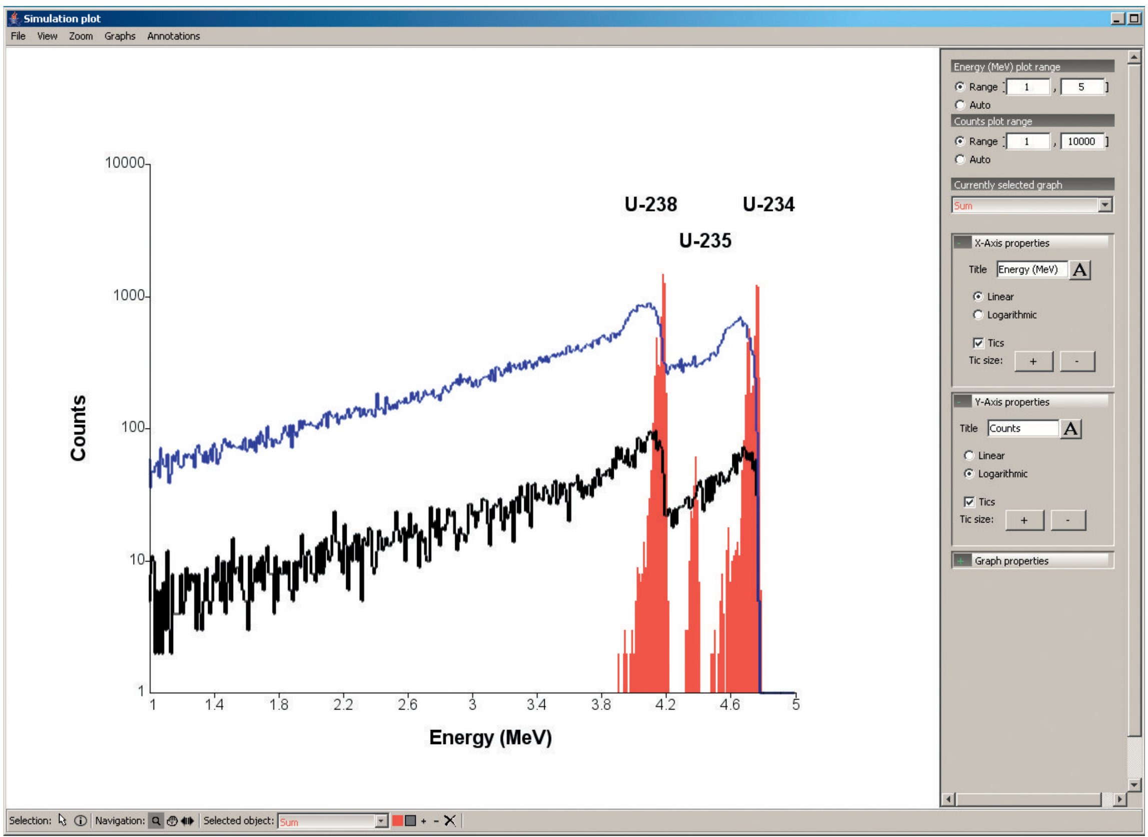

Figure 2: Screen snapshot of the plot page: Thick black line is the measured spectrum from a swipe sample containing natural uranium. Thin blue line is from the simulation of the same swipe sample using the source parameter values presented in Figure 1. Energy spectrum from a massless source containing natural uranium (filled red color) represents the case when peak shape is determined only by the detector properties, not by the sample.

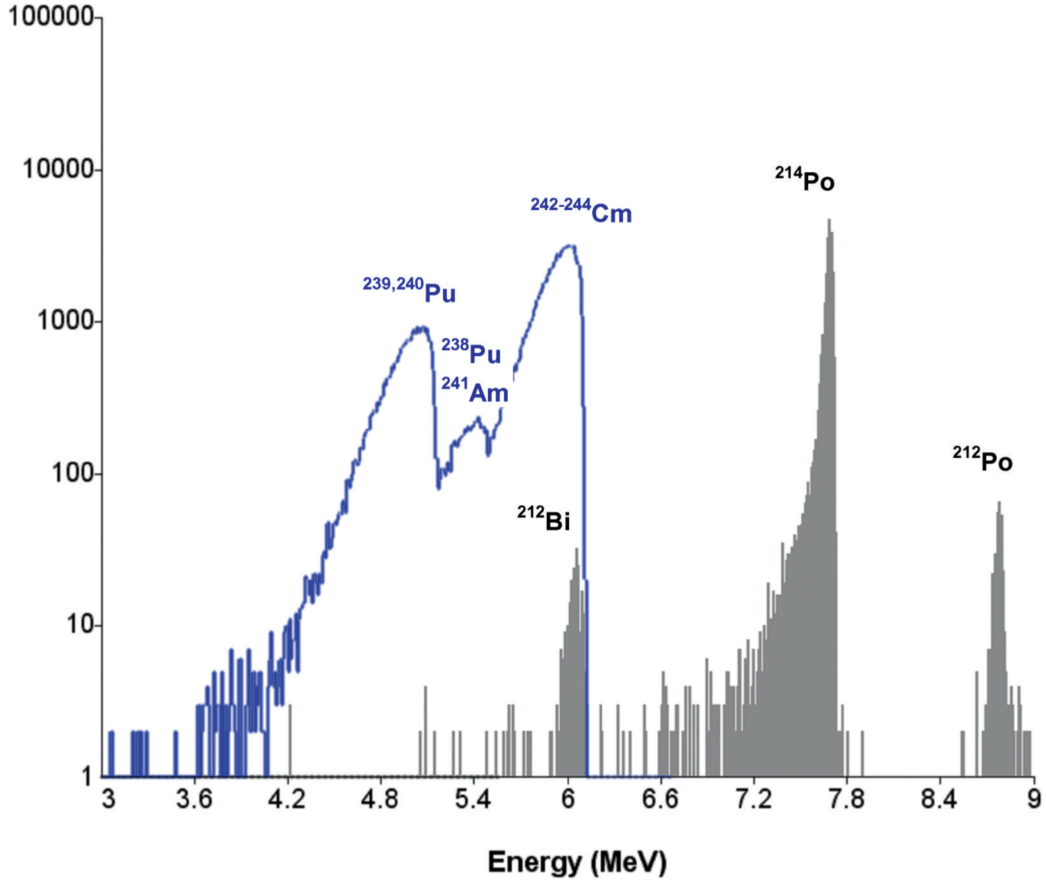

Figure 3: Typical measured alpha spectrum (filled line with grey color) from outdoor natural radionuclides present on a Fluoropore membrane filter (see e.g. [5,6]). The simulated alpha spectrum (blue line) has a nuclide composition similar to Chernobyl fuel with an average burnup [7]. A lognormal fuel particle size distribution (mean diameter 1.0 μm, geometric standard deviation 1.5) is assumed in the simulations.

may complicate the spectrum analysis or, in the worst case, totally hinder it. Here, nuclear fuel particles are assumed to be present in a membrane filter and the nuclide composition corresponds to that of the Chernobyl accident [7]. Figure 3 shows that the fuel particle characteristics have a notable influence on the alpha spectra. In spite of the peak broadening, three alpha particle peaks are clearly visible in the spectrum, corresponding to Pu, Am and Cm isotopes. Moreover, the naturally occurring nuclides do not hinder the spectrum analysis.

3.3. Coincidences studies

Separation of plutonium isotopes 239 and 240 is challenging in alpha spectrometry because their main alpha peaks are only 12 keV apart. This is the main reason why their sum activity is usually reported. In the case of a thin source, the separation may be possible with a high-resolution semiconductor detector. However, even then, careful spectrum unfolding is needed to obtain reliable activity estimation. An additional challenge is the coincidence phenomenon: alpha particles emitted from the plutonium isotopes may be detected in coincidence with the conversion electrons and photons emitted from the uranium daughters. AASI code can be applied to find the real shape of the alpha peaks in the presence of the coincidence summing. This shape can be used as an input to the spectrum unfolding code and, thus, facilitating the separation of ^{239}Pu and ^{240}Pu.

3.4. Other applications

Source characteristics, especially the source matrix thickness (i.e. mass per unit area), have a notable influence on the alpha particle energy spectrum. Unfortunately, experimental verification of the source matrix properties is a laborious task and requires special techniques. With the AASI simulation code the influence of various source properties, such as thickness and its variations, elemental composition, protective layers etc., on the alpha particle energy spectrum can be investigated [8]. Vice versa, the source properties can be investigated using measurements with an alpha spectrometer and simulations [9]. A special case is the characterisation of an individual radioactive particle containing alpha emitting radionuclides [10]. Simulations may also be useful for quality control purposes since, for example, the impact of a non-uniform source to the spectrum quality can be easily checked [8].

Other approaches may be the investigation of aerosol particle deposition in air filters as a function of depth using naturally occurring airborne radionuclides, such as ^{214}Po or ^{212}Po, as tracers.

4. Conclusions and future perspectives

High-resolution alpha spectrometry combined with advanced simulation capability gives tools for different applications extending from basic research to special applications such as nondestructive forensic analyses. Characterisation of the source properties is an application where benefits are obvious. In direct alpha spectrometry, substantial development of sampling techniques may be possible by selecting the sample material properly and by designing the sampling procedures carefully on the basis of simulations. Simulations are also indispensable when samples with challenging source matrices or nuclide compositions are encountered: simulated peak shapes can be used as an input to spectrum unfolding code.

The AASI computer code with relevant documentation is available on STUK's www-pages (http://www.stuk.fi/tutkimus/programs/aasi/en_GB/aasi/).

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Working Groups activities

Introduction to the Articles from a Seminar on Export Control of Dual-use Items and Technology

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The ESARDA Working Group on Verification Technologies and Methodologies (VTM) was established in the late 1990s. The group's mission is to provide 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.

A lot of activities of the VTM working group have been reflected in the following book, published in 2006: "Verifying Treaty Compliance", Springer, ISBN-10 3-540-33853-5, ISBN-13 978-3-540-33853-5. However, the book does not deal with the important issue of dual use and export control.

Therefore, the ESARDA Working Group on VTM considered it highly desirable to organize a one-day seminar, to discuss the export control of dual use items. This seminar was held at the Joint Research Centre at Ispra on 14 November, 2006. Experts from various national organisations in Europe and the US, nuclear industry, research institutions, Euratom Safeguards Directorate, European Commission, and the International Atomic Energy Agency (IAEA) participated and presented papers.

It was agreed that the presentations should be published, to bring them to the attention of a broader audience, the detection of clandestine trade networks in recent years having raised the issue of export control with the wider community. However, export control was always a main pillar in the overall non-proliferation complex, and this holds true not only for the nuclear field. In other technology areas, there are also relevant control regimes:

- Missile Technology Regime (MTCR)
- Wassenaar Arrangement (WA) for conventional armament
- Australia Group (AG) for biological and chemical weapons
- Nuclear Suppliers Group (NSG)

The implementation of export control clearly belongs to the States' authorities. But, since the "triple S" concept has become more prominent, i.e., to treat safety, security, and safeguards as interlinked problems, the responsibilities between States and multi-national or international organisations like the IAEA seem to mingle. This trend becomes more evident under the implementation of Additional Protocol safeguards, with the Agency having the task to detect undeclared nuclear activities and materials, and with the profile of a suspected actor not being fully identifiable.

In this context, it is therefore very much welcomed that the Agency has established a division on information collection and analysis, including a group dealing with clandestine nuclear networks.

The chairman of the ESARDA Working Group on Verification Technologies and Methodologies wishes to convey his sincere thanks to the Joint Research Centre at Ispra and, especially, to Louis-Victor Bril and Cristina Versino for arranging and publishing the results of the seminar on export control of dual use items.

Nuclear Export Controls

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Abstract

This article, which was written primarily for safeguards practitioners, is intended as a short introduction to the world of nuclear export controls. As necessary, the jargon of export controls is introduced. The article gives an overview of the origins and development of nuclear export controls, especially in relation to the Nuclear Suppliers Group and the Zangger Committee. The European legal framework applying to dual-use export controls – essentially the Dual-Use Regulation – is introduced. The nexus with safeguards is also examined, in particular the nexus with the Additional Protocol. Recent developments, notably in relation to civil nuclear co-operation with India are briefly covered. Some aspects of the nuclear export control regime are not in the public domain and hence have not been covered in this article.

Keywords: NSG; Zangger; Dual use; Export controls; Additional Protocol.

1. Terminology

The terms *goods*, *equipment*, and *material* are used in this note in relation to physical transfers of the same, whereas the term technology refers to information and includes, for example, technical data such as calculations, designs, or software. The term *technology* also covers technical support. Thus the term technology as used in the jargon of export control is based on a lawyer's notion of technology rather than an engineer's.

The term *item* means physical *goods*, *equipment* and *materials* together with related *technology*.

Technology transfers may be *tangible*, e.g. transfers on paper or they may be *intangible*, e.g. transfers by email.

2. The History of Nuclear Export Controls

The small circle of nuclear technology holders at the beginning of the nuclear age viewed the spread of military nuclear technology as being undesirable. Well aware that many materials and equipments used for civil nuclear purposes could also be used in the production of the fissile materials necessary for military nuclear explosives, they viewed the uncontrolled spread of the capability to produce weapons grade fissile materials as being equally undesirable.

The Atoms for Peace initiative brought a relaxation of this position, from the United States at any rate. Henceforward, nuclear technology would be disseminated, but only to states providing verifiable guarantees that the supplied materials and installations would not be diverted. Euratom and IAEA (International Atomic Energy Agency) safeguards were created in the 1950's in order to provide such guarantees.

A decade later, the NPT (Treaty on the Non-Proliferation of Nuclear Weapons) brought a basis in international law for export controls through its Article 3.2 which provides that:

Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non nuclear weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this Article.

Led by Switzerland, a group of 15 nuclear supplier states, signatories as well as prospective signatories of the NPT, came together in 1971 to reach a common understanding as to what constitutes **'equipment or material especially designed or prepared'**, since the NPT itself does not include any technical annexes. This group of states known as the NPT Exporters Committee is better known as the Zangger Committee after its first Chair, Claude Zangger. France was not a member because of its then opposition to the NPT.

The states agreed two technical lists: Memorandum A covering source materials and special fissionable materials; and Memorandum B covering uranium conversion, uranium enrichment, fuel fabrication, reactors, reprocessing, and heavy water production. Together these two lists constituted the ***'Trigger List'***, so named because export of such materials or equipment would trigger the application of IAEA Safeguards.

Zangger states undertook to make their nuclear exports to states not party to the NPT conditional upon the supplied materials or equipment falling under a safeguards agreement with the IAEA. Moreover, receiving states were obliged to supply assurances that the same arrangements would be applied in case of retransfer to a state not party to the NPT. In 1974 several of the Zangger states declared by means of diplomatic letters to the Director-General of the IAEA that they would act in accordance with the Zangger Memoranda, published by the IAEA as INFCIRC/209. The Zangger Memoranda are known as Understandings, meaning that they are to be considered as a gentlemen's agreement rather than as an agreement binding under international law.

In 1974 India detonated a nuclear device in the Rajasthan desert, using plutonium from a research reactor donated by Canada. The conclusion drawn by nuclear supplier nations was that nuclear export controls needed tightening. A new group consisting of the seven major nuclear supplier states, including France, which at that time was still outside the NPT, started meeting in London to draw up strengthened controls. The group, known at the time as the London Club, came to be known as the Nuclear Suppliers Group (NSG). The result of its deliberations was first published by the IAEA in 1978 as INFCIRC/254 Guidelines for the Export of Nuclear Material, Equipment or Technology. The NSG Guidelines, like the Zangger Understandings, are an international gentlemen's agreement, the aim of which is to ensure that all states capable of supplying nuclear materials and equipment can exercise restraint when circumstances demand, without fear of being *undercut* by one of the other states in the supplier club.

The inclusion of the word technology in the title indicates one significant difference to the Zangger Understandings: NSG controls would also apply to technology transfers [1] related to the most sensitive facilities – enrichment or reprocessing facilities. Otherwise, the NSG Guidelines consisted of an extended version of the Zangger Trigger List containing complete fuel cycle facilities together with some of the major critical equipment as well as a number of new stipulations (listed below) intended to reduce the risk of nuclear proliferation:

- Transfer of Trigger List items was made conditional upon suppliers' receiving formal governmental assurances of no explosive use from the recipient state.
- Effective physical protection should be applied to transfers.
- The safeguards requirements were strengthened so that recipients' safeguards agreements with the IAEA would be of appropriate duration and that facilities constructed as a result of technology transfers should also be subject to IAEA safeguards.
- Exporters were to exercise 'restraint' in the transfer of particularly sensitive materials and facilities, and where transfers would take place, suppliers were to encourage multilateral control of the facilities – once again a topical subject.
- The provisions on retransfer were strengthened so as to cover retransfers of plant replicated by the recipient.
- Exported enrichment plant was not to be used for the production of uranium enriched beyond 20%.

Though the NSG Guidelines were to apply to all transfers and not just transfers to non-NPT states, the required IAEA Safeguards did not have to conform to the INFCIRC/153 model. Even the most creative legal mind would struggle to argue that some of the new stipulations derive from Article 3.2 of the NPT. Therefore, the NSG Guidelines are less firmly rooted in the NPT than are the Zangger Understandings.

Having drawn up its Guidelines the NSG then stopped meeting until the aftermath of the 1991 Gulf War, when the clandestine Iraqi nuclear programme was being – sometimes literally – unearthed. A major strand of the nearly successful, covert nuclear programme was based upon circumventing existing Trigger List based export controls by purchasing unlisted equipment and components in order to assemble or fabricate Trigger List items.

The lesson was clear and the NSG reactivated itself, informing the IAEA in 1992 of the revision of the NSG Guidelines. The most notable change was the addition of a second list of controlled items together with a number of stipulations regarding the transfer of these items. The document was entitled Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Material and Related Technology and was published by the IAEA as INFCIRC/254 Part 2 – the original NSG Guidelines henceforth being identified as INFCIRC/254 Part 1. NSG Part 2 contained *procedures in relation to the transfer of certain equipment, material, and related technology that could make a major contribution to a "nuclear explosive activity" or an "unsafeguarded nuclear fuel-cycle activity."* The list of controlled items annexed to NSG Part 2 is composed of 8 categories of items

- Industrial Equipment
- Materials
- Uranium Isotope Separation Equipment and Components
- Heavy Water Production Plant Related Equipment
- Implosion Systems Development Equipment
- Explosives and Related Equipment
- Nuclear Testing Equipment and Components
- Other

Clearly, some of the items are single use rather than dual-use in the sense of dual-use items being usable in both civil and military applications. Be that as it may, most of the items have civil applications, both in the nuclear field and beyond and, therefore it is necessary to ensure that legitimate trade is not hindered. Since many of the items have non nuclear uses, their transfer cannot be made conditional upon the recipient having satisfactory safeguards arrangements in place (also bearing in mind that we are still four years from the approval of the model Additional Protocol).

The keystone of NSG Part 2 is the Basic Principle reproduced verbatim below.

Suppliers should not authorize transfers of equipment, material, or related technology identified in the Annex:

- *for use in a non-nuclear-weapon state in a nuclear explosive activity or an unsafeguarded nuclear fuel cycle activity, or*
- *in general, when there is an unacceptable risk of diversion to such an activity, or when the transfers are contrary to the objective of averting the proliferation of nuclear weapons.*

Transfers of items from NSG Part 2 are conditional upon suppliers receiving guarantees of no nuclear explosive purpose for the transfers, an End-User statement, and prior consent rights in respect of re-transfers to states not applying the NSG Guidelines. Supplier states, when deciding whether to authorise transfers, should take a number of largely subjective factors into account including the declared end-use of the items and the appropriateness of the declared end-use, whether the recipient state is in compliance with its international non proliferation obligations, and whether the recipient is a party to the NPT subject to full scope IAEA safeguards, or, if the recipient is not an NPT party, whether the recipient operates unsafeguarded facilities.

NSG Part 2 also instituted exchange of information on procurement activities of concern, and national governments' refusals to authorise transfers (*denials* in export control jargon), providing for consultations if one state intended to authorise export of a type of item which had been denied by another.

NSG Part 1 was also updated at the same time. The principles section was unchanged but the Trigger List section was considerably extended to include items down to the level of sub systems and components and replacing vague descriptions of controlled items with more detailed technical specifications, with both positive and negative effects. On the one hand the detailed control list helps exporters to be sure as to which of the items of equipment are subject to export controls. On the other hand, the inclusion of technical specifications in a control list turns it into a piece of useful guidance for would be proliferators.

In 1992 the NSG also adopted a policy requiring **full scope safeguards** [2] as a condition for authorising transfers of Trigger List items. Another important later addition to NSG Part 1 was the Non-Proliferation Principle which provides that *suppliers should authorize transfer of items or related technology identified in the trigger list only when they are satisfied that the transfers would not contribute to the proliferation of nuclear weapons or other nuclear explosive devices.* The Non proliferation Principle is important because it requires suppliers to refuse transfers of Trigger List items to states where the IAEA applies full scope (INFCIRC/153) safeguards but which are nonetheless suspected of possessing a covert nuclear programme.

At the time of writing, the NSG had not added signature or application of the Additional Protocol (INFCIRC/540 model) by recipients as a condition of supply for Trigger List items. Of course, nothing prevents NSG states from applying stricter supply conditions than the ones in the Guidelines but then they run the risk that other NSG states supply the items in their place.

3. The NSG and Zangger Today

The NSG has 45 member states, including all 27 member states of the EU, and the European Commission participates as permanent observer. The NSG is not an international organisation, has no permanent secretariat, and is chaired by a different state every year. The Chair hosts the annual plenary meeting, which is where all decisions concerning both sets of Guidelines and both control lists are made. All decisions require unanimity. The plenary can set up working groups which may meet between the plenary meetings.

It may be surprising to learn that the Zangger Committee still holds meetings. It has 36 member states, all of which are members of the NSG, but unlike the NSG not all EU member states are members of Zangger. The latest (eighth) revision of the Zangger Trigger List was published by the IAEA in February 2008 as INFCIRC/209/Rev.2/Mod.1. The Zangger and NSG Trigger Lists are almost identical and indeed the two groups aim to harmonise their respective Trigger Lists. Given this and the fact that NSG's Guidelines are much more restrictive than Zangger's, one might wonder why the Zangger Committee still exists. One reason is that Zangger has a direct link to the NPT's article 3.2, and indeed sees itself as the interpreter [3] of article 3.2. For some states this link to the NPT bestows upon the Zangger Trigger List a legitimacy that the NSG's Guidelines lack.

4. The Dual-use Regulation

Council Regulation (EC) 1334/2000 (as amended) governs export from the European Community of dual-use goods [4]. The Regulation is in two main parts.

The first is the body of the regulation, which describes the 'mechanics' of how Community controls on dual use exports function. There are sections devoted to customs procedures, to defining which transfers are subject to Community export controls and to defining the processes for obtaining export licences from national authorities. Other sections describe the various types of export licence, mutual recognition of export licences, as well as the procedures for consultation and co operation between member states. The member states are responsible for the practical operation of the export control system created by this regulation.

The second main part is Annex I to the Regulation – the list of controlled items, which runs to 238 pages in its current version [5] and is composed of items from the international export control regimes addressing dual-use goods [6] as well as some items specified in the technical annexes to the Chemical Weapons Convention. Apart from NSG Part 1 items, which appear together in one category, controlled items from the various lists are mixed together. There is some overlap between the various regimes' control lists. For instance, the Wassenaar list includes Pu238 and Np237 whilst the Australia Group's list includes corrosion resistant vessels usable for wet processing in the nuclear cycle.

National licensing offices are responsible for deciding on how to respond to applications for export licences; the Regulation does not specify the grounds on which their licensing offices should authorise or refuse requests for export licences. Instead, the relationship of the Regulation to the export control regimes is described in its Article 8 where we find:

In deciding whether or not to grant an export authorisation. Member States shall take into account the obligations and commitments they have each accepted as a member of the relevant international non proliferation regimes and export control arrangements.

This device translates into European law the undertakings made in the export control regimes by the EU's member states. It also explains in part why it is important that all EU member states be members of the relevant export control regimes.

The body of the regulations also contains provisions relating to items that are not included in the control list. Exporters who are aware that items are for use in a weapons of mass destruction programme must obtain an export licence. An export licence may also be required for transfers of items to countries subject to embargos as well as under certain other circumstances. Another provision permits member states to require authorisation for transfers of non listed items to certain destinations or even to prohibit transfers for reasons of public security or human rights. These types of provision are known in export control jargon as *catch-all* or *end-user control*.

Annex II to the Regulation is EU001, the Community General Export Authorisation, which in effect is an export licence issued by the Community for almost all items in the control list, valid for transfers to a select club of seven destinations (a *White List*). The authorities of the Member States issue all other export authorisations. The Community General Licence lists the dual-use items which it excludes rather than those whose export it authorises. The entire Trigger List is excluded from the scope of this licence. Indeed, the current version of the Regulation subjects nuclear transfers within the single market, with the exception of natural or depleted uranium, to a requirement to obtain a licence. This requirement would seem to be at odds with the Nuclear Common Market established by the Euratom Treaty.

Even though the severity of penalties for breaches of the Regulation is determined by the member states, the Regulation obliges member states to properly enforce it and to set *effective, proportionate and dissuasive* penalties for breaches.

A Commission Proposal [7] for modification of the EU's dual-use regime is currently passing through the EU's legislative machinery [8]. Themes being addressed include the necessity of further harmonisation of the operation of the regime, especially insofar as it concerns controls on non listed items, as well as ensuring that the EU's dual-use regime complies with the requirements of UN Security Council Resolution 1540, specifically those concerning transit, trans shipment, and brokering.

5. IAEA and the Additional Protocol

As is well known, the discovery of Iraq's undeclared nuclear programme led to a strengthening of NPT safeguards and nuclear export controls. In a sense, the Additional Protocol (AP) symbolises the strengthening of the two systems. The Model Additional Protocol, INFCIRC 540, obliges States to report international transfers of the goods listed in its Annex II to the IAEA. The list is almost identical to the NSG/Zangger Trigger list: the chief differences being the absence of technology transfers, and the absence of nuclear materials, which are caught by safeguards accountancy. Annex I, a list of sensitive manufacturing activities to be reported to the IAEA, is the other Annex of the Model Additional Protocol and can be viewed as an indirect means of reporting on some items in the NSG Part 2 list. Information relating to the approval or denial of nuclear transfers is commercially very sensitive, not least because exporters fear that competitors may use the information as sales 'leads', and so the fact that states are willing to report information to the IAEA that by and large they do not share with each other is quite remarkable.

Although the model AP provides for its Annexes to be updated by the Board of Governors, this has not yet been done; with the result that Annex II is slowly drifting away from the Trigger List. If and when the Board of Governors does update Annex II, it will be interesting to see whether updating goes beyond harmonisation with the Trigger List, and particularly whether Part 2 items relating to weaponisation are added.

The IAEA's untangling of the strands of Iraq's nuclear procurement web provided the IAEA with an unparalleled expertise in the strategies proliferators employ to defeat export controls. This expertise was recently fortified by what was learned from the investigation of Libya's covert procurement activities. To capitalise on this expertise, in late 2004 the IAEA established a unit (NUTRAN) within its secretariat to centralise the analysis of nuclear trade and covert supply networks. The unit's role is not to check the effectiveness of export controls but rather to prepare output for feeding into the IAEA's State Evaluation process. (Note that the European Commission does not evaluate the AP declarations that some EU member states send it for forwarding to the IAEA).

6. The Indian Exemption Future Developments

On the 18th July 2005 US President Bush and Indian Prime Minister Singh issued a joint statement [9] on relations between the US and India. Many observers were taken by complete surprise by one section of the statement where it was stated that the US would work to achieve full civil nuclear co operation with India, both by adjusting US domestic laws and by working with international partners to adjust the rules of international regimes (i.e. NSG), thereby taking the first steps towards ending three decades of Indian nuclear isolation.

In exchange for this, the Indian Prime Minister conveyed (in the same statement) that India would separate its civilian and military nuclear facilities and file a declaration regarding its civilian facilities with the International Atomic Energy Agency (IAEA); place its civilian nuclear facilities under IAEA safeguards; sign and adhere to an Additional Protocol; continue India's unilateral moratorium on nuclear testing; work for the conclusion of a multilateral Fissile Material Cut Off Treaty; refrain from the transfer of enrichment and reprocessing technologies to states that do not have them; introduce comprehensive export control legislation; and adhere to the Missile Technology Control Regime (MTCR) and Nuclear Suppliers Group (NSG) guidelines.

As might be expected the Statement aroused controversy and initially, little progress towards achieving the aim of the Statement was visible publicly, but during the summer of 2008 the pace quickened dramatically and the last steps needed to bring India back into the nuclear fold were taken in rapid succession, culminating 06/09/08 in the NSG's adoption of a policy statement [10] exempting India from the NSG's requirement on full scope safeguards.

The granting of the exemption was preceded shortly beforehand by two other noteworthy events, the publication 25/07/08 of India's plan for separating its civil and military nuclear facilities [11] and the adoption [12] by the IAEA's Board of Governors 01/08/08 of the (at the time of writing) still unpublished Safeguards Agreement with India.

One important intervention, which may have helped sway undecided decision makers in NSG states was that of IAEA Director General ElBaradei who described the safeguards agreement as being "good for India, good for the world, good for non-proliferation, good for our collective effort to move towards a world free from nuclear weapons" [13].

The safeguards agreement with India would warrant a dedicated article in its own right and so will not be analysed here, other than to note that it is an INFCIRC/66 type safeguards agreement, in the form of an umbrella agreement allowing facilities notified by India in the future to be subject to its provisions.

7. Future Developments

A few themes are likely to dominate thinking about nuclear export controls in the near future. Recent revelations have served to show that supply networks are able to source equipment from a widening circle of countries, as advanced manufacturing technologies spread and as interest in nuclear energy builds-up once more. The new supplier countries will need to be convinced of the importance of maintaining effective export controls. They may also need to be plugged into the international information exchanges on suspicious procurement activities. Finally, the guidelines on export controls could be brought into line with today's safeguards: full scope safeguards combined with the Additional Protocol, i.e. to make the Additional Protocol a condition of supply for Trigger list supply, and at least a factor for consideration when deciding whether to authorise transfers of NSG Part 2 items. In any case, it can only be hoped that it will not take a major failure of nuclear export controls to produce the international consensus necessary for strengthening of the nuclear export control regime.

Disclaimer

This note has been prepared from open source information only. Any opinions expressed herein are entirely the author's own opinions and should not be considered as representing those of the European Commission.

References

[1] Note to INFCIRC/254 Part B, "*Technology*" *means technical data in physical form designated by the supplying country as important to the design, construction, operation, or maintenance of enrichment, reprocessing, or heavy water production facilities or major critical components thereof…..*

[2] The transfer of nuclear facilities, equipment, components, material and technology as referred to in the export trigger list of the Guidelines for Nuclear Transfers (see INFCIRC/254), should not be authorised to a non-nuclear-weapon State unless that State has brought into force an agreement with the IAEA requiring the application of safeguards on all source and special fissionable material in its current and future peaceful nuclear activities.

[3] http://www.zanggercommittee.org/Zangger/Misssion/default.htm

[4] Defined as follows in Council Regulation 1334/2000: *'dual-use items' shall mean items, including software and technology, which can be used for both civil and military purposes, and shall include all goods which can be used for both non-explosive uses and assisting in any way in the manufacture of nuclear weapons or other nuclear explosive devices;*

[5] Council Regulation (EC) No 1183/2007 of 18/09/2007

[6] The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-use Goods and Technologies; the Australia Group which covers chemical and biological weapons; and the Missile Technology Control Regime.

[7] COM(2006) 829. Final. Proposal for a Council Regulation setting up a Community regime for the control of exports of dual-use items and technology.

[8] The Commission's website on Dual-use related issues can be found at: http://ec.europa.eu/trade/issues/sectoral/industry/dualuse/index_en.htm

[9] Joint Statement by President George W. Bush and Prime Minister Manmohan Singh. White House Press Release, Office of the Press Secretary, Washington, DC, July 18, 2005

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[11] INFCIRC/731, 25 July 2008 Communication dated 25 July 2008 received from the Permanent Mission of India concerning a document entitled "Implementation of the India-United States Joint Statement of July 18, 2005: India's Separation Plan"

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Nuclear Trade Analysis May Provide Early Indications of Proliferation

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Abstract

A dedicated Nuclear Trade and Technology Analysis Unit (TTA) has been established in the Department of Safeguards as an IAEA response to transnational proliferation risks caused by covert nuclear trade and proliferation networks. This action strengthens the IAEA's verification activities and State evaluation processes by centralizing the analysis of all available covert procurement network related information. The IAEA General Conference has repeatedly invited all States to voluntarily co-operate with the IAEA by providing safeguards with relevant nuclear trade related data. This includes export denials and suspicious procurement enquiries received by companies. Whilst several States are already cooperating with the IAEA, this type of support needs to be extended to a wider circle of States in order to address the biggest proliferation challenge – nuclear proliferation networks.

Keywords: Safeguards, proliferation networks, nuclear trade analysis, export denials, procurement enquiries.

1. Introduction

Nuclear proliferation networks have been considered as one the biggest concerns to international safeguards [1]. Even though several well-known players in these networks have been revealed and stopped, there are no indications that covert nuclear trade in proliferation sensitive goods, software and technology is decreasing.

The revelation of the Libyan covert nuclear weapons programme in December 2003 was a surprise to most of the world – but not to all. For some time indicators of undeclared activities had been followed by some States. The International Atomic Energy Agency (IAEA) had also detected weak indications in Libya but there was no clear understanding whether these indicators were important. Before the Libyan case, the IAEA had gained relevant experience in monitoring and clarifying in detail Iraq's undeclared nuclear weapons programme and verifying the extent of Iran's nuclear programme.

The IAEA General Conference (GC) has recognized the proliferation risks related to the trans-national proliferation networks. Since 2005, the GC has repeatedly passed a resolution which *welcomes efforts to strengthen safeguards, including the Secretariat's activity in verifying and analyzing information provided by Member States on nuclear supply and procurement, taking into account the need for efficiency, and invites all States to co-operate with the IAEA in this regard* [2]. These resolutions mandate the IAEA to investigate covert nuclear related trade to create knowledge of nuclear black markets for safeguards verification purposes. Close cooperation with States providing complementary data is crucial for the success in these efforts.

2. Trade controls need strengthening

Verifying the correctness and the completeness of State declarations has always been the objective of the IAEA safeguards system [3]. However, it was the additional protocol (AP) that improved the IAEA's capabilities to verify that States' declarations are complete. In parallel with the AP entering into force in an increasing number of States, the IAEA has also improved information analysis. The on-going State evaluation process, established in the mid 1990s, has become the main process supporting the drawing of annual safeguards conclusions.

The AP declarations [4] provide the IAEA with additional information related to manufacturing and construction of sensitive equipment, exports of specialized equipment and material for example, and imports if requested by the IAEA. All this information is useful for verifying that States are fulfilling their safeguards' obligations.

However, the State may not always be aware of all safeguards relevant activities on its territory, for example in so-called free-trade zones, where trade controls may be minimal at best. As well, the State itself may indeed be involved in undeclared nuclear activities and clearly will not declare these to the IAEA.

Export controls are the responsibility of States. Information available from the implementation of the UNSCR 1540 [5] reveals that nuclear export controls are not always well developed and not capable of effectively controlling global trade in proliferation sensitive goods, software and technology. Other arrangements to curb nuclear proliferation include voluntary arrangements such as the Nuclear Suppliers Group (NSG) Guidelines adhered to by 45 States.

The AP provides information on specific nuclear related activities to develop a better understanding of States' nuclear programmes. To curb proliferation, the NSG Guidelines require comprehensive safeguards in the recipient State as a condition of export of nuclear use and related dual use items, in addition to other requirements. The NSG members inform each other of export denials in an attempt to prevent an export denied by one member being licensed by another. Currently, the IAEA does not receive such NSG denial data on a regular basis.

In addition to the national and international control measures, corporate level export control compliance programmes are increasingly used by ethically aware companies to make sure company sales are not used to advance proliferation of weapons of mass destruction (WMD). Additional motivation for improving awareness and avoiding expert control violations include the risk of becoming black-listed, being penalized up to one hundred million dollars and losing export privileges. Identifying suspicious procurement enquiries and deciding not to supply improves defense-in-depth in fighting proliferation. Denying an export by companies based on an identified proliferation risk rather than mechanistic reading of control lists, improves selectivity and the effect of such control measures.

3. The need for nuclear trade related information

The need for additional information in developing a better understanding of covert nuclear related trade has long been recognized by the IAEA. In addition to the GC resolutions mentioned above, detection of undeclared nuclear material and activities is identified as one of the priorities of the IAEA Medium Term Strategy (MTS) 2006-2011 [6]. One specific action of the MTS calls for obtaining, through appropriate mechanisms and channels, pertinent information on international nuclear activities and trade relevant to safeguards implementation [7].

Improving access to complementary nuclear related trade data was one of the proposals of the IAEA Secretariat to Committee 25 [8] aiming at further strengthening of safeguards. It was proposed that the Board of Governors would request all Member States to provide to the Agency, on a voluntary basis, relevant information on exports of specified equipment and non-nuclear material, procurement enquiries, export denials, and relevant information from commercial suppliers in order to improve the Agency's ability to detect possible undeclared nuclear activities. The information would have been processed within the existing structure for the evaluation of safeguards related information. The Committee was, however, not able to adopt any specific recommendations.

4. Nuclear trade analysis

The Libyan case made visible a widespread international nuclear procurement network. It revealed that the traditional, facility oriented safeguards developed in the late 1960s, and strengthened in the 1990s to address the State as a whole, was facing new challenges. The biggest proliferation risks were no longer just State specific but also trans-national in nature with non-state actors increasingly involved. The problem was that the IAEA had no specific verification tools to address such new challenges. This is why innovative approaches in the IAEA, in addition to regulatory control and voluntary compliance on the State level, were and still are needed to curb nuclear proliferation.

To address the safeguards challenges of covert nuclear related trade, a Nuclear Trade and Technology Analysis Unit (TTA) [9] was established in the IAEA in November 2004. The Unit, located in the Department of Safeguards, is mandated to centralize the analysis of all procurement networks related information available to the IAEA. In cooperation with other organizational units, TTA investigates the activities of known networks and endeavors to reveal presently unknown networks. It also maintains the IAEA's institutional memory on covert nuclear related procurement activities [10] [11]. These measures are pivotal to the analysis by enabling access to nuclear trade related data both now and in the future.

TTA provides expert services using technical and trade analysis expertise to support verification activities and the preparation of State evaluations, a core safeguards activity. Close cooperation with other information analysts and inspectors has improved the potential of the IAEA to understand better weak proliferation indicators related to transnational trade activities.

A specific procurement outreach program was launched in 2006 [12] by the IAEA to facilitate acquiring of nuclear trade related information provided by States and companies. Responding to the requests of the General Conference, some 20 States had been contacted by the Secretariat by the end of 2007, inviting them to provide complementary information on a bilateral, voluntary basis to aid a better understanding of safeguards relevant, covert nuclear related trade. The programme is based on the premise that developers of an undeclared nuclear programme need to buy sensitive items from the open market thereby leaving traces that, once analyzed, may reveal early indicators of proliferation. States have shown interest and several of them are already providing complementary information on export denials and unfulfilled procurement enquiries received by companies. Outreach information is handled with high confidentiality by the IAEA as has been agreed with States participating in the programme.

5. Conclusions

Trans-national proliferation networks and the increased involvement of non-state actors in covert nuclear related trade activities pose a challenge not only to national and international safeguards but also to other WMD verification regimes. Nuclear trade analysis aims at developing better understanding of such networks. Declarations based on safeguards agreements do not provide the type of data networks analysis needs. This is why the needs of nuclear trade analysis call for States to increase information sharing with the IAEA on a bilateral and voluntary basis. It is obvious that synergies in analytical approaches, methods and tools could be found between different WMD verification regimes. International safeguards would also benefit from increased cooperation with State authorities and companies controlling proliferation sensitive exports. While controls can only address the symptoms, internal export control and compliance programmes can change the culture of curbing proliferation. In these endeavors, the former subject and object of controls become partners in fighting proliferation. Increased support of Member States in providing information forms the basis the IAEA needs in addressing the biggest proliferation challenge, the nuclear proliferation networks.

References

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[2] Resolution GC(49)/RES/13, para 21 (2005); GC(50)/RES/14, para 24 (2006) and GC(51)/RES/15, para 25 (2007).

[3] According to INFCIRC/153 (Corr) para 2: “The Agreement should provide for the Agency’s right and obligation to ensure that safeguards will be applied, in accordance with the terms of the Agreement, on all source or special fissionable material in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere, for the exclusive purpose of verifying that such material is not diverted to nuclear weapons or other nuclear explosive devices.”

[4] Additional Protocol Article 2.a. declarations.

[5] UNSCR 1540, adopted by the Security Council at its 4956th meeting on 28 April 2004, www.un.org/sc/1540/index.shtml.

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The European Union Dual-use Export Control Regime

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Abstract

To comply with international export control regime commitments, EU Member States have introduced specific provisions in national legislation dedicated to the export of dual-use goods. Such national provisions require traders to apply for an export authorisation for dual-use goods and technologies, which, under certain circumstances, can be denied. The achievement of the common market in 1993, and the consequent free movement of dual-use items within the European Community, raised the necessity to harmonise national export control regimes. Member States have always been reluctant to consider that such harmonisation could happen through the establishment of a single EU Export Control Regime. A complex system of harmonisation has been adopted instead. The present contribution analyses the different elements that govern the transfer of dual-use items into and out of the European Union.

Keywords: Dual-use, European Union, export control, non proliferation.

1. Principles of international dual-use trade exchange

The international trade of goods is governed by principles established by the World Trade Organisation and, in particular, the General Agreement on Tariffs and Trade (GATT). The aim of this agreement is to ensure that international trade is without discrimination, predictable and free. In this regard, trading barriers have been progressively lowered, and exceptions are strictly limited. Article XXI of the GATT sets down conditions for a State to adopt or maintain derogations to the GATT principles. Such derogations are related to the protection of a State's essential security interests, or its obligations under the United Nations Charter for the maintenance of international peace and security.

Due to the potential for military application, the trade of dual-use items falls within the GATT derogation. Governments have introduced specific provisions dedicated to the export of dual-use goods. These address commitments taken under the Nuclear Suppliers Group, the Wassenaar Arrangement, the Missile Technology Control Regime, the Australia Group, and/or other Weapons of Mass Destruction international export control regimes. Such national provisions require traders to apply for an export authorisation for dual-use goods and technologies, which, under certain circumstances, can be denied.

2. The European Union implementation of the international dual-use export control principles

Different authorities of the European Union may intervene in the organisation of dual-use transfers to or from Member States. To understand the process of intervention, one should distinguish between the inter-governmental cooperation mechanism, set up by the Treaty on the European Union (the EU Treaty), and the European Community legislation, instituted by the Treaty establishing the European Community (the EC Treaty).

The main difference between the two mechanisms lies in the consequences of the decision adopted. Default by an EC Institution or a Member State against an obligation imposed by EC Regulation opens the possibility of intervention by the EU Court of Justice. In contrast, intervention by the Court of Justice is explicitly excluded by the EU Treaty[1] in the case of default by a Member State against an act adopted through the inter-governmental cooperation mechanism in the field of the Common Foreign and Security Policy (CFSP). Therefore, only political pressure brought by other Member States may oblige a Member State to respect its commitments under the CFSP framework.

Initially, the trade of dual-use goods and technology had been considered by Member States as falling into the area of arms trade, and intervention under the EC Treaty was therefore rather restricted. Article 296 stated explicitly that:

1 Article 46 of the EU Treaty.

"The provisions of this Treaty shall not preclude the application of the following rules:

[…]

(b) Any Member State may take such measures as it considers necessary for the protection of the essential interests of its security which are connected with the production of or trade in arms, munitions and war material; such measures shall not adversely affect the conditions of competition in the common market regarding products which are not intended for specifically military purposes.

2. The Council may, acting unanimously on a proposal from the Commission, make changes to the list, which it drew up on 15 April 1958, of the products to which the provisions of paragraph 1(b) apply."

However, the April 1958 list of arms, munitions and war material was never published. As a result, the borderline between specifically military items (submitted to this exception) and items such as dual-use goods remained vague. Considering that dual-use items and technology were not ruled by the common market provisions, Member States adopted national provisions to control the export of dual-use items inside and outside of the European Community.

The achievement of the common market in 1993, and the *de facto* (if not *de jure*) free movement of dual-use items within the European Community, raised the necessity to harmonise national export controls, possibly through the adoption of a dedicated EC Regulation.

Extensive discussions failed to achieve a consensus between Member States under the common commercial policy established by article 133 of the EC Treaty: most States considering that the export of dual-use items was the Member State's exclusive competence. Finally, the Council adopted two instruments: a Council Regulation, which defined the procedure and the criteria to be applied by Member States to award export authorisations, and a Council Common Action, which defined the list of items to be controlled together with authorization criteria. Cross-references between the Council Regulation and Council Common Action were introduced to maintain coherence in this dual instrument.

Nevertheless, in 1994, during the procedure of references for preliminary rulings, a German Court submitted questions to the European Union Court of Justice about the interpretation of articles 133 and 296 regarding dual-use items. In its judgement[2], the Court stated that neither the particular nature of dual-use goods, nor the fact that control measures are taken in light of foreign policy or security consideration, could exclude them from the Common Commercial Policy established by article 133 of the European Community.

As a consequence, a new Regulation proposal was tabled by the Commission[3], which included the Common Action provisions. The proposal was extensively discussed within the Council. Some Member States were not ready to accept that the European Community would be competent in this field, superseding national export controls. Finally, after almost two years of debate, the Regulation was adopted in 2000 including that: (i) each Member State upholds the responsibility for deciding on the export of dual-use items; (ii) any amendment to the list of dual-use items proposed by the Commission has to conform fully with the non-proliferation commitments and public security interests of Member States.

Since its adoption, the annexes of the Council Regulation 1334/2000, which set up a Community regime for the control of exports of dual-use items and technology[4], have been amended almost every year to include new entries in the dual-use list. Until now, amendments have always been adopted by consensus.

In 2006, the Commission tabled a proposal to amend core articles of the Regulation, to meet the standards set by UN Security Council Resolution 1540 and to implement the recommendations noted by the General Affairs Council after the 2004 "peer review" on the implementation of the Regulation by the Member States. The proposal is currently being discussed within the Council.

3. Principle of the European Union export control regime as defined by Regulation 1334/2000

Contrary to what its title may seem to imply, the Regulation did not establish a real Community re-

2 Judgement of the Court of 17 October 1995, Case C-70/94, Fritz Werner Industrie-Ausrüstungen GmbH et Bundesrepublik Deutschland, Rec. 1995, p. I-3189 and Judgment of the Court of 17 October 1995, Case C-83/94, Peter Leifer, Reinhold Otto Krauskopf, Otto Holzer, Rec. 1995, p. I-3231

3 Proposal COM(1998) 257 final for a Council Regulation (EC) setting up a Community regime for the control of exports of dual-use goods and technology (Official Journal of the European Communities 29.12.1998 C399/1)

4 Council Regulation (EC) n° 1334/2000 of 22 June 2000 setting up a Community regime for the control of exports of dual-use items and technology (Official Journal of the European Communities 30.06.2000 L 159/1) This Regulation has been amended several times.

gime for the EU export of dual-use items and technologies. Rather, it harmonised the Member States export control regimes through the adoption of common definitions and principles. These need then to be implemented by Member States authorities.

The two main principles of the Regulation are, first, the establishment of a common external fence by the adoption of an identical list of items requiring an export authorisation, and, second, the mutual recognition of export authorisations granted by Member States Authorities, which makes these valid in the whole Community.

Due to its objective to rule the export control of all dual-use items as defined by the five main international export control regimes[5], the definition of dual-use items used by the Regulation is rather inclusive. It covers all items, software and technology, that can be used for both civil and military purposes. It also includes all goods that can be used for non-explosive uses or assist in the manufacturing of nuclear weapons or other nuclear explosive devices. The definition is not limited to Weapons of Mass Destruction; it also covers conventional weapons' dual-use items. This second part of the definition has been added to conform to the NSG's definition, which does not distinguish between civil and military use but rather between safeguarded and non-safeguarded items.

It includes the transfer of tangible technology (blue prints, documents, software), as well as the transfer of intangible technology (skills, training, working knowledge and consultancy services). Normally, it should not cover the transfer of basic scientific research or of technology available in the public domain. However, the interpretation of such an exception is not uniform across Member States, as there is no agreed definition of what is meant by 'basic scientific research' or 'public domain'. Some Member States consider that industry does not conduct basic research, because its aim is to develop a marketable product, and it is not in the interest of industry to publish research results in an unrestricted way. In this regard, it is to be expected that the export of some technologies will always be submitted to authorisation in some EU Member States and not in others.

A major achievement of the Regulation is the elaboration of a single list of items to be controlled that reflects the five international export control regimes. The list is comprehensive and compulsory for Member States and does not leave room for Member States authorities to interpret whether an item should be submitted or not to authorisation. However, an impact assessment study, conducted by the European Commission in 2004, showed that there are still diverging interpretations among Member States. Only if industry reports on those differences can the Member State act, either to propose to international regimes that definitions are changed accordingly or to act at EU level. The Commission's ability to act is bound by article 11 provisions, which state that any modification to the list has to be in full conformity with commitments that each Member State has accepted as a member of the international non-proliferation regimes and export control arrangements, or by ratification of relevant international treaties.

To counteract the risk that proliferators profit from the delay between the evolution of technology and its integration into the dual-use list, three mechanisms have been introduced in the Regulation to control 'non-listed items'. These mechanisms, called catch-all clauses, require an exporter to request an export authorisation whenever the risk exists that a non-listed item is used or contributes to a WMD programme. This clause applies in the two cases where the exporter has direct knowledge of the risk or he has been informed of this risk by his national authority.

A third catch-all mechanism in the Regulation allows for Member States to adopt or maintain in national legislation an obligation for the exporter to apply for an authorisation whenever he has "grounds for suspecting" that the item is intended for any misuse as described above. Such an obligation, which moves the non-proliferation responsibility from the authorities to the exporters, is currently applied in only 16 of the Member States. As a consequence, there is a potential for an exporter to attempt to avoid personal responsibility by trading non-listed items through a Member State where this clause has not been adopted and implemented. It should be noted that the catch-all clause principle is decided and implemented individually by Member States. There is no coordination on the decisions adopted at national level. This means that some non-listed items might be covered by a catch-all clause in one Member State and not in others.

The effectiveness of the catch-all clause mechanism established by the Regulation may also be affected by the way information is exchanged between Member States. Typically, a Member State is required to inform other Member States about denials of export authorisations. In contrast, a Member

5 The Wassenaar Arrangement, the Missile Technology Control Regime (MTCR), the Nuclear Suppliers' Group (NSG), the Australia Group and the Chemical Weapons Convention (CWC).

State is not required to inform other Member States on cases where it implemented a catch-all clause for a non-listed item. Because of this, and due to the principle of free movement within the European Union, when an industry has been notified by a Member State that a non-listed item is subject to export authorisation, it might be tempted to export such an item through a branch established in another Member State, where such authorisation is not required and where the national decision to control such non-listed item might not have been transmitted by the Member State where the industry's headquarters are established.

The Regulation governs essentially two types of transfer of dual-use items.

The first concerns the export, import and external transit of dual-use items to or from an operator established outside the EU. However, external transit and import are not ruled directly by the Regulation and Members States may adopt national provisions to control such transfer operations. Currently, Belgium, Luxembourg, Malta, the Netherlands and Poland have adopted national provisions to control the external transit of dual-use items. Poland is the only Member State to submit the import of dual-use items to authorisation, despite the fact that dual-use items imported through other Member States can be transferred within the Community without restriction.

The second operation covered by the Regulation is the transfer of dual-use items within the Union, where the principle of free movement is subject to exceptions. It concerns the intra-Community transfer of dual-use items considered to be more sensitive in terms of potential contribution to WMD. This includes all items listed in the NSG guidelines. It should be noted that such derogation (imposed by some Member States as a condition to the adoption of the Regulation in June 2000) appears to be in contradiction with the principles established by the Euratom and European Community Treaties as restated by the Court of Justice in 1994.

Finally, it should be noted that, even if Member States hold the responsibility to grant and deny export authorisations, the Regulation has limited such competence through the Community General Export Authorisation. This is granted directly by the Regulation, and is valid for a large number of dual-use items when exported to major economic partners of the EU (namely, Australia, Canada, United States of America, Japan, Norway, New-Zealand, Switzerland). This means that operators can export directly to those countries without any national authorisation. However, in contradiction with the Regulation's initial objective, some Member States restrict the use of the Community General Authorisation by additional conditions that they assimilate to "national registration" requirements, such as pre- or post-notifications or an ISO certification. Furthermore, even if the Regulation did not establish conditions of supply for Member States to grant an export authorisation, some 'common criteria' have been listed that need to be taken into consideration in the authorisation process. They relate to (i) commitments taken under relevant international non-proliferation regimes, (ii) sanctions imposed by the CFSP, OSCE or a binding resolution of UN Security Council, (iii) considerations of national foreign and security policy (including those covered by the European Union Code of Conduct on arms exports) and finally (iv) the intended end-use and risk of diversion.

4. Action regarding the control of dual-use items taken under Title V of the EU Treaty

Regarding the inter-governmental cooperation mechanism (i.e. the Common Foreign and Security Policy) set up by Title V of the EU Treaty, Member States intervene regularly, by Common Position or Action, in the field of export control of arms and related items.

Whilst most trade embargoes are decided by the Security Council of the United Nations or, in some cases, by national decision, the implementation measures are usually decided by the States. In this respect, the provisions adopted by a State could be different from the ones adopted by other States. These variations could be due to legal, commercial or political factors, such as the importance of trade exchanges.

In the European Union, the question appears to be slightly different, as embargoes applied by Members States can be decided not only by the Security Council of the UN, or individually by States, but also on an EU-wide basis: either by a Common Decision or a Regulation adopted by the Council of Ministers within the Common Commercial Policy of the European Community Treaty, or within the Common and Foreign Security Policy (CFSP) established by the EU Treaty.

The selection by the Council of a European Community legal instrument or an intergovernmental one depends on the category of items concerned by the embargo. If the embargo is on arms, munitions and war material, it should be implemented by EU Member States provided the Foreign Policy remains an unshared prerogative of the Member States – even if the Council adopts a common decision[6] within the CFSP. This was the case for the 2004 embargo against Sudan[7]. If the embargo is on any other goods, and, in particular, on dual-use items, it should be organised by a Regulation adopted within the Common Commercial Policy constituted by Title VII of the EC Treaty. This was recently the case with the 2007 embargo concerning restrictive measures against Iran, listing essentially nuclear dual-use items[8].

Nevertheless, most embargo decisions concern primarily trade of arms, and, rarely, other goods. Consequently, an EC Regulation sometimes reinforces the CFSP Common Positions adopted by the Council on arms trade. For example, the embargo imposed on North Korea is implemented, on the one hand, by the Council Common Position 2006/795/CFSP and, on the other hand, by the Council Regulation 329/2007.

Since its establishment, the European Council has also intervened, through the Presidency Conclusions or it annexes, several times in the field of export control of items related to Weapons of Mass Destruction and, in particular, in the field of nuclear non-proliferation.

As an example, in 1998, after the nuclear tests conducted by India and Pakistan, the European Council expressed its deep concern, and called upon India and Pakistan to adhere to international non-proliferation regimes by signing the Comprehensive Test Ban Treaty and by actively contributing to negotiations on a Fissile Material Cut-off Treaty[9].

Further, since the September 11th attacks, the European Council has regularly adopted statements regarding efforts needed on non-proliferation and export controls on arms, chemical, bacteriological and nuclear substances usable for terrorist purposes.

Finally, the European Council has adopted since June 2003 several statements and declarations on Iran's sensitive nuclear activities.

Conclusions

The export control of dual-use items in the European Union has always been a controversial issue. Whilst the necessity to control the export and, sometimes, the external transit of such items has never been questioned, the competence of the Union and, in particular, of the European Commission in its regulatory function, has been challenged by the Member States. This attitude can be explained: firstly, by the particular nature of the dual-use items which could neither be assimilated to standard goods and services nor to weapons; and, secondly, by the fact that dual-use items trade is immediately subject to specific foreign policy concerns, such as non-proliferation and terrorism. For these reasons, Member States have always considered that the control of dual-use items should remain politically and, if possible, legally within their exclusive competence. Nevertheless, even if Member States have been reluctant to be controlled by an EC Regulation, the implementation of the common market induced Member States to accept some EC coordination in order to maintain the efficiency of national export control systems. Such an ambiguous situation has guided the EU policy since the first Regulation in 1994 and explains the complexity of the present system.

6 Article 296 of the EC Treaty which allows Member States to take "measures considered necessary for the protection of the essential interests of their security which are connected with the production of trade in arms, munitions and war material").

7 Council Common Position 2004/31/CFSP of 9 January 2004 concerning the imposition of an embargo on arms, munitions and military equipment on Sudan (Official Journal L 006 , 10/01/2004 P. 0055 – 0056).

8 Council Regulation (EC) No 423/2007 of 19 April 2007 concerning restrictive measures against Iran.

9 Presidency Conclusions on India/Pakistan Nuclear Tests (Cardiff European Council of June 15 and 16 1998).

WATCH LISTS: Methods to Reinforce Export Control on Potentially Proliferating Uncontrolled Items and Materials

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Abstract

The idea of this concept of watch lists is to help proliferation and export control experts and officers to detect illicit activities. A watch list is established for the suspected country and for its preferential ways to procure nuclear materials, items and equipment. The method of establishing such a watch list is given in relation with existing export control lists and non-listed items.

Keywords: watch list; export control; proliferation.

1. Introduction

The recent attempts at circumventing control export rules have been revealed by affairs linked, for example, to the proliferating role of the Abdul Qader Khan (AQK) network in Libya, Iran and North-Korea. Such revelations make it necessary to conceive new methods to counter proliferation and to close the loopholes in the legislation.

One possible concept, i.e., the watch list concept, is to develop more elaborate and more comprehensive lists than the existing Trigger and Dual-Use lists [1] that are devoted to controlling nuclear exports. Although the present paper deals with nuclear proliferation only, the concept can be used for countering missile, chemical and biological proliferation.

The main objectives of watch lists are to give strengthened indicators to detect proliferating countries and to screen front companies. Such a list has to be established preferentially for a given country, because reducing the number of processes that can be involved in a nuclear military programme, allows a deeper control of the components and equipments of concern.

The analysis of the process that can be used by a given country has to be performed. Preliminary information on geopolitics, scientific, technological and industrial levels, and civilian existing nuclear equipments has to be reviewed by the experts. In a second stage, they have to determine what path (uranium and/or plutonium) and, in each path, what kind of processes are involved, especially regarding the conversion processes and the uranium enrichment processes (e.g., centrifugation, laser isotope separation, calutrons), and the kind of reactors (e.g., heavy water, gas graphite).

This control is made necessary due to the improved ways of proliferation, in particular, those linked to the AQK network. Furthermore, the role of front companies is to be analysed, as can be derived from the following examples:

– Installations for the production of centrifuge components have been sold under false denomination (in the case of Libya, see for example S. Lucas and P. Louvet [2]),

– Installations, like production plants of components, have been imported like in Malaysia [2]. As a consequence, the watch lists should cover the loopholes concerning the equipment of the production plants.

Finally, the role played by the intangible transfers, such as numerical codes, software, technological know-how, and technical assistance, as well as second-hand items, has to be taken into consideration.

2. Expertise

The acquisition of expertise is quite straightforward to achieve for the nuclear countries, as the national nuclear entities are skilled to do it. In France, the *Commissariat à l'Energie Atomique* acts as the national expert. Primarily, the expert has to determine which processes are in the focus, as proliferating countries usually encounter difficulties to study all the possible processes due to limitations based on the huge cost and the lack of skilled staff. Thus, such countries are obliged to focus on a limited number of processes, like centrifugation or laser isotope separation for uranium enrichment, or heavy water reactors or graphite reactors for the production of plutonium. Then, a detailed functional analysis and decomposition of each process help to list the components that are expected and needed to proliferate.

3. Methodology to establish lists

Five main ideas are involved in establishing these watch lists:

- Filling loopholes in the legislation,
- Reinforcing the control on some "weakly" controlled technologies,
- Monitoring the use of "down-graded items",
- Taking into account the improvement of evolving technologies or new technologies,
- Including items that can be used for nuclear proliferation and that are controlled by other means.

3.1. Filling loopholes in the legislation for materials, subassemblies, manufacturing and inspection equipment

The loopholes are induced in different ways. First, some items, in few numbers, have been simply omitted as they have not been judged critical or too difficult to control at the time of elaboration of the lists. Secondly, the loopholes are quite often related to materials, subassemblies, manufacturing and inspection equipment that are necessary to produce items or assemblies that appear in the Trigger list and Dual-Use list. Numerous examples can be found such as samarium and neodymium powders, the associated magnetization equipment, the magnetic measurement and control instrumentation to produce permanent magnets for the bearings of the centrifuge. Other cases are encountered in the key electronic components involved in the controlled power supplies or converters.

A lot of quite common chemicals that are not controlled are often needed for conversion, enrichment or reprocessing operations. They have to be added to the watch lists to draw the export control officer's attention. Some other more or less classical manufacturing equipment is also of concern.

3.2. Reinforcement of the control

The reinforcement of control can be achieved by increasing qualitatively and/or quantitatively the level of control in the items that are already covered by the Trigger and Dual-Use Lists.

Qualitatively, restriction notes that are applied to the paragraphs have to be checked and modified or suppressed if necessary. A classical example is given by the control exemptions for medical applications.

Numerous examples have been observed for a lot of items, especially laser or laser components, materials like maraging steel or aluminium alloys, and fibres. The solution is to lower the threshold values far below the values that are needed, to be more severe and to review carefully the Trigger and Dual-Use lists.

Another possibility is to widen the field of applications to different geometries or material. For example, in order to prevent illegal manufacturing of centrifuge rotors, maraging steels and aluminium alloys are controlled in the form of tubes in §2C11 and §2C1:

§2C1 – « Aluminium alloys (…) with an ultimate tensile strength greater than 460 MPa (…) and in the form of cylinders or tubes (…) with an outside diameter more than 75 mm. »

As some other minor parts can be made of these alloys in any form (e.g., rod, plate), it is necessary to enlarge the control of these material as well. Furthermore, some proliferators can make simple metallurgic transformations using the alloys that they are not able to produce to get the correct product.

Quantitatively, the main problem is raised by the numerical values that are set in the lists. The technique used by proliferators is to buy items just below the threshold values, or to buy two or three production units instead of one with reduced performances to remain below the threshold.

Another possibility is to reinforce the control of insufficiently controlled technologies.

In this category, heavy water production technologies are globally insufficiently protected, as a number of production processes are available: G-S, ammoniac exchange, distillation, cryogenic distillation, electrolysis. Only a few parts related to these possibilities are under export control.

Another way of circumventing the legislation is to ask for isotope separation devices (or parts) of isotopes other than uranium or plutonium, which are not *"especially designed and prepared for"* (EDP) and can replace or allow reverse engineering, as well as helping to develop and to optimise the processes without using radioactive nuclear materials. The main example in this category is the laser vapour isotope separation process that has been developed by South-Korea for rare-earths isotope separation (ytterbium, gadolinium) and that has been applied in uranium isotope separation experiments [3].

3.3. Down-graded items

A so-called down-graded item is defined here as an item that will not be classically used in an EDP item, because of its unreliability or its inappropriateness for nuclear industry, but that can be operational for a reduced life-time and sufficient to proliferate. A classical example was constituted by items like valves (but not only as vacuum quality pumps, seals, piping are also used in centrifuge plants for auxiliary circuits), that are made of stainless steel[1] instead of being made of or coated with materials resistant to UF_6 corrosion like monel, nickel or fluoropolymers. This is possible for auxiliary circuits which involved the presence of traces of UF_6 in regular operations and even for principal circuits in processes that are operating with UF_6 at low pressure and nearly room temperature.

In addition, it can be noticed here that second-hand items are also usable.

3.4. New or evolving technologies

The main example is constituted by the laser, solid state technologies and measurement instrumentation which are evolving or emerging rapidly. One of the main examples is the possible replacement of copper vapour lasers by solid laser diodes or the emergence of new types of lasers like quantum lasers.

Of course, this can be done by revising the Trigger and Dual Use lists, but this work is huge and time consuming, and it comes often late, although it could be started in parallel with the watch lists.

3.5. Inclusion of items that are controlled elsewhere

The export control lists that are published by the EU [4] include items that are controlled by lists other than the nuclear ones, i.e. chemical and biological lists originated from the Australian Group, Wassenaar list and MTCR missile list. In the EU lists, in order to avoid ambiguities, the most restraining redaction has been chosen. An obvious example to illustrate this fact is the export control of hydrogen fluoride which comes from the chemical weapons lists: this acid, essential in the cycle of production of UF_4 and UF_6, is not controlled by the nuclear Trigger and Dual-use lists. Some other cases are much less obvious dealing, for example, with lasers or laser components on the Wassenaar list which can be applied for laser isotope separation.

Thus, although these items are already covered by the export control, it is desirable to include them in the watch lists, in order to draw the attention of export control officers as they reveal a nuclear activity on a given nuclear process and complete the scheme of export attempts and acquisitions by a proliferating country.

4. Conclusion

The method to draw up watch lists is quite straightforward, as the main idea is to cover all that is necessary for a given country to proliferate with the processes that have been chosen. The work to elaborate such lists is important as a large number of items (hundreds in the front end of the fuel cycle) and materials are concerned even if the number of involved processes has been voluntarily reduced. This kind of lists has to be derived specifically for non-compliant proliferating countries and acts as indicators of proliferation.

The main interest of these watch lists is to allow high reactivity, to close the loopholes with a better flexibility than with the official one. In particular, some propositions can be taken into account for export control much faster than in the classical way. Furthermore, the watch lists can give justification to apply the catch-all clause with an increased accuracy especially for countries of proliferation concern like Iran and North-Korea.

Following a French initiative, watch lists have been used as a basis and discussed with the EU member states to derive a complementary list of items in the case of Iran, which will be submitted to export control in the frame of the UN resolution n°1737 and will be published in the Official Journal of EU.

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Developing the Capabilities to Make Strategic Export Controls Effective

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Abstract

The International Nonproliferation Export Control Program (INECP) of the U.S. Department of Energy has been focused for over 10 years on engaging partner countries to strengthen global efforts to prevent proliferation. This paper summarizes some of the key lessons learned regarding the development of the capabilities needed to make strategic export controls truly effective.

Keywords: export control, nonproliferation, commodity identification, illicit procurement, interdiction.

1. Introduction

While export control systems are necessary to stem the proliferation of strategic materials, equipment, and technology needed to develop weapons of mass destruction, the systems themselves, comprising laws, regulations, control lists, and export licensing requirements are not sufficient. Networks of procurement agents, brokers, and front companies are systematically and successfully working to defeat these systems. Countering illicit procurement depends on the successful implementation of three key countermeasures: enterprise compliance, export licensing, and enforcement.

- Enterprises must be alert to indicators of suspicious procurement activities. They need to know how their goods and services could contribute to WMD programs and apply for export permits or licenses. Achieving this level of awareness and compliance requires extensive government outreach.
- When enterprises apply for licenses, government analysts must competently assess the proliferation risk associated with proposed strategic transfers by uncovering inconsistencies between the commodity, its stated end use, and the activities and credentials of the end user.
- To deter enterprises, brokers, freight forwarders, or individuals from attempting to bypass an export control system, Customs and other frontline inspectors must be able to detect and interdict illicit shipments without unduly hindering legitimate commerce. Export control enforcement, especially with respect to the unique challenges related to dual-use commodities with both commercial and military applications, requires special training and ready access to technical specialists.

Implementing each of these countermeasures depends on underlying capabilities, expertise, and methods.

2. Government Outreach for Enterprise Compliance

Enterprises, by dealing directly with buyers, are the "first line of defense," in preventing the proliferation of export-controlled goods or technologies. However, while export licensing procedures and control lists are available to industry, enterprises do not always understand the WMD-significance of the dual-use goods and technologies they produce.

As a first step, it is important that key suppliers and technology holders are identified. The government should then conduct outreach to explain national export control laws and regulations, including penalties for violations. The government should also promulgate compliance guidelines and raise awareness of the proliferation threat to sensitize enterprises to suspicious procurement attempts. Effective outreach can take several forms, ranging from official government publications, newsletters and websites to industry-specific conferences or even targeted site-specific visits or seminars.

Technical experts can enhance government outreach programs by explaining the rationale behind the control lists and their technical specifications. This is especially important with regard to promoting export control understanding and compliance among research and scientific institutions. INECP approaches enterprise outreach from DOE's unique experience implementing compliance programs at US National Laboratories, focusing on the special challenges posed by public sector and tertiary enterprises engaged in sensitive research and development, legacy WMD sectors (nuclear, missile, chemical, biological), and issues of intangible technology control and high-risk property management.

3. Proliferation Risk Analysis in the Licensing Process

The Guidelines of the Nuclear Suppliers Group state that suppliers should not authorize transfers of dual-use commodities when there is an *unacceptable risk of diversion* to a nuclear explosive activity or an unsafeguarded nuclear fuel-cycle activity. Technical assessments integral to the export licensing process are vital assessing this risk diversion. The model shown in Figure 1 illustrates several of the considerations important to assessing proposed transfers of a strategic commodity. Answers to the questions shown in the figure could either affirm the credibility of the acquisition or reveal inconsistencies indicating suspicious procurement, such as an end-use inconsistent with technical specifications of the commodity or with the apparent business activities of the end user, or connections between parties to the transaction and known front companies or other entities of proliferation concern.

It is important to note that technical experts do not make the final decisions on denying export licenses or imposing conditions on their approval. Appropriate officials make these decisions taking the technical analysis into account together with many other political and economic factors. Put another way, the technical expert help evaluate the risk of diversion, but only policy makers can judge when that risk is unacceptable.

4. Detection and Interdiction of Illicit Shipments

Recent revelations about the ongoing proliferation of nuclear-related technologies, equipment, and materials place a premium on improving export control enforcement capabilities worldwide. Enforcement of export control laws deters noncompliance with the threat of meaningful penalties, and when all else fails, allows interdiction of the illicit trafficking that nevertheless takes place.

Because the majority of items that would be procured for a nuclear weapons program are dual-use and fairly common, determining if a shipment of material or equipment is, in fact, an export controlled item is a technically challenging task. Furthermore, if the shipment being inspected really is an illicitly trafficked strategic commodity, it is likely that the identity of the item(s) will be obscured or disguised. The ability of the inspector to be familiar with the controlled commodities - to know what they look like, how to identify them, and when analytical help is needed - is of paramount importance. INECP provides training and tools to improve the ability of export control enforcement personnel to recognize and respond to potentially illicit shipments of strategic items.

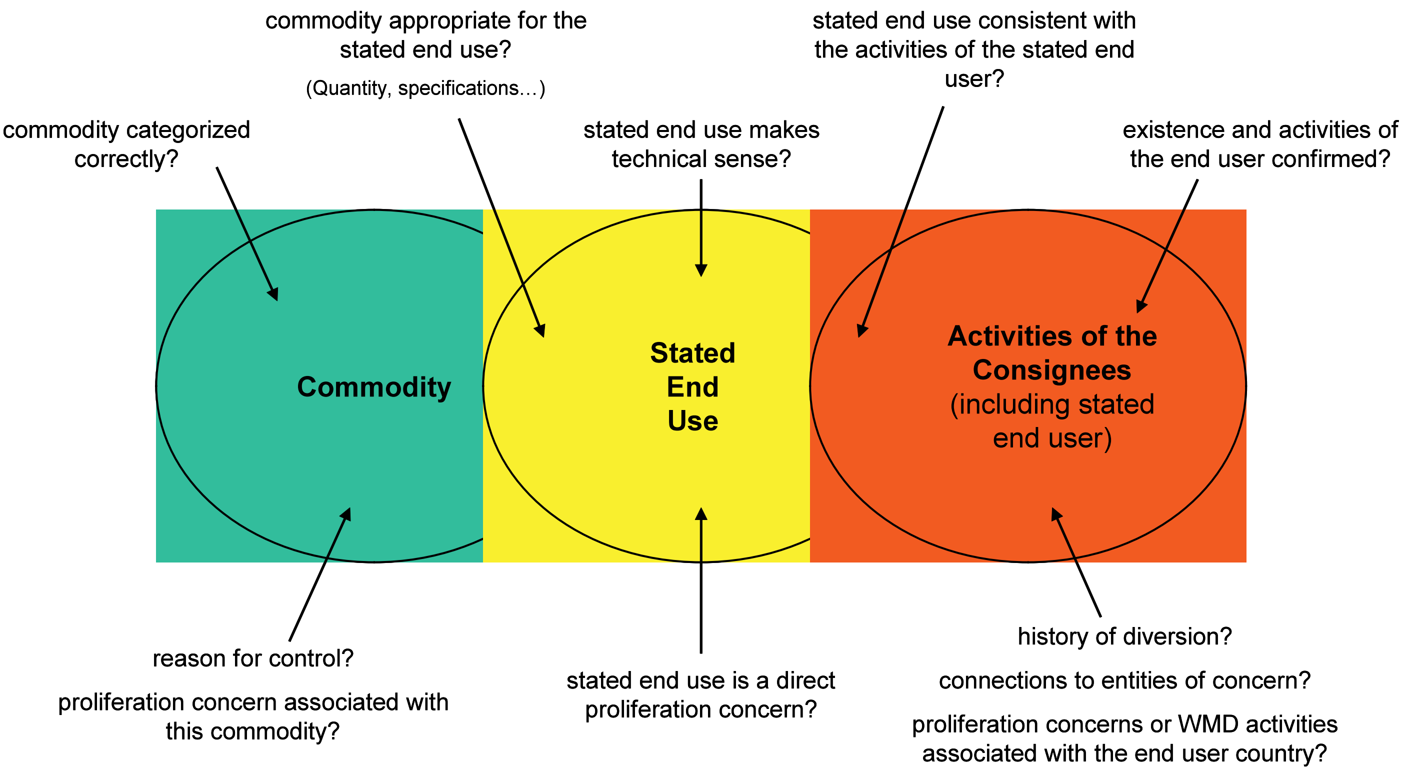

Figure 1: Framework for assessing proliferation risk through end use/end user analysis.

INECP has developed a range of strategic commodity identification training (CIT) courses to familiarize customs inspectors and others associated with enforcing or implementing export controls with WMD-related materials and equipment (pictured in Figure 2). CIT is organized and presented to reduce the complexity of the various export control lists and to give the student a "trained eye" to recognize and interdict potentially controlled commodities by focusing primarily on appearance and other readily identifiable criteria such as special markings, typical packaging, sizes, weights, and monetary values. Even with solid familiarity training, however, inspectors can not become deeply knowledgeable about every controlled commodity. It is very important that inspectors have the ability to reach back to trained cadres of technical experts for timely analytical support.

Figure 2: INECP-trained instructor conducting Commodity Identification Training in Ukraine, here examining a dual-use photomultiplier tube.

For some strategic commodities visual inspection is insufficient, and the inspector must be armed with technology. The control lists of the multilateral export control arrangements include numerous strategic metals and alloys, such as high strength aluminum, maraging steel, and zirconium that are visually indistinguishable from many uncontrolled metals. In addition, the process of determining whether an item being inspected may be controlled often requires the ability to rapidly identify special materials of construction. INECP has enhanced the commercially available, hand-held, portable multi-element analyzer (shown in Figure 3) that uses X-ray fluorescence (XRF) spectrum analysis to quickly (10 – 30 seconds), quantitatively, and non-destructively identify the elemental composition of metal alloys, including nonproliferation-related materials.

Figure 3: INECP-customized XRF unit provides rapid elemental analysis, flagging potentially controlled alloys and providing supplemental information about applicable export controls.

5. Conclusion

A pervasive theme underlying successful implementation of an export control system is the role of technical expertise and the vital importance of integrating technical experts into export control functions. Ideal characteristics for the cadre of technical experts include:

- Ability to combine their technical expertise with specialized knowledge on proliferation and export control
- Ability to provide objective, factual advice and to work closely and productively with governmental officials, including licensing and customs officers.
- Collective ability to address technical questions related to both the civilian and military uses of the full range of WMD-related items subject to export control

Fostering the development and emergence of cadres of technical/nonproliferation specialists that can support and sustain the export control system (including outreach, licensing, and enforcement functions) over the long term is DOE's hallmark accomplishment, defining INECP's unique strength among nonproliferation outreach and engagement programs. The development of such cadres nationally, regionally, and globally, represents the best long-term protection against the erosion of the nonproliferation regime.

The Future of Nuclear Export Controls

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Abstract

Controls over the export of items that can play a role in nuclear weapons programmes have become an essential part of the overall nuclear non-proliferation effort. Since 1990 countries have reinvigorated their cooperation to develop modern and effective national laws and regulations to ensure that export transactions are assessed before goods leave the jurisdiction of the exporting country. They have also worked to develop agreed rules to be applied during the assessment of individual transactions.

Changes in the international market for nuclear items and nuclear-related dual-use items are challenging the system of export controls that has been developed over the past 20 years. A new approach to export controls may be needed if the effectiveness of this instrument is to be assured in future.

Keywords: export control; non-proliferation; Nuclear Suppliers Group.

1. Introduction

Export controls have become a very important instrument in the international effort to prevent countries from acquiring nuclear, biological and chemical (NBC) weapons as well as the delivery systems for them. The risk that any country would be able to buy a complete NBC weapon, i.e., weapon of mass destruction (WMD), and a delivery system for it is very remote. However, recent cases (Iraq, Libya and North Korea) have proved that there are countries willing to make a dedicated and sustained effort to acquire nuclear weapons [1]. Another country, Iran, is assembling the technological and industrial capacities that could support a nuclear weapons programme if the government decided to launch one.

Countries that are seeking to develop and build a nuclear weapon as well as an effective delivery system for it have sought materials, goods and technologies from foreign suppliers. Acquisition has sometimes been carried out using illicit trafficking rings, a phenomenon that attracted much attention in the cases of Iran and Libya. However, the process can also depend on using legitimate trade, exploiting any lack of awareness or knowledge among exporters about the potential uses their products may find in weapon programmes [2].

Export controls allow a choice to be made about whether or not to allow a particular export to take place. The fact that data is gathered on exports and permission required before certain items can be exported does not imply that governments are attempting to deny any specific item to any specific end-user, though export controls may be used as an important instrument to enforce an embargo.

Regulating international transfers of items that could contribute to the spread of nuclear, chemical, and biological weapons and missile systems for their delivery helps to reduce the risk that legitimate trade might assist proliferators. Export control laws also provide a basis for sanctioning illicit traffickers.

There is a continuous discussion within the export control community about how to make existing instruments more effective. Export controls criminalize the movement of specific items (normally those conforming to technical parameters that are published on a control list) across an international border without the necessary authorisation, which is normally provided in the form of an export licence. The basic approach is still based on a model of international trade in which items manufactured in one country are moved to foreign markets.

In this article my argument will be that the nuclear export controls that are currently in place are likely to be undermined by a number of political, economic, technological and industrial trends that are already visible in the marketplace. Looking ten or fifteen years into the future the current laws (already strained by changes in technology and changes in the way industry carries out its business) will not be sustainable. Moreover, simply updating and amending current laws may not be sufficient to maintain the effectiveness of the system. A new basis enabling international nuclear cooperation while still maintaining barriers to proliferation will have to be found.

In the next sections the current status of export controls will be briefly reviewed and the challenges to those controls will be outlined. Finally, some thoughts will be offered about the possible future direction of export controls.

2. Export controls current status

The transfer of items specially designed and developed for nuclear weapons is prohibited and the focus of export controls has increasingly fallen on so-called items that can have military applications, so-called dual-use items. There have been challenges to the standard approaches to export control and in response regulators are trying to adapt to new conditions. The questions who should be the focus of controls, what items should be subject to control and how controls can be organized have all been revisited in the past decade.

During the Cold War the main focus of export controls was to deny the former Soviet Union and its allies access to items that could enhance certain military capacities [3]. The Soviet Union did not need nuclear material or technology, but because the United States and its allies depended on maintaining a lead in key military technologies to offset the greater numbers of forces ranged against them, trade in leading edge skills and equipment were tightly restricted. This problem no longer exists and the main concern are countries that may seek nuclear weapons as an asymmetrical response because they are unable to develop the most modern conventional armed forces.

The number of countries where there are proliferation programmes of concern is small and the problem facing export controllers is how to prevent sensitive items from flowing to these specific locations, rather than being a general and global problem.

Whereas military programmes sponsored a great deal of leading edge technology development in the past, most dual-use items are nowadays developed and in the first instance used in civilian rather than military applications. Therefore, dual-use export controls are designed to permit most transactions because of the positive contribution that they make.

The increasingly civilian character of leading edge technology development has contributed to export controls becoming a more critical element within the overall effort to combat proliferation. Traditionally, arms control has been a discussion among governments about the rules that apply to capacities which they own and control. Since dual-use items are largely owned and operated by private actors rather than governments, what industry does is critical to non-proliferation. In comparison with other types of arms control, export controls present opportunities for interaction with industry and the private sector.

Apart from owning many controlled items, one of the main security threats is now posed by non-state actors with malicious intent. It would be of particular concern if there was clear evidence of an "insider threat" within branches of industry or research where materials are available that can be directly applied in such attacks.

The greater availability of a much wider band of technologies has required that the traditional approach of licensing items on lists compiled according to the technical characteristics of the products has been supplemented by end-use (or "catch-all") controls [4]. Evidence from Iraq indicated that countries of proliferation concern might well acquire unlisted items that fall just outside the technical parameters of the controlled goods. Programmes of concern are also likely to need other uncontrolled items (such as electronics and machine tools) that are in widespread industrial use and that are not in and of themselves particularly sensitive. Without end-use controls there would be no legal basis to deny such items to a country or programme of proliferation concern.

The tendency for industry to work in international teams to develop, manufacture and market dual-use but proliferation-sensitive items, combined with the worldwide availability of wide-area computer networks (including the internet) have created a need for effective controls over "intangible" technology transfers.

There are a growing number of countries in which items of potential proliferation concern are developed and manufactured. In the past there were few suppliers of particular controlled items and many of these suppliers had a habit of cooperation. With the steady international diffusion of technology and the development of new centres of innovation—including countries that were considered part of the developing world until recently, buyers may now turn to a wider range of suppliers. Moreover, these suppliers may have a relatively short history of cooperation with international export control groups or might be outside such groups.

The procurement networks of countries seeking unauthorized access to controlled items have also changed their behaviour. Goods may be bought using deliberately complicated deals to obscure the true nature of the transaction. The true end-use and end-user may be disguised by falsifying documents or by using a series of front companies. Disrupting this kind of illicit trafficking demands information exchange among regulators in a larger group of countries, including trans-shipment centres and major international commercial hubs even though these countries do not themselves develop or manufacture sensitive items.

The debate about how to strengthen and adapt export controls has been most active among representatives of approximately 45 states that cooperate in informal groups that were established to help the participants to strengthen their own national controls [5]. Within these groups lists of items to be controlled are agreed, standards (which need to be reviewed and periodically updated) are set for the contents of national legislation, licensing and enforcement communities are able to establish networks that facilitate cooperation on specific export cases, and information is exchanged.

These multilateral arrangements do not have decision authority over individual transfers, they are places where governments come together to discuss export control issues, and in each case any agreed position or rule is put into effect through a national export control system.

The export control regimes have put more emphasis on making their activities transparent and reaching out to non-participating states in recent years. However, the benefits gained from participation in these groups are still mainly limited to a relatively small number of states. For the countries that do participate the pace at which regulations are being adapted is probably too slow to keep up with the changes in the industries that are being regulated. Moreover, the pace of change in industry may accelerate in the next decade.

3. The changing nuclear industry

A number of factors acting together appear to be reducing public resistance to expanding the role of nuclear energy. Studies of environmental change have underlined the need to meet the continuous growth in the demand for electricity without increasing carbon emissions into the atmosphere. Rising fossil fuel costs have changed the economics of generating electricity using nuclear versus other technologies. Advances in technology and better regulation have made nuclear power plants safer as well as more efficient. Finally, political uncertainties in the Middle East, in Russia and elsewhere have fed a feeling that relative autonomy or greater security of electricity supply should be weighted more heavily in the overall basket of factors influencing energy policy [6].

Many key companies in the civilian nuclear energy sector have tended to have a narrow specialisation and a predominantly national focus in the past. However, developments in the marketplace are pushing the nuclear industry generally in the direction of greater internationalisation, diversification and consolidation. There is anecdotal evidence to support the hypothesis that new CO2-free energy conglomerates are forming and positioning themselves to compete for work globally, hoping to eat into the market share of energy suppliers offering coal, oil and gas.

The need for capital to finance new construction is stimulating internationalisation. In future, nuclear will increasingly compete for investment with other forms of electricity generation as there is a gradual trend in the electricity supply industry to replace state monopolies with competition open to private suppliers. The running costs of nuclear power plants are relatively low and this may offer competitive advantages in the future if the price of electricity resumes its long-term downward trend and oil and gas prices remain relatively high. However, the main sources of private capital have been reluctant to invest in projects that expand the nuclear sector because the long waiting period for a return. The perception of unpredictable risks (such as the difficulty of securing the necessary licences from regulatory bodies and vulnerability to changes in the political acceptability of nuclear energy) have also dampened enthusiasm.

In response, the financing of major nuclear projects has become international as investors spread risk. Further privatisation could also stimulate international investment in the corporations that implement projects rather than the projects themselves if investors are convinced of future growth prospects and revise expectations about the competitiveness of nuclear electricity in the marketplace. The result is likely to be concentration, leaving a smaller number of larger but more internationalised companies able to part-finance future projects themselves and recover their investment by sharing future income with electricity distributors.

Some companies may be thinking along these lines as they increasingly try to offer customers "energy solutions" rather than discrete products. To be competitive in new energy markets (either regionally or internationally) these conglomerates are likely to insist that their suppliers, and service providers in turn improve quality and lower costs. For nuclear suppliers, this means that there could be significant rewards for companies with modern reactors licensed and certified in many countries because that reactor design could become a de facto international standard purchased by many energy conglomerates.

Further internationalisation is also likely to be stimulated by decisions made in the countries that will provide the main demand for civil nuclear programmes. Countries in Asia, such as China, India and South Korea, are likely to insist on significant local participation as a condition of doing business. At present the United States, which might develop a significant national programme to construct nuclear power plants after 2010, is making international partnerships intended to help restore the leading position the US occupied in the global nuclear energy market in the 1970s.

If internationalisation might be expected to be a general tendency in the nuclear sector there are also indications that fuel suppliers would not be excluded from that general trend. In 2006 the US firm GE Energy bought the rights to an Australian laser-based process for enriching uranium called Silex in an attempt to enter the commercial market for enrichment services. The European company URENCO is currently building a uranium enrichment plant in the United States based on modern centrifuge technology. The French company AREVA has acquired joint control over ETC, the part of URENCO that develops and manufactures centrifuges for uranium enrichment, and the new company is building the modern centrifuge enrichment plant being constructed in France.

In future the global supply of enrichment services is likely to be dominated by 3 suppliers: (Areva/URENCO in Europe with its US subsidiary), USEC in the United States (currently building a modern centrifuge-based enrichment facility to replace an obsolete gas diffusion plant) and Rosatom in Russia (including its foreign sales arm, TENEX). However, although these will probably be the dominant actors, they will not be the only suppliers. Current plans and programmes suggest that there will be small capacities in other places including Brazil, China, Iran and Japan and it is possible that others will also enter the commercial market.

4. Approaches to export control reform

Efforts to respond to the changing threat environment, and in particular the concern about acts of mass impact terrorism, are putting pressure on governments to introduce additional controls not only on state behaviour but also on the companies and enterprises operating within their jurisdiction.

United Nations Security Council Resolution 1540 of April 2004 requires the criminalization of any WMD-related acts carried out by individuals (including legal or physical persons) that would contribute to proliferation or mass impact terrorism [7]. One of the objectives of the resolution is to increase the range of measures and the severity of sanctions available against people who knowingly assist people or groups that have illegal and malicious intentions.

Resolution 1540 followed in the wake of two others that required states to put in place measures with a direct impact on individuals (Security Council Resolution 1267 that imposed sanctions on Al Qaeda and the Taliban and Resolution 1373 requiring states to take actions to combat terrorism.) The measures required in these resolutions apply not only to exports but also to transactions taking place within the boundaries of a state. This means that companies are now having to take care not to have contact with or make transfers to named individuals (often listed in annexes to relevant national, United Nations or European Union decisions) as well as countries of concern and entities in those countries engaged in proliferation.

Whereas arms control treaties have largely left it to the discretion of States Parties to decide how to implement their obligations at the national level, UNSCR 1540 went a step further by prescribing some elements of national implementation that would have a direct impact on industry. In Europe there is a similar process of strengthening laws and regulations as part of the wider effort to counter mass impact terrorism.

In December 2004 the European Union adopted specific measures on combating terrorist financing, civil protection policy, prevention of recruitment, critical infrastructure protection and external security policy [8]. Following the London attacks in July 2005, EU interior ministers held an extraordinary meeting where they agreed that all measures already decided on should be implemented as a matter of urgency. In September 2005, the Commission suggested a further package of measures including a proposed directive on data retention and in December 2005 the EU agreed a Strategy to Combat Terrorism from which further measures may flow [9].

As laws are tightened in response to these agreements the types of material and the range of items subject to control is expanding, and this is likely to bring more private companies and non-governmental entities within the scope of regulation. UNSCR

1540 also requires states to put in place effective measures to account for, secure and physically protect proliferation-sensitive materials. In mid-2005 a group of 89 states agreed to amendments to the Convention on Physical Protection of Nuclear Materials that will extend agreed international standards for physical protection, currently applied to international shipments, to any nuclear material used for peaceful purposes and to nuclear facilities used for peaceful purposes.

In January 2004 the IAEA Code of Conduct for the Safety and Security of Radioactive Sources was finalized [10]. The Code, which is focused on sealed source management and control, prescribes legislative frameworks, regulatory programmes, and import/export provisions for IAEA Member States. A number of states, including all EU Member States, have committed themselves to introduce the elements contained in the guidance on export and import of radioactive sources that is associated with the Code of Conduct into national legislation and to conduct outreach to try and persuade other states to take the same step.

As regulations are strengthened against malicious actors, governments have also introduced new types of export licence to simplify legitimate business transactions. For example, some general licences allow the export of specified controlled items by any exporter to any end-user in specified destinations provided that the conditions in the licence are met. These licences are intended to make regulation as light a burden as possible on legitimate traders. However, they have the effect of transferring greater responsibility onto industry to ensure that the terms of the licence are complied with.

For example, in Regulation no. 648/2005 of the European Parliament and the Council of 13 April 2005 amendments were introduced to the Council Regulation (EEC) No 2913/92 that established the Community Customs Code [11]. The Regulation creates the status of ‘authorised economic operator’ that may be awarded to any entity that meets common criteria relating to the operator’s internal control systems, financial solvency and record of compliance with existing laws and regulations.

This approach is intended to create incentives for companies to manage their obligation to control sensitive technologies more efficiently by integrating this obligation into their internal management and control procedures. A company that can demonstrate to regulators that it is able to exercise vigilance with respect to the risk of diversion would benefit from simplified procedures. However, the success of this incentive based approach remains to be seen. If the approach is to succeed then there must be a significant take-up by exporters and the internal systems that they put in place must reflect a common (and high) standard. There would be no security gains if the bar is set too low when exporters are rewarded with the opportunity to use simplified procedures. In fact the reverse could be the case since enforcement agencies would lower the level of their scrutiny of companies on the false premise that it is safe to do so. Similarly, if the conditions for being permitted to export under simplified procedures are applied unevenly the system is likely to fail.

Exporters must balance whether the advantages on offer outweigh the costs incurred to put in place the internal systems needed to win the trust of the regulators. If an exporter does benefit from simplified customs controls relating to security, the entity is not exempt from the consequences of misusing a licence even if the misuse is accidental. An operator that invests in internal procedures to gain the trust of regulators might anyway be vulnerable to bad behaviour or negligence at some other point in supply chains of which it is a part.

In considering whether or not to invest the resources necessary to adapt their internal processes to strengthen security exporters will also have to consider the consequences for them in cases where their internal reform effort breaks down. Enforcement agencies currently have limited flexibility in the penalties they can impose for violations of export control laws. The options largely involve legal sanctions, including criminal penalties. There are arguments based on both effectiveness and fairness in favour of a wider dialogue about the penalties used to enforce export control laws.

5. Corporate security responsibility

Over the next few years the implementation of new controls may increase the responsibility of business for public security across a range of different fields. Those mentioned above are in fact only a few of a long list of new responsibilities that companies may have to take on. At the same time, the imperative on industry and commerce to maintain and increase the volume of trade and investment will continue.

As sketched above, in the nuclear, chemical and bio-industries, companies are likely to be pressed to supplement safety controls on substances that can cause harm to employees or public by accident with security controls that take into account the risk of malicious acts in regard to substances and technologies that may be ‘weaponised’ or used in acts of mass impact terrorism.

Companies are likely to take a closer interest in the security programmes being implemented by their supply chain partners. Moreover, responsibility is being extended beyond the manufacturing industry to include the provision of a range of different services. Companies and financial institutions are being reminded of and pressed to observe their expanding responsibilities in regard of international and national rules relating to terrorist financing as well as informed of the universal prohibitions on any actions that facilitate trade and transfer in WMD-relevant materials and knowledge; transportation and travel security.

To shoulder this responsibility it is necessary for business to enforce internal security discipline through employee vetting, knowledge control, security routines and their monitoring and enforcement. In addition, the direct impact of business on security requires observance of all relevant (national or international) technology and export controls, embargoes, provisions of humanitarian law and other defined ethical standards.

The findings from an extensive SIPRI study of the role of the business in helping to build security suggest that the basic approach of making industry a partner in export control (rather than the target) is the most promising way to adapt regulations to future conditions [12]. However, there are convincing arguments that a more integrated approach could help companies to strengthen their capacities to handle transactions in a lawful and responsible way given that regulators are now bearing down on industry from several directions at once.

The basic approach of focusing enforcement actions on those acting with knowledge and malicious intent while helping and providing simplified procedures for those that are ready and willing to comply with regulations is sound. However, it will probably be necessary to go further down both paths. A lot of attention is already being paid to the ‘hard’ enforcement against traffickers and terrorists. However, more can be done on the positive side of the balance sheet to assist legitimate industry.

An alternative approach would be to offer regulators insight into future transactions and activities undertaken by companies while allowing companies to demonstrate their own capacity to control all of the security-sensitive elements of their business practices, not only those related to exports.

The company would need to provide the authorities with a single document containing a detailed picture of its future activities during an agreed time period. The document would have to include a regulatory impact assessment that would explain all of the different obligations of the company in regard to the reported future transactions in different jurisdictions and an explanation of how these obligations were being met.

The regulatory authorities would have the opportunity to extract individual activities for further scrutiny and licensing, but for others the company would receive a ‘letter of comfort’ or similar document authorising the transaction. This would release the company from seeking the multiple separate authorisations currently needed to satisfy non-proliferation and counter-terrorism requirements in several jurisdictions. This authorisation would be valid in all of the different jurisdictions in which the company was carrying out the specified activities, and the process of authorisation would therefore also have to include all of the relevant authorities—which would require a new quality in cooperation among regulators.

As noted above, although the number of countries that participate in existing export cooperation arrangements has expanded it is still very limited in comparison with the degree of internationalisation of industry and the diffusion of technology. Moreover, even within cooperation arrangements decision making is still national and the amount of information shared between partners is limited. The current system, which was designed for national licensing of cross-border transactions involving manufactured goods, could not cope with the approach proposed above.

The question arises which regulatory authorities need to be part of the discussion about new approaches to trade control. A regional system could be feasible in Europe as the European Union has both the law making capacity and the institutions to take responsibility as a regulator. However, the patterns of trade and internationalisation of industry are not confined to any given region. A new approach to trade control should be discussed with the widest possible group of states and it would be ideal if participation was global. The United Nations is at an early stage of developing mechanisms that could provide a framework for this first phase of the discussion.

While this broad regulatory process would focus on how to reduce risk in legitimate trade, the task of monitoring the implementation of laws and regulations focused more narrowly on those with genuine criminal intent would clearly be the domain of national authorities working through different channels.

The United Nations has developed a number of mechanisms for dialogue with business about how partnerships and alliances between the UN and the private sector and foundations can further mutual goals. For example, one such mechanism, the Global Compact, brings companies together with UN agencies, labour and civil society to support universal environmental and social principles.

Clearly, many aspects of this approach would need to be examined in much greater detail before it could be considered a fully fledged proposal. However, the process of building corporate responsibility for security should be seen as a high priority in risk reduction. Initiating such a dialogue through one of the existing mechanisms of the United Nations or, should this prove impossible, in Europe would be a useful step to modernizing the current system of protection against the proliferation of nuclear weapons.

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Report on the Workshop on Measurements of Minor Isotopes in Uranium

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Abstract

The ESARDA Working Group on Standards and Techniques for Destructive Analysis (WG DA) organised a Workshop on 10 and 11 April 2008 at the Joint Research Centre IRMM in Geel, Belgium on MEASUREMENTS OF MINOR ISOTOPES IN URANIUM IN BULK AND PARTICLE SAMPLES in order to exchange views and information on the needs, the applicable mass spectrometric techniques and the required quality of measurement results for the minor isotopes of uranium. The aim of this workshop was to address various applications of uranium minor isotope ratio measurements also beyond nuclear safeguards purposes. The workshop objectives were to identify the needs for uranium minor isotope measurements in nuclear safeguards and related areas, to review the current state-of-the-art of relevant measurement techniques and to increase the knowledge exchange between nuclear safeguards and environmental sciences. 40 representatives from the main European and international nuclear safeguards organizations and nuclear measurement laboratories, but also experts from geochemistry and environmental sciences institutes participated in this workshop. Plenary lectures were given by invited speakers from the IAEA on the need for accurate measurements of high-quality for the minor isotopes of uranium, the ITU on the information that is inherent to uranium minor isotopes in view of nuclear forensics, and from the Earth and Environmental Sciences & OUUSF, The Open University, Bristol on application of uranium and thorium minor isotope dating in earth and environmental sciences. The workshop sessions focused on areas of application and mass spectrometric techniques, plasma mass spectrometry, and quality control. The findings and points of discussions from these sessions were discussed in two separate working groups; one on bulk samples and the other one on particle sample analysis. This report is a summary of the findings and points of discussions raised during the sessions and in the working groups, including recommendations for improved measurement techniques and procedures, quality control, reference materials and data interpretation, emphasizing also new fields of application. All the workshop participants recognized the need and the benefit of intensifying the cooperation between the nuclear safeguards and the environmental sciences institutes. This report is an attempt to share the outcome of this workshop with a broader community.

Keywords: Minor isotopes in uranium; nuclear safeguards; environmental sampling; mass spectrometry; earth sciences.

1. Introduction

The ESARDA Working Group on Standards and Techniques for Destructive Analysis (WG DA) organised a Workshop on 10 and 11 April 2008 at the Joint Research Centre IRMM in Geel, Belgium on *MEASUREMENTS OF MINOR ISOTOPES IN URANIUM IN BULK AND PARTICLE SAMPLES* in order to exchange views and information on the needs, the applicable mass spectrometric techniques and the required quality of measurement results for the minor isotopes of uranium. The aim of this workshop was to address various applications of uranium minor isotope ratio measurements, not limited to those for nuclear safeguards purposes. The announcement was distributed to all the WG DA members and posted on the ESARDA and on the IRMM web-sites. The response to the workshop announcement was overwhelming. As a result not only representatives from the main European and international nuclear safeguards organisations and nuclear measurement laboratories but also experts from geochemistry and environmental sciences institutes participated in this workshop. Eventually, 40 participants attended the workshop, which is quite remarkable for a workshop on such a specific topic. The positive response to the announcement was a confirmation that the workshop organisers chose, at the right point in time, a topic that is of great interest to a broad community. The institutions participating in this workshop are listed in Table 1.

Institution	Country
AREVA NP GmbH	Germany
Atomic Weapons Establishment plc AWE	United Kingdom
Belgian Nuclear Research Centre SCK·CEN	Belgium
Commissariat à l'Énergie Atomique - CEA / DAM Ile de France	France
Commissariat à l'Énergie Atomique - CEA Marcoule	France
Earth and Environmental Sciences, The Open University Milton Keynes	United Kingdom
Ente per le Nuove Tecnologie, l'Energia e l'Ambiente - ENEA, Casaccia	Italy
Geographical Sciences, University of Bristol	United Kingdom
Institute of Isotopes, Hungarian Academy of Science	Hungary
International Atomic Energy Agency - IAEA	United Nations
International Atomic Energy Agency - Safeguards Analytical Laboratory – IAEA-SAL	United Nations
Joint Research Centre-Institute for Transuranium Elements - EC-JRC-ITU	European Commission
Joint Research Centre-Institute for Reference Materials and Measurements - EC-JRC-IRMM	European Commission
Korea Atomic Energy Research Institute - KAERI	South Korea
Laboratory for Microparticle Analysis	Russian Federation
Nuclear Material Control Center - NMCC	Japan
Paul Scherrer Institut - PSI	Switzerland
QinetiQ Malvern	United Kingdom
University of Leicester and British Geological Survey	United Kingdom
University of Mainz	Germany
University of Natural Resources and Applied Life Sciences BOKU	Austria
US Department of Energy, Lawrence Livermore National Laboratory - LLNL	United States of America
US Department of Energy, New Brunswick Laboratory - NBL	United States of America

Table 1: List of participating institutions.

2. Objectives of the workshop

The workshop objectives, as outlined in the announcement to the event, were recalled to the participants at the beginning of the meeting:

- To identify the needs for uranium minor isotope measurements in nuclear safeguards and related areas
- To review the current state-of-the-practice / state-of-the-art of relevant measurement techniques
- To increase the knowledge exchange between nuclear safeguards and environmental sciences
- To draft recommendations for
  - Improved Measurement Techniques and Procedures
  - Quality Control and Reference Materials
  - Data Interpretation
  - New fields of application

3. Workshop structure

The director of IRMM, Mr. Herrero-Molina, welcomed the participants recalling the long standing tradition of his institute in high accuracy measurements, including isotope ratio measurements. Subsequently Mr. Mayer from ITU, in his capacity as chairman of the WG DA, opened the first workshop day with a short review on past approaches on the use of minor uranium isotope measurements in nuclear safeguards and outlined the workshop objective, structure and practicalities to the participants [1,2].

The first workshop day was dedicated to 17 presentations from workshop participants in one plenary and three topical sessions. The findings and points of discussions of this first workshop day were discussed during the second workshop day in two separate working groups; one dealing with bulk samples and the other one focusing on particle sample analysis. The chairpersons of the two working groups presented a summary of the conclusions/discussion to all workshop participants. The workshop was closed by Mr. Mayer with an overall conclusion and an outlook to the future, emphasising the need to intensify the cooperation between the nuclear safeguards and the environmental sciences institutes.

3.1. Plenary session

Three invited speakers from international safeguards, nuclear forensics and earth sciences gave lectures in the plenary.

The first presentation in the plenary was given by Mr. Vilece from the IAEA and addressed the need for high-accuracy measurements of the minor isotopes of uranium. Mr. Vilece stressed the fundamental importance of measurements of minor uranium isotopes in environmental sampling (ES) and gave an overview of the ES life cycle from inspection planning through sample taking; sample shipment; sample analysis; and result evaluation, up to the preparation of the evaluation report that is sent to the IAEA inspection division. The minor uranium ratios are measured in almost all of the environmental samples. ES swipes taken at enrichment plants indicate different feed materials or enrichment processes, and may provide additional information about equipment or plant design. ES swipes taken at facilities with hot cells indicate key information about irradiation history, and also help to evaluate mixing, and decay scenarios. Bulk uranium samples can give indications of possible origin and subsequent history of the material. Wide-area ES can indicate the presence of small amounts of man- modified uranium in the environment (from processes such as enrichment and reprocessing). Evaluation of ES results often encounters limitations due to insufficient accuracy in measurements of minor isotope ratios in uranium, such as for samples only slightly differing from natural uranium. In addition, measurement and subsequent evaluation of samples where ^{236}U is actually present but at low abundances (i.e. 1-200 ppm) is very challenging. Therefore, improved measurements of uranium minor isotopes, including a low detection limit for ^{236}U and reliable uncertainty estimates, are desirable and crucial for the evaluation.

The WG DA chairman, Mr. Mayer, gave the second plenary lecture on the information that is inherent in uranium minor isotopes results from the viewpoint of nuclear forensics. This presentation began by exploring the early days of nuclear forensics, from illicit trafficking just after the discovery of Iraq's clandestine nuclear programme in 1991, to its current objective. Nuclear forensics aims at identifying the origin and intended use of the material. Different parameters such as macroscopic appearance, microstructure, isotopic composition, elemental composition, impurities and decay products need to be looked at in a material to succeed in source attribution and age determination. Different analytical methods from safeguards, material sciences and geology are used to achieve this goal. Examples on the analytical approaches in nuclear forensics were given from the samples discovered in Iraq and from different uranium materials found in Europe, with particular emphasis on the uranium isotopic fingerprint of these samples when measured by mass spectrometry. As a conclusion it was clear that minor isotope measurements in uranium samples help in source attribution and are an important part of 'nuclear fingerprinting' of discovered, unknown material. Furthermore, relations between materials can be established by means of minor isotope measurements in uranium samples. The need for low detection limits for ^{236}U -, for lower uncertainties for ^{234}U - and to include ^{232}U measurements in the considerations was said to be of major importance in nuclear forensics. The reliability and comparability of measurement results of minor isotope ratios in uranium samples need to be guaranteed and monitored via the correct use of reference materials and quality tools.

The third presentation in the plenary on 'Application of uranium and thorium minor isotope dating in earth and environmental sciences' was given by Mr. van Calsteren from the Earth and Environmental Sciences & OUUSF, The Open University, Bristol.

Uranium series dating is a powerful tool that can be applied in such different fields as climate change, seismic hazard, archaeology, and volcanology. A uranium-series date is not actually a true age but the time since uranium was chemically fractionated from its daughter element, e.g., dissolution in water, where protactinium or thorium daughters are insoluble. This method requires very accurate measurements of the uranium isotopic ratios as well as the uranium/daughter ratio, and applies over an age range from recent to 350 000 years. The age of a bone or a sediment layer can establish its historical or environmental context, and allow correlation with other records. A time-span between two dates gives a rate of change and may indicate the process that caused the change. After presenting basics and assumptions of uranium series dating, Peter van Calsteren gave an example where uranium series dating of stalagmites was combined with paleoenvironmental reconstruction of past vegetation to draw new conclusions about possible Neanderthals colonisation in the British Isles. Because precise dates require high accuracy isotopic and elemental ratio measurements for the actinides, there is a continuing strong effort invested in reliable isotope ratio measurements of uranium and thorium for earth and environmental sciences applications.

3.1.1. Areas of application and mass spectrometric techniques

In session 1 the different application fields and different mass spectrometric techniques for measuring minor isotope ratios were presented by speakers from BOKU-Vienna, CEA, IAEA-SAL, NBL, IRMM and ITU. Needs, limitations, challenges and areas of improvement for different mass spectrometric techniques were discussed for samples ranging from bulk nuclear material, through actinide environmental samples, to micrometer-size particles of uranium. Environmental samples taken during the IAEA inspection of nuclear facilities are analysed for the isotopic composition of uranium and plutonium, in as either bulk or particle samples. The NetWork of Analytical Laboratories (NWAL) performs these analyses for the IAEA. The methods commonly used in particle analysis are Fission Track Thermal Ionisation Mass Spectrometry (FT-TIMS) and Secondary Ion Mass Spectrometry (SIMS) [3, 4]. Recently there have been also attempts to use Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) to analyse uranium particles. The advantages and limitations of all these techniques were presented. Topics and concerns expressed in the presentations included screening approaches to locate the uranium particles of interest, isobaric interferences for SIMS measurements of minor uranium ratios, reduced availability of reactor facilities for neutron irradiation for FT-TIMS, and the best approaches to achieve the required uncertainties and quality of measurement results to meet safeguards needs for minor isotope measurements in uranium.

For bulk analysis presentations on TIMS and Accelerator Mass Spectrometry (AMS) and results from interlaboratory comparisons were given. It was shown that the correct use of well-certified reference materials for minor uranium isotopes in combination with state-of-the-art measurement techniques improve the reliability and quality of the measurement results considerably. This was illustrated with examples from recent publications in geochemistry on the redetermination of the ^{234}U half-life [5]. From the results of REIMEP 18 on uranium isotope ratios in nitric acid solution it was seen that correct results were mainly achieved with TIMS and multi-collector ICP-MS techniques. Sources of the deviations between the participant results and the reference values for the minor ratios $^{234}U/^{238}U$ and $^{236}U/^{238}U$ could be due to tailing correction, non-linearity of Secondary Electron Multiplier (SEM) detector, and inter-calibration of SEM versus Faraday cup, especially for ratios such as $^{236}U/^{238}U$. In low-level bulk analysis using TIMS, a significant improvement in ionisation efficiency via filament carburization has resulted in values for minor uranium isotope ratios with considerably smaller uncertainties [6].

The final presentation in this session was explicitly dedicated to the challenges in measuring $^{236}U/^{238}U$, since ^{236}U is an important environmental and nuclear tracer. Multi-Collector Inductively-Coupled Plasma Mass Spectrometry (MC ICP-MS) and TIMS can measure a $^{236}U/^{238}U$ ratio of as small as 10^{-9}, whereas AMS can even measure a ratio of as small as 10^{-12} - 10^{-13}, due to the ability to eliminate isobaric interferences. In AMS, negative ions are produced from the sample using a sputter ion source, are accelerated through a tandem accelerator and then passed through a thin foil where electrons are stripped. The resulting positive ions are passing through a series of filters, magnetic and electrostatic analyzers and are finally detected after passing through a time-of-flight detector. Measurement results were presented from the Vienna Environmental Research Accelerator (VERA) installation for uranium ores and soil, and for water samples from the surface ($^{236}U/^{238}U$ ratio of 10^{-7}) and deep wells ($^{236}U/^{238}U$ ratio of 10^{-11}). Potential applications of

^{236}U measurements are not only anthropogenic tracing of earth processes but, also, in nuclear forensics for source attribution of uranium materials. Possible applications for measurements of pre anthropogenic ^{236}U lie in the areas of hydrology ($^{236}U/U$ ratio of waters on earth was between 10^{-14} and 10^{-13}), dating of sediments and uranium ore mining [7, 8].

3.1.2. Plasma mass spectrometry

Session 2 focused on uranium measurements in the expanding field of Inductively Coupled Plasma Mass Spectrometry (ICP-MS), with a number of researchers investigating the Laser Ablation (LA) technique. Presentations were given by speakers from BOKU-Vienna, British Geological Survey, Hungarian Academy of Sciences, Lawrence Livermore National Laboratory (LLNL), Paul Scherrer Institut (PSI), and School of Geographical Sciences of the University of Bristol. The applications of ICP-MS techniques to uranium range from measurements of spent fuel to environmental particle analysis, to personnel history of uranium exposure, to geochronology. In isotope geochemistry, MC-ICP-MS is applied to uranium and thorium isotope ratio measurements for age determination. These geochemistry approaches encounter many similar technical challenges to safeguards measurements. Main concerns for uranium minor isotope ratio measurements with MC ICP-MS are correction for detector linearity, peak tailing, blank, and uranium hydride interferences, which together are the main contributions to the uncertainty of measurement results in uranium minor isotope ratios. Instrument upgrades (for instance by adding an energy filter to cut peak tailing) can improve reliability of the minor uranium isotopic ratio measurements, as can the application of suitable reference materials, and lessons learned through interlaboratory comparisons. Recent interlaboratory comparison results confirm that uranium minor isotope ratio measurements with MC-ICP-MS are comparable to TIMS results [9].

LA-ICP-MC-MS was reported as promising new technique for both bulk and particle analysis, but is still in the exploratory phase. In this technique the material is ablated from a small area of a solid surface using a laser beam and swept to the ICP-MS by an argon or helium carrier gas. One study showed results from an environmental and bioassay study on contamination by depleted uranium from burning of scrap depleted uranium metal in the 1960s. Sand, soil and dust samples from the contaminated area were collected and screened with Scanning Electron Microscope/Energy Dispersive X-ray spectrometry. Measurement results on major and minor uranium isotope ratios with LA-ICP-MC-MS on those uranium particles were presented. Through very low level bioassay techniques, it was possible to determine historical inhalation exposures of various populations, demonstrating that the information provided by all the uranium isotopes is a powerful tool for unravelling mixtures of natural and anthropogenic uranium sources for health and environmental concerns [10, 11]. Examples were also given of isotopic analysis of uranium and plutonium in more than 100 soil particles collected around Chernobyl. The LA-ICP-MC-MS results on these particles showed that the isotopic compositions of uranium and plutonium and hence the burn-up grade agree well with the theoretical variation over the RMBK reactor core. It was shown that even low-abundant isotopes can be measured using LA-ICP-MS [12]. Another presentation examined the isotopic composition of irradiated nuclear fuel on the microscopic scale, of interest both from safeguards and scientific perspectives. High-Performance Liquid Chromatography (HPLC)-ICP-MS can also be used for the determination of uranium minor isotope ratios in spent nuclear fuel. These studies yield results that vary in precision and are influenced by spectral interferences and also demonstrate that for single collector LA-ICP-MS, the accuracy of measurement of the uranium isotopic ratios is limited due to the rapidly varying signal. In general for LA work, issues were encountered even for multi-collector instruments due to signal spikes exceeding the linear range of an ion counting detector, and potential effects due fragmentation rather than vaporization of particles, resulting in fragments being swept into the ICP torch and only then (partly) vaporized and ionized. These observations suggest future effort should be applied in the measurement of particles smaller than 10 µm, (precise particle locating), the feasibility of shorter laser pulses, and corrections for possible spectral interferences.

3.1.3. Quality control

The last session of this workshop was dedicated to quality control tools and uranium reference materials. The Nuclear Material Control Center (NMCC) is the designated national organization for safeguards implementation in Japan. Among its duties are inspections of all nuclear facilities in Japan, evaluation of inspection results, and record keeping of nuclear material accounting reports. In particular, NMCC carries out destructive analysis of inspection sample in its Tokai safeguards analytical laboratory. The measured samples range from uranium and

Name	Characteristic Ratios	Certified for	Available Conc. Levels
IRMM-073	$^{235}U/^{238}U=1$ $^{233}U/^{238}U=1 - 10^{-6}$ (15 Units)	Ratios	3µg/g* (quartz ampoule)
IRMM-074	$^{235}U/^{238}U=1$ $^{233}U/^{238}U=1 - 10^{-6}$ (10 Units)	Ratios	200µg/g (quartz ampoule)
IRMM-075	$^{236}U/^{238}U= 10^{-4} - 10^{-9}$ (6 Units)	Ratios	1 mg/g (quartz ampoule)
IRMM-3636 "Double Spike"	$^{233}U/^{236}U=1$ $^{234}U/^{236}U<0.00037$	Ratios & Conc.	1 mg/g, 0.1 mg/g 5µg/g* (quartz ampoule)
IRMM-3660 "Single Spike"	$^{236}U/U>99.96\%$	Ratios & Conc.	1 mg/g, 100µg/g*, 10µg/g* (quartz ampoule)
IRMM-3100 "Quad Spike"	$^{233}U/^{235}U/^{236}U/^{238}U=1/1/1/1$	Ratios	0.1 mg/g, 10µg/g* (plastic vial)
IRMM-(3)183 to (3)187	$^{235}U/^{238}U= 3\cdot10^{-3} - 4.7\cdot10^{-2}$ (5 Units)	Ratios	1 g U in 5 mL (glass ampoule) 0.2µg/g U in 1- 5mL* (plastic vial)

*** ∂-activity below 1000 Bq, for easier transport.**

Table 2: IRMM certified uranium reference materials.

plutonium oxides to mixed oxide (MOX) fuel samples to uranium hexafluoride (UF_6). The materials are measured for amount content using potentiometric titration or coulometry, but mostly TIMS with isotope dilution. The isotopic composition is measured by TIMS using the total evaporation method. Internal quality control procedures (using certified reference materials) are in place to check the mass fractionation and the ion yield.

The final presentation was given by IRMM on recently produced uranium reference materials for bulk and particle analysis, particularly for measurement of uranium minor isotope ratios. There is a need for certified uranium isotopic reference materials that can be used in method validation, instrument calibration, detector linearity and quality control. They are tools to establish traceability of a measured value (i.e. the analytical result) to a primary unit of measurement as defined in the SI system and thus enable comparability of measurement results. IRMM presented the synthetic uranium isotope mixing programme. The approach is to produce uranium reference materials from highly enriched oxides of ^{233}U, ^{235}U, ^{236}U, ^{238}U as starting materials, to dissolve and chemically purify them under controlled conditions and to sinter the final pure oxides in parallel under the same conditions to ensure the same stoichiometry for all materials. Subsequent weighing and dissolution of those purified, highly enriched oxides and gravimetric mixing of the solutions in the correct proportions resulted in a series of new IRMM certified uranium reference materials as shown in Table 2.IRMM-073/1-15 and IRMM-074/1-10 are dedicated to check SEM detector linearity. IRMM-075/1-6 can be applied to measurements of the ^{236}U abundances typically found in the environment and in the nuclear fuel cycle. The use of the IRMM-3636 'double spike' is advantageous when the highest accuracy is needed in measuring uranium content and isotopic composition, particularly also for the cases where the sample size is very restricted. One main application field for the 'double spike' could be in isotopic 'fingerprinting' of various uranium materials in nuclear safeguards and earth sciences applications. Internal mass fractionation correction of the $^{235}U/^{238}U$ and $^{234}U/^{238}U$ ratios can be performed by means of the certified $^{233}U/^{236}U$ ratio. Due to the extremely low abundance of ^{236}U in nature the IRMM-3660 'single spike' is a very suitable spike isotopic reference material for measurement of the uranium content of samples by IDMS. The 'quad spike' is designed to assess multi collector detector efficiencies. In addition the procedure to produce realistic reference particles via the hydrolysis of well-certified UF_6 in the gas phase, recently developed at IRMM, was presented. The intention is to produce uranium reference particle quality control samples with tailor-made isotopic abundances. The first Nuclear Signatures Interlaboratory Measurement Evaluation Programme NUSIMEP-6, on uranium isotope amount ratios in uranium particles was launched in spring 2008 [13].

3.2. Working Groups

After a full day of presentations underlining the need for minor uranium isotope ratio measurements, the second day of the workshop was reserved for detailed discussions in two working groups. The aim was to review in more details the state of the art, the limitations and strategies for improvements of the relevant measurement techniques. The discussions between experts from the various fields of application proved to be highly beneficial.

3.2.1. Working Group on Bulk samples

During the working group session about 'bulk analysis' a table was made up to summarize the most important factors affecting the accuracy for minor uranium isotope ratio measurements for the different techniques considered.

Detector effects

One common aspect for all techniques is the linearity response of the detectors, in particular for Secondary Electron Multipliers (SEM). Proper linearity investigation and required corrections were discussed, reports were given about linearity investigations and logarithmical corrections made at NBL and IRMM and ThermoFisherScientific [14, 15]. It was agreed to share observations and developments for SEM detectors within the ESARDA WG DA. A new publication about the SEM linearity issue is planned, jointly by IRMM, ThermoFisher Scientific and PSI, demonstrating procedures for the SEM linearity testing using the new IRMM-074 series of reference materials. Another detector aspect for the accuracy of minor ratio measurements is the peak tailing effect. This applies in particular, to measurements of low $^{236}U/^{238}U$ ratios using ICP-MS, but also to TIMS using the 'classical' total evaporation technique (TE). As clearly shown during the REIMEP-18 interlaboratory comparison [16], several safeguards laboratories still use the 'classical' Total Evaporation technique as a routine technique, but without performing any type of correction for the tailing at masses 234 and 236 that originates from the large peaks at 235 and 238. In order to overcome this problem, the so-called Modified Total Evaporation technique (MTE) was developed at NBL and refined at IRMM, but is not yet considered user-friendly enough and applicable at routine safeguards laboratories such as SAL, ITU, and on-site laboratories. This method is expected to allow determination of the $^{235}U/^{238}U$ major ratio as well as of the $^{234}U/^{238}U$ and $^{236}U/^{238}U$ minor ratios, within the same measurement, with improved precision and accuracy, and on a routine basis. Therefore a collaboration between IRMM, ITU, NBL with ThermoFisherScientific was started to implement the MTE technique into the standard software of the TRITON TIMS. After a first programme script was provided by ThermoFisherScientific, it was modified, extended and thoroughly tested at IRMM. The performance is encouraging, precision and accuracy for the major ratio is better than 0.05%, and, for the minor ratios (≥ 0.00005 which is close to natural $^{234}U/^{238}U$), better than 0.1%.This is in line with the needs for better precision and accuracy for minor ratio measurements of samples only slightly different from natural uranium, which Mr. Vilece from the IAEA requested in his plenary lecture. The software has now been installed at IAEA-SAL for further testing during the coming months, and is also planned to be tested at ITU and NBL. After successful implementation of the MTE technique into the standard software, a report will be published describing the method and giving recommendations for its use. Further aspects for the accuracy are the detector cross-calibration and, in particular for LA-ICP-MS, transient signals.

Interferences & Corrections

For many applications ^{236}U detection limits (< 0.1 ppm desirable) and ability to detect deviation from a 'natural' $^{234}U/^{238}U$ ratio of about 55 ppm are driven by the presence of isobaric interferences, as well as blanks. These interferences are observed in all types of isotope mass spectrometers, e.g., for ICP-MS, various interferences can be created in the hot plasma, whilst for TIMS interferences can be caused by impurities left in the sample or in the TIMS filaments (e.g., K6-molecules interfere at both masses 234 and 236 in non-zone-refined filaments). For ICP-MS, the hydride correction can be significant, i.e., from ^{235}U+H at mass 236. Some interference can be eliminated by using high mass resolution or by a desolvating sample introduction in ICP-MS.

Quality Control - QC samples, inter-comparisons

It was determined that composition- and matrix-matched standards would be most suitable for quality control samples and inter-laboratory comparisons. This applies to all techniques, but no particular matrices were specified.

Isotopic Reference Materials

It was mentioned that reference materials (RMs) with adequate uncertainties for minor ratios should be used on a routine basis. Recently, IRMM has re-certified the IRMM-183-187 series for the minor ratios, which were found to be very suitable reference materials for this purpose [17]. They have now been adopted by SAL as well. Furthermore, re-measurements for some of the NBS-U series materials have been undertaken and recently published by NBL recently and will be continued, e.g. NBL-CRM112A, a natural uranium standard [18].

Reliable Uncertainty Estimation

It was re-iterated that proper uncertainty estimation is important for reporting of results for minor uranium ratios, and should include all aspects of the measurements as discussed at this WG meeting. It is still a common problem that some of the uncertainty components are underestimated or even ignored.

Software

Since instrument control and data reduction software strongly affect the ability to make accurate measurements and produce realistic uncertainties, a regular exchange of software issues among the DA WG members was proposed.

3.2.2. Working Group on Particle samples

From what was discussed during the first day of presentations the main conclusions were the following in respect to the particle analysis:

- The IAEA have seen in their evaluations that there are background and bias effects in sample results measured by SIMS. The current SIMS method is limited in its performance due to its background problems caused by molecular interferences. This problem is not seen in TIMS analysis, the current state-of-the-art technique for particle analysis.
- The uncertainty, in particular for SIMS measurements is often under-estimated.
- There is a need for as low detection limits as possible, in particular for ^{236}U (< 1ppm).

	TIMS	MC-ICP-MS	LA-ICP-MS	SIMS	FT-TIMS
Accuracy	Peak tailing, in total evaporation SEM linearity	Detector cross-calibration and its stability, Peak tailing, SEM linearity	Detector linearity, transient signals		SEM linearity
Detection Limit	Interferences, e.g. from filaments, detector dark noise	Interferences, detector dark noise	Interferences, detector dark noise		Interferences, detector dark noise
Interferences & Corrections	From Filaments	H-correction	H-correction		
Quality Control- QC samples, inter-comparisons - Acceptance criteria, correlations	Composition-& Matrix-matched standards	Composition-& Matrix-matched standards	Composition-& Matrix-matched standards		Composition-& Matrix-matched standards
Isotopic Reference Materials	Use of RM with adequate uncertainty for minor ratios	Use of RM with adequate uncertainty for minor ratios	Use of RM with adequate uncertainty for minor ratios	Use of RM with adequate uncertainty for minor ratios	Use of RM with adequate uncertainty for minor ratios
Reliable Uncertainty Estimation	Underestimation of uncertainties	Underestimation of uncertainties			
Hardware	Energy filter adjustments Faraday cups for minor isotopes	Energy filter adjustments Faraday cups for minor isotopes	Energy filter adjustments		
Software	Fix Bug in Total Evaporation/Triton (Evap Fil. Down) Future: Modified total evaporation				

Table 3: Summary on major aspects of different measurement techniques for minor uranium isotope ratio measurements in bulk samples.

- There is a need for as precise and accurate minor and major isotope measurements as possible.
- New candidates for particle analysis are Large Geometry (LG)–SIMS, LA-MC-ICP-MS. (AMS is not a candidate for this, due to the requirement for larger amounts of material but is a tool for low level analysis, predominantly of ^{236}U in bulk samples).

The participants expressed a need for uranium particle Quality Control and Reference Materials. In particular the following requirements were defined:

1. Uranium particle standard U_3O_8 or UO_2 and UF_4 with 1-2 pg per particle (Certified amount for efficiency measurements) with isotopic compositions of natural uranium, low-enriched uranium, and highly enriched uranium
2. Standard beads of Si with absorbed U.
3. Particles of different size: 0.1-10 µm

Furthermore improved measurement techniques and procedures were discussed.

TIMS:

The TIMS technique in combination with Fission Track (FT) for location of particles is the current state-of-the-art technique. Some issues in TIMS analysis were still mentioned as factors where improvements can be made.

- Differences in performance between laboratories are likely to be due to variations in sample loading techniques, the amount of interfering materials and differences in instrumentation.
- It is difficult to determine the difference between man-made natural uranium and environmental natural uranium. (This is also the case for SIMS). It is difficult with TIMS to identify other materials like thorium that could be used to determine if a particle is man-made or not.
- The sometimes large uncertainties are due to the small sample size in combination with loss of ion yield due to agglomerations of other materials that are loaded on the filament together with the uranium particle.

SIMS:

- A change from SIMS to LG-SIMS (also called UHS-SIMS) will significantly improve the measurements of minor isotopes due to the removal of background interferences and improved total efficiency. (The efficiency gain is mainly due to the availability of multi-ion counting detector systems).
- More work is needed in enhancing efficiency and reducing the effects of background interferences for the currently used normal SIMS.
- There is a need for dedicated instrument software for particle analysis.
- The detection limit for ^{236}U is mainly set by the uncertainty in the hydrogen correction and not by the signal-to-detector noise ratio as is the case for TIMS. The uncertainty of ^{234}U and ^{236}U measurements is mainly defined by counting statistics.

LA-MC-ICPMS:

The use of LA-ICP-MS and its current limitations were discussed in detail. Also ways to overcome these limitations were indicated. The group concluded that LA-MC-ICP-MS is a technique under development that should be further investigated, showing also a potential application in particle analysis.

Topics covered during the discussion

- The current useful yield is at a level today of 10^{-3} ions per uranium atom. This needs to be improved, particlualry for investigation of low-abundant isotopes (e.g. ^{236}U). Moreover, the ablation leads to short transient signals which exhibit 'spikes' during ablation. The use of helium instead of argon as carrier gas is one possible improvement. Additionally, the use of secondary electron multiplier is another option. It is obvious that the ICP is a limited ion source and the question arose if there is any possibility to make use of the ions already produced during the laser ablation
- Nano-second pulse lasers are most commonly employed, using wavelengths of 193, 213 or 266 nm. Recently, the use of femto-second lasers show a potential improvement with respect to the formation of homogeneous particles and, thus, a less pronounced spiking, as well as particle dependent mass fractionation
- The fixation of the particles is a major concern in order to avoid material from being dispersed during the ablation process
- The extension of the work to natural or swipe samples where the single uranium containing particles are mixed with bulk material, raised one major question: How to find the particle of interest in laser ablation? The optical microscopes are obviously not sufficient. It was suggested

that the technique needs to be combined with Scanning Electron Microscope or Fission Track location

- LA-MC-ICPMS has an additional advantage in that it allows for simultaneous measurements of e.g. thorium besides uranium

MC-ICP-MS:

The use of solution-based MC-ICP-MS was only briefly discussed. The major remaining problem was the identification of the particle of interest and subsequent dissolution. The process is similar to TIMS, where single particles can be selected using a micromanipulator. The digestion and blank issue was discussed since final concentrations might be found in the low $pg \cdot g^{-1}$ level.

Scanning Electron Microscopy:

Scanning Electron Microscopy was mentioned as a tool for finding particles of interest and also as a tool for SIMS efficiency measurements by taking microscope pictures before and after the measurements.

Data Interpretation:

There is a need for improved error propagation and identification of error sources to reach a better estimate of the overall uncertainty.

4. Summary and Outlook

The workshop had a clearly defined technical focus. The discussions held in the working groups and in the plenary meeting resulted in broad recommendations. The different measurement communities participating in the workshop agreed that accurate measurements of the uranium minor isotope abundance ratio provide useful information on the nature of the sample under investigation. Many of the technical challenges in measuring the minor uranium isotopes are shared by most of the communities, and advances would benefit them all.

A number of measurement-related issues need to be addressed:

- The latest developments in measurement protocols should be included in commercial instrument software
- Well certified reference material has to be available
- Uncertainty estimation has to be carried out according to the *Guide to the expression of uncertainty in measurement (GUM)* [19]
- Careful detector calibration is required
- Interferences have to be identified and corrected for
- Quality control must be extend also to the minor isotopes
- New methods, like LA-ICP-MS should be investigated further and mature applications have to be developed

Overall, the outcome of the workshop exceeded by far the expectations of the organisers with respect to participation and to meeting the objectives. Applications and needs of minor isotope measurements in uranium in the nuclear field and in geochemistry and earth sciences were clearly addressed during this workshop. In particular, the participants from environmental sciences and nuclear safeguards would like to continue to discuss/exchange information also after the workshop, using the ESARDA WG DA as platform. The present paper is a first attempt in this direction to share the outcome of this workshop with a broader community. The ESARDA WG DA will organise a workshop on chemical impurities in uranium at ITU, Karlsruhe in March 2009, using a similar approach; i.e. discussing needs, techniques and applications whilst bringing different measurement communities and evaluators together. Participants in this workshop will not only come from the regular nuclear safeguards measurement community but also from fuel manufacturers, inspectors, evaluators, environmental sciences and geochemistry (ICP-MS). Organising this kind of ESARDA workshop, which is also of interest beyond the nuclear safeguards community is very much in line with what has been said by Mr. Ristori, Deputy Director General at Directorate General for Energy and Transport at the 30th ESARDA Annual Meeting, in May 2008 at Luxembourg … "*the culture of silence needs to shift to a culture of debate seeking also the support from the public ... cooperation with universities, schools and other institutions outside the common nuclear sector…*"

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forts and contributions made by the chairpersons of the sessions and working groups, the speakers and the participants resulting in a successful workshop.

List of Acronyms

- **AMS** - Accelerator Mass Spectrometry
- **ES** - Environmental Sampling
- **WG DA** - Working Group on Standards and Techniques for Destructive Analysis
- **FT-TIMS** - Fission Track Thermal Ionisation Mass Spectrometry
- **ICP-MS** - Inductively Coupled Plasma Mass Spectrometry
- **LA-MC-ICP-MS** - Laser Ablation Multi Collector Inductively Coupled Plasma Mass Spectrometry
- **LG-SIMS** - Large Geometry Secondary Ion Mass Spectrometry
- **MOX** - mixed oxide fuel
- **NWAL** - Network of Analytical Laboratories
- **RM** - Reference Material
- **SEM** - Secondary Electron Multiplier
- **SIMS** - Secondary Ion Mass Spectrometry
- **TE** - Total Evaporation Technique
- **TIMS** - Thermal Ionisation Mass Spectrometry
- **VERA** - Vienna Environmental Research Accelerator

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Technical sheets

The Application of Mailboxes in Safeguards

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1. Introduction

This Technical Sheet provides an overview of the mailbox concept and information on the e-mail based mailbox currently operating at the IAEA. The mailbox concept is particularly useful when used in conjunction with Short Notice or Unannounced inspections. The transfer of spent fuel to dry storage in Canada is used as an example of such an application. It will be recognised that the mailbox is a tool that can be used in a variety of ways; specific implementations will vary.

2. Short Notice and Unannounced Inspections

The possibility of unannounced inspections was available under Full Scope Safeguards (see INFCIRC/153, paragraph 84), but it has not been used routinely. The Hexapartite Safeguards Project from 1983 adopted inspection activities according to a "Limited-Frequency Unannounced Access" model. On the basis of this agreement, unannounced inspections, in conjunction with mailbox submissions have been carried out routinely in Gas Centrifuge Enrichment Plants for more than 20 years. In this case, a variety of safeguards tools were introduced to accommodate safeguards needs without exposing sensitive technology.

For those states with the Additional Protocol (INFCIRC/540) in force, the adoption of Integrated Safeguards has encouraged new options to meet safeguards objectives by using more effective and more efficient methods. Article 2 (a) (ii) in INFCIRC/540 makes reference to information "on the basis of expected gains in effectiveness or efficiency…. on operational activities..". In particular, the greater use of Short Notice and Unannounced Inspections is being encouraged. Under these arrangements, the plant operator sends agreed information to the IAEA, which then has the option to send an inspector on short notice or unannounced to confirm the claimed status. The method by which the information is delivered to the IAEA is a "Mailbox".

Short Notice/Unannounced Inspections are most usefully applied in situations where material is moving quickly through a series of processes. Bulk material plants, enrichment plants, fuel fabrication plants and transfers of spent fuel to dry storage are potential areas of application. In these cases, traditional measures might require extensive inspector presence or unacceptable production delays for the facility. Through 100% availability for inspection, Short Notice and Unannounced Inspections provide the IAEA with high confidence in their knowledge of activities at the plant while expending reduced inspection resources. A secure and trusted Mailbox to accept the appropriate information is an essential partner for these inspections. The Mailbox must be trusted by all three parties, the inspector, the plant operator and the state authority.

Different arrangements may be in place in different states. Also, in some states, a national or regional inspector would need to be present; such arrangements might present logistical challenges.

3. Mailbox Implementations

The information provided via a mailbox is generally operational information. There appear to be two scenarios:

– Notification of material movements/changes after they have occurred

– Notification of plans for movement of material in advance

In the first case, there may be a requirement for material to be held at the announced location for a pre-determined period so that the facility's statement can be verified. This period is referred to as a "retention period"; its need and duration has to be agreed. Following the retention period, if there is one, the operator is free to move the material to the next stage of processing whether it has been inspected or not.

The use of advance information may be applied to safeguard the transfer of spent fuel to dry storage. The schedules for these operations are provided in advance, but there may be delays due to a variety of operational factors. Inspectors appearing unannounced will need to have current information preferably before arrival.

In both scenarios, establishing the time for message delivery is important if misunderstandings are to be avoided. Not only must any retention period be strictly observed by both parties, but also enhanced surveillance may be triggered. It is important to note that advance or operational information submitted by the operator does not replace the declarations normally made by the state authority.

4. Method of Delivery

A Mailbox can be implemented using a traditional letter or fax, but current implementations are likely to use secure electronic mail. In some cases, the information is sent directly to the IAEA, in others, there is short delay allowing a review by the state authority. In some cases, the information is regarded as sufficiently sensitive that it cannot be sent offsite. Instead it is delivered to an on-site Mailbox, from which the authorised inspector can recover it on his next visit.

5. General Requirements for a Safeguards Mailbox

Agreed information can be sent using various means including regular mail and fax transmission as well as electronic mail. While many of the following requirements are generic, the focus is on electronic mail.

The Mailbox may be physically located at the facility, at the IAEA's headquarters or perhaps at another location such as an IAEA regional office. Special features have been implemented in the IAEA Mailbox to assure the sender that the message has been securely received, and to assure the IAEA that the message is valid. A high level of trust with all parties must be established in the communications. Reference [1] provides a detailed analysis of the Mailbox requirements from the perspectives of both the IAEA and the plant operator.

The IAEA will need to be confident that:

- security of the Agency computer or computer system is not compromised by the Mailbox System infrastructure;
- any message sent to the Mailbox cannot subsequently be denied by the plant operator (non-repudiation);
- the time that the message was sent is true (trusted time stamp);
- the message cannot be altered following its initial transmission (in-alterability);
- in-alterability must not prevent the plant operator from submitting corrections to the Mailbox, as long as the corrections are fully traceable by the Agency; and
- the sender is not an impostor and is authorized to submit information for that facility.

The plant operator may need:

- assurance that no unauthorized party or impostor can make a submission (counterfeit not possible);
- an acknowledgement that the submitted information has been received (trusted acknowledgement);
- a timely acknowledgement from the IAEA (within minutes);
- assurance that sensitive information is only available to the parties that need to know (confidentiality);
- the ability to provide to the IAEA inspector any recent message sent to the Mailbox while the inspector was en-route to the inspection site; the authenticity of this message must be digitally verifiable by the inspector.

The state authority (State System for Accounting and Control of nuclear material [SSAC] or its regional equivalent [RSAC]) may also require:

- a copy of all of the plant operator's submissions to the Mailbox and the corresponding acknowledgements; and
- assurance that the original message and its acknowledgement are genuine.

The general contents of messages sent to the Mailbox should be specified in the procedure agreed by the IAEA and the SSAC/RSAC and operator. The advance information may contain updates to a schedule for transfers to dry storage and associated activities. Other submissions may include statements on the current operational status and material holdings.

In some facilities the data is considered too sensitive to be sent off-site. An electronic mailbox incorporating this functionality can be located on site. In this case the inspector would evaluate the mailbox information on-site during an unannounced inspection for instance.

6. The IAEA Mailbox

The IAEA has developed a specially configured electronic Mailbox to meet the above requirements using standard secure mail protocols. In this way, standard desktop computers and software can be used to submit the information. The mailbox installed at the IAEA's headquarters meets the security needs for most of the commercial facilities submitting information. Besides generating an acknowledgement automatically, the IAEA Mailbox also has the ability to recognize senders and distribute their messages according to their associated Material Balance Area (MBA) and responsible IAEA inspector.

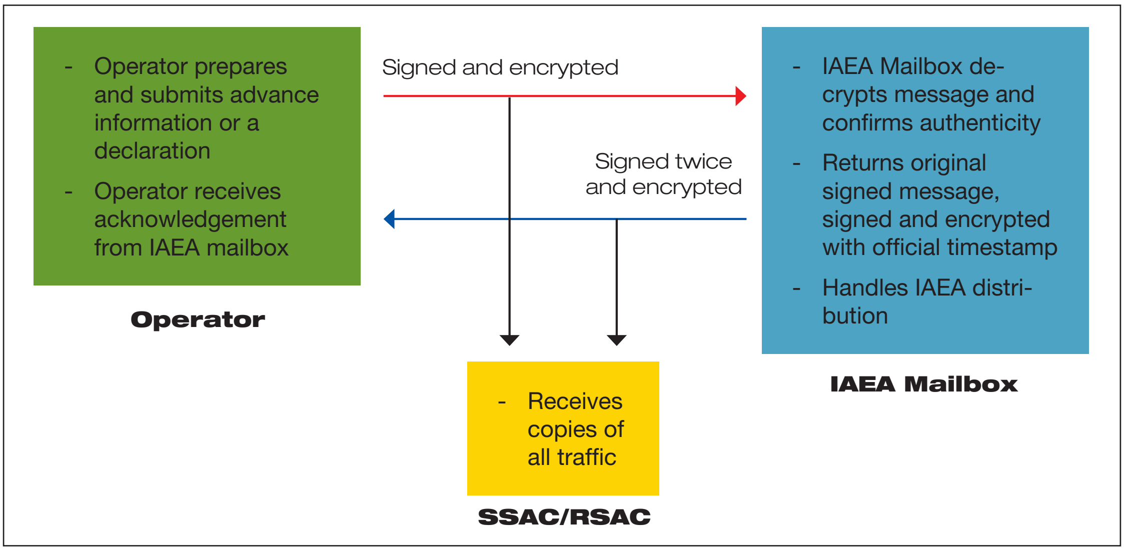
To send mail securely, the designated plant operator must be in possession of a PKI certificate, preferably one which has been issued through his organization's Public Key Infrastructure (PKI). The operator's message can be sent as plain text within the e-mail or as an attachment to the e-mail; both the plain text and the attachment will be signed and encrypted. Mail systems such as Microsoft Outlook will automatically handle the authentication and encryption of the text body and any attachments as well as the reverse processes.

7. Exchange of Information with the Mailbox

When the plant operator's message is received by the IAEA Mailbox, it is decrypted and its digital authenticity verified. If it is accepted, an acknowledgement is automatically sent to the originator and (if required) to the SSAC/RSAC. The acknowledgement contains the original submission including the sender's digital authentication (signature) along with the digital signature and official time stamp provided by the IAEA Mailbox. The whole package is encrypted. Notice that the message contains two authentications within the encrypted package: the original signature of the sender and the time-stamped signature of the Mailbox. The two authentication blocks in the confirmation are necessary, so that:

- the originator can confirm that the original message has not been altered (original signature intact);
- the time stamp issued by the IAEA cannot be altered (IAEA's signature would not be intact);
- the sending of the original message by the originator cannot be denied by the originator, since it contains his signature;
- the IAEA's acknowledgement cannot be denied by the IAEA, since it contains their signature;
- the IAEA inspector could validate the original operator submission while at the inspected facility by obtaining a copy of the message from the operator and validating the corresponding signatures.

The official (trusted by the IAEA) time for the delivery of the information will be that provided in the timestamp given in the Mailbox's acknowledgement. It will be a few minutes later than that of the original transmission, not a significant delay. Should an operator not receive a timely acknowledgement, he should consider the option of resending the message. The SSAC/RSAC may retain an authentic



copy of the original m essage sent by the operator and also the acknowledgement sent by the IAEA. If there is ever any dispute over the communication of advance information, the SSAC/RSAC would have at its disposal the information to arbitrate.

8. Transfers of Spent Fuel to Dry Storage at Canadian multi-unit stations

Under Integrated Safeguards, new safeguards approaches are being implemented; in Canada, these approaches are guided by a State-Level Approach (SLA). The SLA identifies procedures which enhance the effectiveness and efficiency of safeguards activities within the state.

One area where the use of Unannounced Inspections is attractive is in the transfer of used fuel to dry storage. In Canada's case, the IAEA's effort required to oversee all transfers to dry storage under Full Scope Safeguards had been substantial and the need for a more efficient method of verifying compliance had been apparent for a long time.

8.1. Full Scope Safeguards

Dry Storage Containers (DSCs) are used for the long term storage of spent fuel at multi-unit stations in Canada. They have built-in tubes to verify contents and weigh 70 tonnes when loaded. DSCs are loaded with spent fuel in the spent fuel bay and then transferred to another location for permanent closure by welding and long term storage. Under Full Scope Safeguards, the removal of spent fuel from the bay and the transfer of the temporarily closed DSC to the Dry Storage Facility required the presence of an IAEA inspector at every step. Not only did this take considerable inspector effort, but scheduling accurately in advance was a challenge and led to ineffective use of both the inspector's time and that of the facility's personnel.

8.2. Integrated Safeguards

Under Integrated Safeguards, facilities send advance information on planned transfers to dry storage to the IAEA and accept Unannounced Inspections. The IAEA inspector would have the option to arrive unannounced at the facility to verify that the activities conform to the latest information provided by the facility. Special procedures are needed onsite to ensure that the inspector has timely access to the relevant locations. Under these arrangements, PDI (Person Day of Inspection) requirements can be reduced to a fraction of those needed under Full Scope Safeguards. Detailed information on the implementation of these measures can be found in [2 and 3].

The facility will have no information on when an IAEA inspector will visit; they must expect an inspector to arrive unannounced at any stage of the operator's activities. It is in this way, 100% availability for verification can be achieved. The operator must adhere to the activities or schedule provided in the advance information. Should circumstances change, updated information must be provided to the Mailbox. For some more remote facilities, changes to the schedule may have to be made, when the inspector is already on his way to the facility to carry out an Unannounced Inspection. For these reasons confidence in the Mailbox system is crucial. Trusted time stamps and the means to authenticate the messages are critical to ensure there are no disputes.

9. Conclusions

- The use of a mailbox in conjunction with Unannounced or Short Notice inspections is particularly useful when safeguarding material which is subject to a series of processes. The alternatives might be increased inspector presence or rigid adherence to a fixed schedule.
- The mailbox concept was originally developed to provide after the event notification of material movement within a facility. It has been extended to include information given in advance on plans to transfer material, in particular to dry storage.
- An electronic mailbox meeting safeguards requirements is available. For many commercial facilities, electronic submission complying with the IAEA's requirements can be achieved using standard desktop computers and software.
- The use of Unannounced Inspections in conjunction with the mailbox is expected to save the IAEA considerable resources while retaining confidence in the outcome. The integrity of the mailbox is essential to maintain this confidence.

Acknowledgement

Valuable assistance was also provided by Tim Korbmacher, Urenco, and Igor Tsvetkov, IAEA.

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Quality Control in Nuclear Sample Measurements

1. Definition – Quality Assurance and Quality Control (QA/QC)

Quality Control (QC) is a set of procedures, including technical activities, to ensure that a final product or a performed service adheres to a defined set of quality criteria and meets the customer requirements. Quality Assurance (QA) is defined as a systematic process to check whether a service/ product under development is meeting specific requirements before the product or service is completed.

2. Nuclear Safeguards

"*Effective IAEA safeguards remains the cornerstone of the world's nuclear non-proliferation regime aimed at stemming the spread of nuclear weapons and moving towards nuclear disarmament.*" – Olli Heinonen: IAEA Deputy Director General and Head of the Department of Safeguards

The non-proliferation treaty (NPT) comprises a verification mechanism: nuclear safeguards.

Safeguards aims at the verification of the non-diversion of fissile material from its intended and declared (peaceful) use. Therefore a reliable nuclear material accountancy system has to be established by the plant operator. This accountancy is subject to independent verification by the safeguards authorities. Measurement of samples (for their uranium and plutonium content and isotopic composition) taken by inspectors remains the backbone of any verification system. Environmental sampling is a supplementary safeguards tool aiming at verifying the correctness and completeness of a state's declarations. The system of measurements applied in nuclear safeguards is expected to conform to the latest standards:

Accountancy and control of nuclear material require analytical measurements that "*shall either conform to the latest international standards or be equivalent in quality to such standards*" IAEA INFCIRC/153 [1].

International political decisions in view of the peaceful use of nuclear energy and nuclear security are based on confidence in the analytical measurement results provided by laboratories, particularly in view of independent verification of samples of nuclear material, special sample analysis and environmental sampling.

3. QA/QC

Quality Assurance (QA) and Quality Control (QC) in sample analysis for nuclear safeguards measurements are a means to the end of complying with the requirements to provide reliable measurement results for the nuclear safeguards system.

QA and QC in analytical measurements comprise different aspects [2]:

- Method validation and instrument calibration
- Traceability and comparability of measurement results
- Uncertainty of measurement results
- External performance evaluation
- Document/data control and deployment of a quality system

3.1 Measurement Standards

Measurement standards are an indispensable tool wherever measurements are carried out. Their fundamental role is to establish traceability of a measured value (i.e. the analytical result) to a primary unit of measurement as defined in the SI system. Only measurement results that are traceable to a common reference, namely the respective SI unit, can be regarded as truly comparable. In measurements of amount of material, these measurement standards are generally provided in the form of reference materials (RM). Such a reference material shall consist of "a material or substance which is homogeneous and for which one or more values are well established" [3]. Reference materials serve for calibration of a measurement instrument, for validation of a measurement technique and to assess the reproducibility of measurement results. They are also used for the periodic assessment of a measurement system or for the assignment of values to materials [4]. Reference Materials need to be applied in particular for the quantitative verification of nuclear material as used in traditional safeguards, but also in other measurements, for instance, in environmental sampling. Elemental RMs are typically used to calibrate methods such as titration, coulometry or K-edge densitometry for uranium and plutonium assay. Isotopic reference materials are applied to calibrate mass spectrometers. Spike reference materials are isotopically enriched materials that are certified for isotopic amount and amount content and mostly applied for isotope dilution mass spectrometry measurements (IDMS) [5]. Reference materials certified for isotopic amount content and/or isotopic abundance ratios can be obtained from laboratories specialised in their certification, including the IRMM [6], NBL [7] or CETAMA [8].

3.2 QC - samples

Secondary reference materials, also called 'working standards', are used as quality control samples that undergo with a certain periodicity depending on the quality system the same sample preparation and measurement procedure as the unknown sample. Any deviation from the reference values is an indication of (systematic) errors and needs to be looked at. Special attention has been given recently to the development of quality control samples for the analysis of special samples in nuclear forensics and for environmental samples. To meet these needs reference materials laboratories have produced a number of reference materials certified also for minor uranium isotope ratios and are developing uranium reference particles for nuclear safeguards and non-proliferation control [9].

3.3 Uncertainty of measurement results

The uncertainty on the analytical result encompasses the uncertainty from the certification of the RM, the uncertainties resulting from the repeatability of the measurement results and any systematic uncertainty contributions. The uncertainty on the quantitative verification of the accountancy of nuclear material includes, besides the uncertainty on the sample analysis, also the uncertainty on the bulk measurement and on the sample taken from this bulk. The International Target Values (ITVs) 2000 for Measurement Uncertainties in Safeguarding Nuclear Materials represent estimates of achievable uncertainties under routine measurement conditions. They are intended to be used by plant operators and safeguards organizations [10].

3.4 Interlaboratory Comparisons

External control of the quality of measurements of the nuclear fuel cycle materials is indispensable to demonstrate international measurement capabilities. Participation of analytical laboratories in inter-laboratory comparison schemes is an excellent tool to evaluate their measurement performance and to compare analytical measurement results obtained with different analytical methods on samples from a single batch. Since 1982 the IRMM has organised the Regular European Interlaboratory Measurement Evaluation Programme (REIMEP) [6]. In REIMEP campaigns, samples matching materials analysed routinely in the nuclear fuel cycle are sent to participating laboratories for measurements. Subsequently the reported measurement results are compared. REIMEP involves safeguards laboratories and also more recently environmental laboratories throughout the world. The certified test samples proposed to participants in REIMEP comparisons have ranged from uranium hexafluoride (UF_6), uranium/plutonium mixed oxide (MOX) pellets, uranium-, plutonium oxides to uranium-, plutonium nitrate solutions. The Nuclear Signatures Interlaboratory Measurement Evaluation Programme (NUSIMEP) was established in 1996 to support the growing need to trace and measure the isotopic abundances of elements characteristic for the nuclear fuel cycle present in trace amounts in the environment [6]. Participation in the NUSIMEP external quality control exercise enables participants to demonstrate and assess their ability to carry out precise measurements, in particular, on trace amounts of uranium and plutonium. Laboratories participating in REIMEP and NUSIMEP are asked to perform the measurements working under routine conditions using the techniques, procedures and instrumentation of their own choice, and to report a result with a best estimate of the expanded measurement uncertainty. Individual measurement results of participants are compared to the certified reference value provided by IRMM. The certified reference value has a demonstrated uncertainty evaluated according to international guidelines and demonstrates traceability to the SI. Other regular inter-laboratory comparison programmes in the nuclear field are EQRAIN by CETAMA [8] and the Safeguards Measurement Evaluation (SME) by NBL [7].

4. International demonstration of measurement capabilities

Interlaboratory comparisons on isotope ratio measurements in nuclear material are also organized on the level of national metrology institutes and invited expert laboratories as part of the activities of the

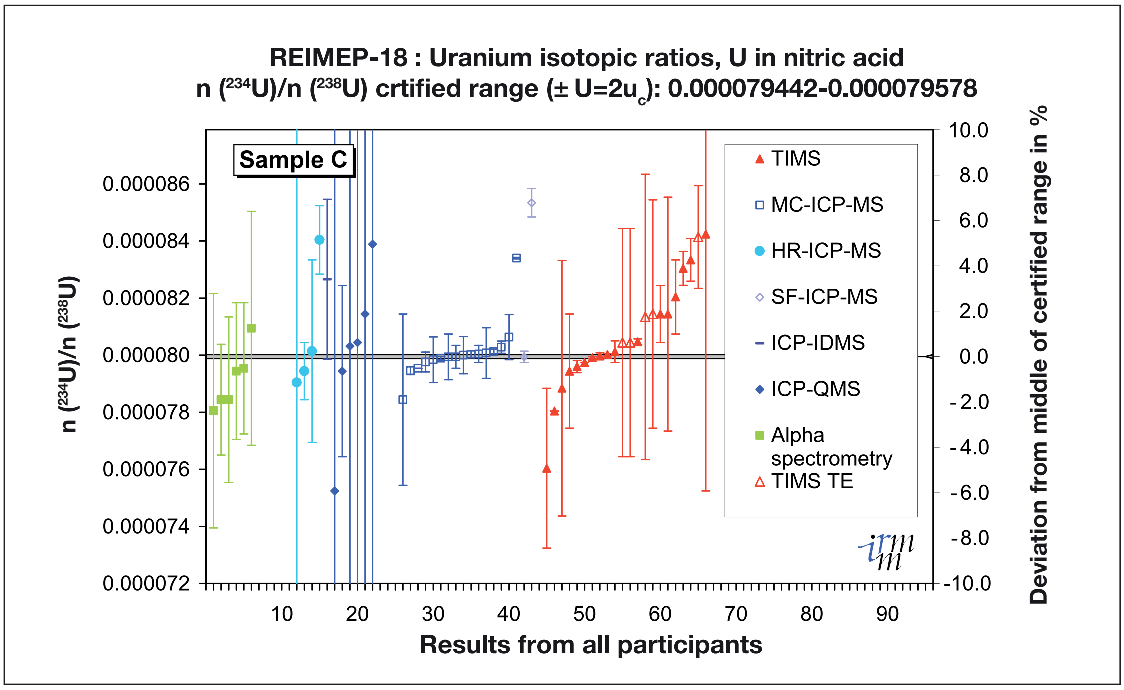

Figure 1: Participant results from REIMEP-18 *'Isotopic abundances of low-enriched uranium in nitrate solutions'.*

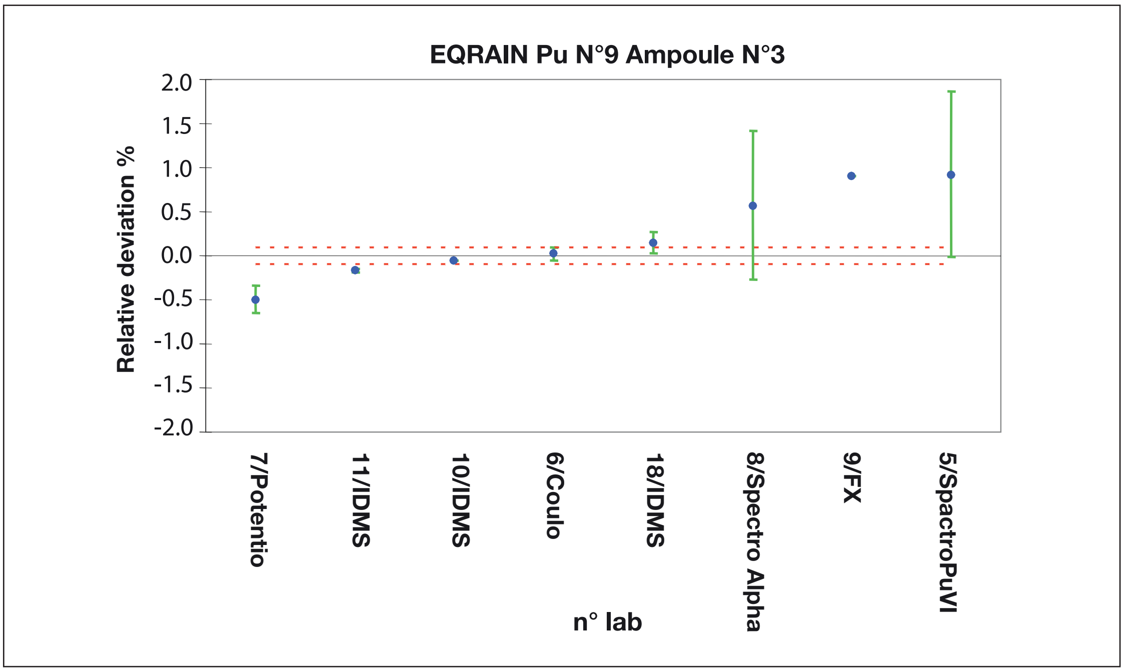

Figure 2 : Participant results on Pu amount in sample no. 3 (6,182 ± 0,007g.kg).

Consultative Committee for Amount of Substance – Metrology in Chemistry (CCQM) of the Bureau International des Poids et Mesures [11]. National metrology institutes not only need to demonstrate that their measurement results are reliable and comparable, they also have to be in compliance with legislation, international standards and international recognition arrangements that support the free trade goal "measured once, accepted everywhere". IRMM assists the CIPM (International Committee for Weights & Measures) to support the CIPM-MRA (Mutual Recognition Arrangement) by making available the same samples as used in NUSIMEP for inter-laboratory comparisons in chemistry among national metrology institutes and expert laboratories. For the pilot study CCQM-P48 (Uranium isotope ratio measurements in simulated biological/environmental materials) material representative for a large range of biological and environmental samples was chosen to produce test samples, among those also NUSIMEP-4 samples [12]. Measurement claims and demonstrated measurement capabilities can therefore be compared in a

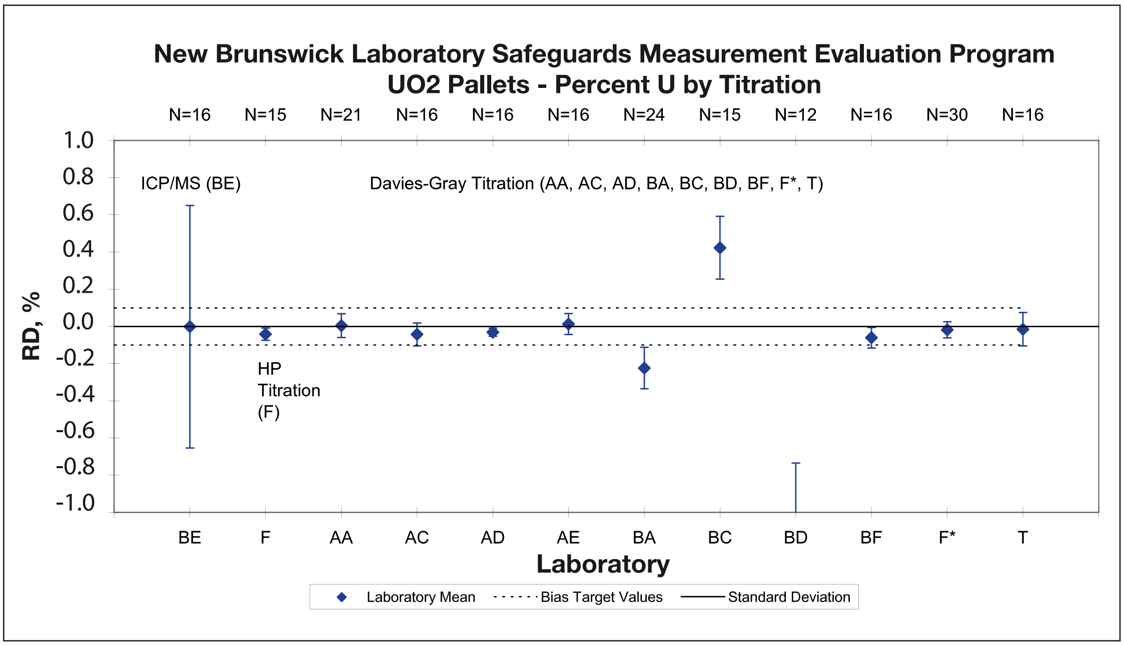

Figure 3: Participant results on uranium concentration in uranium dioxide pellets from SafeguardsMeasurement Evaluation (SME) Program.

transparent way on all levels of the international measurement infrastructure from normal field laboratories to network laboratories to reference laboratories to national metrology institutes involved in measurements for nuclear safeguards.

5. Quality System

An essential part of a well deployed quality system is to assure that analytical staff are well trained, that equipment is operational and suitable for the type of analysis, that a decent project management is implemented and that data and documents are controlled and archived in a proper way. Some laboratories involved in measurements on nuclear materials or in environmental sampling already have or are striving for accreditation, mainly according to the ISO/IEC guide 17025:2005 [2], in order to have an external attestation by an accreditation body with regard to their technical abilities [13, 14]. Participation in inter-laboratory comparisons as part of a well- deployed quality system enables laboratories to assess their measurement performance. At the same time it allows laboratories to demonstrate their competence on a high quality level to accreditation, authorisation, and inspection bodies as well as to safeguards authorities.

6. An example: QC in the Euratom on-site laboratories

Safeguarding the large reprocessing plants undoubtedly poses a challenge to the Safeguards Authorities. The size of the plants and the high material throughput require a significant effort in verification activities. Uranium and plutonium product samples in the form of nitrate solution or as oxide and also MOX need to be analysed. In order to achieve the required high level of detection probability, the safeguards inspectors need to take a large number of samples, several hundred a year, which have to be subjected to independent analysis. Evidently, the results of these analyses need to be highly reliable, reporting times have to be short, costs have to be kept at a reasonably low level and waste production should be kept to a minimum. Based on these aspects, the Euratom Safeguards Office (today called DG TREN) decided in the early 1990's to develop, install and operate safeguards analytical laboratories at the site of the two large European reprocessing plants, namely the 'On Site Laboratory (OSL)' at Sellafield (UK) and the 'Laboratoire sur Site (LSS)', La Hague (France). The common goal of the team of analysts – using the state of the art measurement equipment available in the laboratories – is to deliver measurement results at a constantly high quality. To this end a systematic concept for analytical quality control was developed and implemented. The use and correct application of certified reference materials, quality control samples, performing replicate measurements, comparing results from different analytical techniques, participation in external Quality Control and rigorous data and document control are the pillars of any analytical quality control system. The quality control concept implemented in the onsite laboratories forms an integral part of the laboratories' measurement strategy [15].

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Nuclear Reference Materials

1. Objective

The objective of this technical sheet is to describe nuclear reference materials, their applications and usefulness in safeguards applications, and their evolution into new fields of safeguards inquiry as a result of new needs and analytical techniques.

2. General Overview of Reference Materials

Much analytical instrumentation is comparative and therefore requires a sample of known composition (Reference Material) for accurate calibration and measurement. The classic example of the importance of reference materials in comparative measurements is described by the equal-arm balance, variations of which have been used for centuries.

Figure 1: Two examples of the equal-arm balance.

A sample of unknown mass is placed on a pan on one side of the balance, and objects of known mass (reference materials) are placed on the other balance pan until the pans are level. The sample object is thus directly compared with a reference material of known mass to yield the sample's mass. The accuracy of this measurement is dependent, in addition to the physical construction of the balance, on the accuracy of the reference materials employed. Various users would have reference masses of varying quality, or even high quality reference masses that were damaged or stored under poor conditions. Any deviation of the reference mass from its known value would lead to a bias in the resulting sample measurement. Thus, the intercomparability of these types of measurements was very poor. A gold ore sample weighed on one balance may have yielded a very different mass if weighed on a different balance, or even on the same balance but later in time.

As technology and commerce increased between regions and countries, requirements for the accuracy and intercomparability of measurements across distances and times were raised. Eventually, many of the world governments agreed that a common standard or reference system was required to improve the intercomparability of various measurements. As a result, the International Bureau of Weights and Measures (BIPM) was established by the Convention of the Metre on May 20, 1875 (a day which is recognized as "World Metrology Day"). The BIPM operates under the supervision of the Comité international des poids et mesures (CIPM).

To paraphrase from the BIPM website, its mandate is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from direct dissemination of units (as in the case of mass and time) to coordination through international comparisons of national measurement standards (as in electricity and ionizing radiation). The task of the BIPM is to ensure world-wide uniformity of measurements and their traceability to the International System of Units (SI).

The work of the CIPM and BIPM has direct application to many aspects of everyone's lives. The establishment of a comprehensive set of international standards has ensured that a kilogram of cheese purchased in Zurich is comparable to a kilogram of Tuna purchased in Tokyo; the weight of crude oil loaded on a tanker in Venezuela and off-loaded at a refinery in Texas is accurate and agreed upon, and the amount of uranium input into an enrichment cascade is accurately known to the satisfaction of commercial and political interests.

3. Definition of Reference Materials

The International Organization for Standardization's (ISO) International Vocabulary of Basic and General Terms in Metrology (VIM Guide, 1993) provides the following definitions:

Reference Material (RM) – Material or substance one or more of whose property values are sufficiently homogeneous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials.

Certified Reference Material (CRM) – Reference material, accompanied by a certificate, one or more of whose property values are certified by a procedure which establishes traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an uncertainty at a stated level of confidence.

Reference Material Certificate – Document accompanying a certified reference material stating one or more property values and their uncertainties, and confirming that the necessary procedures have been carried out to ensure their validity and traceability. (ISO Guide 30: 1992)

Two key distinctions between a Reference Material and a Certified Reference Material are that a CRM:

1. requires certification using a procedure which establishes traceability of the certified property value to a common reference, and;
2. requires that each certified value be accompanied by an uncertainty.

These two factors are related and together provide assurance to users of the traceability and ultimately intercomparability of measurements performed using CRM's. Use of a certified reference material is one cornerstone to the foundation of an accurate and traceable (intercomparable) measurement.

4. What is Traceability?

The Vocabulary of Metrology defines traceability as "a property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties".

This means that the result of a measurement is "anchored" to references which do not change over time or location. This ensures that all traceable measurements are comparable to one another, theoretically regardless of where and when they take place. Nearly every country has adopted the internationally accepted references described as the International System of Units (SI). In many countries, national standards for weights and measures are maintained by a National Measurement Institute (NMI) which provides the highest level of standards for the calibration and traceability infrastructure in that country. Examples of government agencies are the National Physical Laboratory in the United Kingdom, the National Institute of Standards and Technology in the US, and the Physikalisch-Technische Bundesanstalt (PTB) in Germany. Each of these institutes is responsible for maintaining their countries measurement references, and for working together to maintain the intercomparability ("anchorage" to the SI) of these references through international collaboration via the CIPM.

It is important to note that traceability is the property of the result of a *measurement*, not of an instrument or calibration report or laboratory. It is not achieved by following any one particular procedure or using special equipment or materials. Simply using certified reference materials to calibrate an instrument or provide quality control is not sufficient to make the measurement result obtained from that instrument traceable to realizations of the appropriate SI unit or other stated references. The measurement system by which values are transferred must be clearly understood and under control.

4.1 What is required to claim traceability?

The provider of a measurement result must document the measurement system used to establish traceability and provide a description of the chain of comparisons that were used to establish a connection to a particular stated reference. There are several key elements required to ensure traceability:

- A clearly defined quantity has been measured
- Use of traceable reference materials for calibration of instruments/methods
- Fitness of methods for purpose
- Method validated
- Method in control (QC's)
- Method monitored as part of larger internal QA program
- Robust and transparent uncertainty analysis of measurement

The customer requiring traceability wants assurance that their measurements are accurate. The only way to prove that measurements are accurate is to prove that their uncertainty is low enough to allow the desired conclusions to be drawn from the results. This makes traceability part of substantiating the stated uncertainty for the measurement. Therefore the best way of demonstrating traceability is by starting with the uncertainty budget for the measurement.

4.2 Uncertainty Budgets

Uncertainty budgets should be developed in accordance with the ISO "*Guide to the Expression of Uncertainty in Measurement*" (GUM). This standard guide provides a method for calculating measurement uncertainties that allows intercomparability of measurements and uncertainties, use of uncertainties from one measurement to be incorporated into further measurements whether performed at the same time or at a later date, and also allows the comparison of two measurements of the same item to determine whether they agree or not, given their uncertainty.

The GUM guide requires the evaluation of all contributors to measurement uncertainty, the calculation of uncertainty budget for each certified value, and finally the publication of determined values, their associated uncertainties, and the uncertainty budget associated with the value assignment. Transparency of the method and details in calculating the uncertainty is called for in the GUM guide, and this allows customers and users of measurement data and certified reference materials to evaluate their quality and traceability.

5. How are Nuclear Reference Materials Used?

Reference materials play an important role in analytical quality assurance. The basic purpose of their use is to validate the measurement process, and thus to provide a record of the analytical performance of a facility. They are an essential tool for laboratories in meeting the demands of a quality assurance system and, in many cases, also help laboratories to improve their analytical performance. Reference materials are used for:

- Calibration of instruments or measurement systems
- Method development and validation
- Quality control
- As part of a Quality Assurance system

Verification and accountancy of nuclear materials are just two examples of activities that require accurate measurements of nuclear materials. In traditional accountancy, a small sample of a facility's inventory (e.g. uranium oxide) is measured, and the value determined is then applied to establish the facility's entire inventory of uranium. Due to the advances in analytical instrumentation and the rising costs of maintaining measurement facilities, the size of samples and frequency of sampling has steadily decreased. It is not unusual in today's safeguards scheme for a sample of a few grams to be measured and the result used to establish an inventory in the hundreds or thousands of kilograms. A small error in the sample analysis would lead to large errors in the extrapolated inventory values.

Therefore, the proper and judicious use of highly characterized certified reference materials is extremely important in maintaining accuracy and confidence in nuclear material inventories.

Most quality assurance schemes (e.g. ISO 17025) also require laboratories to participate in interlaboratory sample exchange programs as a means of verifying the performance of the laboratories. In many cases, the nuclear reference material producers operate these comparison programs. Samples are prepared and certified at the CRM production facilities and sent 'blind' to participating laboratories who send in their measured results and receive in turn the certified values. This provides an important, independent and anonymous verification of safeguards laboratories performance. Currently, the three primary nuclear reference materials providers conduct these measurement exchange programs, and in many cases also participate in each other's programs.

CRM Producer	Exchange Program Name	Description
CETAMA (CEA-France)	EQRAIN	U and Pu various forms
IRMM (EU-Belgium)	REIMEP & NUSIMEP	U and Pu various forms
NBL (DOE – United States)	SME	U and Pu various forms

Table 1

Type of Reference Material	Properties and Relative Uncertainties	Typical Measurement Methods
Uranium metal	U content (0.005%), isotopic composition (0.1–0.001%)	Titration, IDMS, TIMS
Uranium Hexafluoride	U content (0.05%), isotopic composition (0.1-0.001%)	GSMS, titration, IDMS
U_3O_8	U content (0.01%), istopic composition (0.1–0.001%)	Titration, TIMS, IDMS
UO_2 fuel pellet	U content (0.05%), ^{235}U	Titration, TIMS
U enrichment	Range from <0.02% ^{235}U to >99% ^{235}U	TIMS, MC-ICP
Pu metal	Pu content (0.03%), isotopic abundance (0.001%)	Coulometry, IDMS, TIMS
Pu oxides, nitrates	Pu content and/or isotopic composition	
U, Pu trace element	Trace element concentration in U and Pu	ICP-MS
U and Th Ores	Range of U,Th content by ore type	Various
^{233}U, ^{235}U, ^{239}Pu, ^{242}Pu	element content (0.03%), isotopic composition (0.001%)	IDMS
MOX pellets	U,Pu content (0.01%)	Various

Table 2

Additionally, as the importance of actively verifying nuclear treaty compliance increases, new safeguards technologies and methods are being implemented that require new, more complex reference materials. For example, safeguards inspectors often wipe down surfaces within a nuclear facility using cotton or other 'swipes'. These swipes are packaged and sent to various laboratories for analysis to look for evidence of enriched uranium or other materials that may indicate activities contrary to a facility's declared purpose. Reference materials that are matched to this type of material are more difficult to produce and characterize, and there is much effort among various laboratories to produce materials with sufficient traceability. There are numerous examples of this type of situation which have arisen recently, including the need for reference materials for soils, reactor fuels of various forms/types, use of trace element compositions within nuclear material to determine origin or processing type, and materials in support of advanced power and recycling facilities.

Table 2 lists a few of the types of reference materials currently available and some of the properties certified with associated relative uncertainty

These materials are used throughout the nuclear fuel cycle and safeguards systems to provide accountability measurements and for material control purposes.

Development of a new CRM may take years and encompass validation of a production method, validation of any new measurement method required, design and/or development of prototype, stability testing, study of measurement uncertainty, packaging design and suitability, and certification. Each certificate typically includes a statement of purpose describing the proper or intended use of each reference material.

6. Nuclear Reference Materials Producers

There are three primary producers of nuclear reference materials world-wide. There are additional reference material producers which supply similar or unique materials, and a variety of isotopes or forms which may have safeguards applications. Table 3 lists the primary producers.

CRM Producer	website
CETAMA	http://www-cetama.cea.fr
Institute for Reference Materials and Measurements (IRMM)	http://irmm.jrc.ec.europa.eu
New Brunswick Laboratory (NBL)	www.nbl.doe.gov

Table 3

References

[1] ISO Guide 98:1995 "Guide to the Expression of Uncertainty in Measurement" and additions.

[2] ISO Guide 99:2007 "International Vocabulary of Basic and General Terms in Metrology".

[3] ISO Guide 30:1992 "Terms and Definitions used in Connection with Reference Materials".

[4] ISO Guide 31:2000 "Reference Materials – Contents of Certificates and Labels".

[5] ISO Guide 32:1997 "Calibration in Analytical Chemistry and Use of Certified Reference Materials".

[6] ISO Guide 33:2000 "Uses of Certified Reference Materials".

[7] ISO Guide 34:2000 "General Requirements for the Competence of Reference Materials Producers".

[8] ISO Guide 35:2006 "Reference Materials – General and Statistical Principles for Certification".

[9] ISO 17025:2005 "General Requirements for the Competence of Testing and Calibration Laboratories".

Uranium Assay by Titration Method

1. Objective of the Technique

The Davies and Gray titration is a destructive analysis method for quantitative determination of uranium in samples taken from virtually any point in the nuclear fuel cycle. It is widely used in nuclear safeguards material accountability measurements. A weighed sample is subjected to the titrimetric analysis and the result is the amount of uranium contained in the sample, often reported as a percentage or mass content (i.e. 84.567% U or 0.84567 g U/g sample).

2. Presentation of the Technique

2.1. Principle of Measurement

Uranium in solution is first reduced to U(IV) by the addition of Fe(II) ions, the excess Fe(II) ions being destroyed by oxidation. The U(IV) is titrated against a standard solution of potassium dichromate to U(VI). The end point of the titration is determined through measurement of the electrode potential of the solution. The uranium content is calculated from the amount of dichromate used in the titration. The titration is carried out in phosphoric acid medium in the presence of vanadyl ions, the latter acting as a catalyst for the oxidation reaction.

2.2. Procedure outline

- The uranium in concentrated phosphoric acid medium is first reduced to U(IV) with ferrous sulfate.
- Excess ferrous ion is removed by molybdate-catalyzed oxidation with nitric acid.
- The nitrite formed in the above reaction is removed by sulfamic acid.
- Vanadyl solution is then added to sharpen the endpoint, and the U(IV) is titrated against a standard potassium dichromate solution, or potassium dichromate solution that has been standardized against a standard uranium material such as New Brunswick Laboratory CRM 112-A Uranium Metal.

2.3. Chemical reactions

2.3.1. Reduction to uranium (IV) with excess iron (II)

$$U(VI) + 2Fe(II) \xrightarrow{H_3PO_4} U(IV) + 2Fe(III)$$

2.3.2 Molybdenum – catalyzed oxidation of excess iron (II) with nitric acid

$$2Fe(II) + HNO_3 + 2H^+ \xrightarrow{Mo} 2Fe(III) + HNO_2 + H_2O$$

2.3.3 Nitrite oxidation by sulfamic Acid

$$HNO_2 + NH_2SO_3H \rightarrow H_2SO_4 + N_2\uparrow + H_2$$

2.3.4 Vanadium-catalyzed oxidation of iron (II) and uranium (IV) with chromium (VI)

$$3Fe(II) + Cr(VI) \rightarrow 3Fe(III) + Cr(III)$$

$$3U(IV) + 2Cr(VI) \rightarrow 3U(VI) + 2Cr(III)$$

2.4 Interferences

Several metal ions interfere thereby causing a bias in the measurements. Methods are available to eliminate the interferences so that uranium can be determined quantitatively and reliable ([1], [2], [3]).

The following is a list of metal ions known to interfere (see also ref's [1-3]):

As, Sb, Sn, Mo, Cl, Br, F, Ru, Os, Tc, I, Hg, Pt, Pd, V, Ag, Ir, > 10% Au, Bi, Th, Zr, Si

2.5 Sample size

At NBL, the required sample size for uranium determination by D& G titration is divided into normal, low and low-low levels:

Normal level: aliquants containing 20 to 50 mg uranium

Low level: aliquants containing 8 to 20 mg uranium

Low-low level: aliquants containing 0.5 to 8 mg uranium

Figure 1: Work bench with reagents for D&G titration.

2.6. Apparatus

The apparatus required for performing manual D&G titrations:

pH/millivolt meter, platinum electrode, calomel reference electrode, chemical balance to determine mass of dichromate solution used with uncertainty no more than 0.1 mg, chemicals shown in Section 2.3 for preparing reagents at required concentrations, beakers, pipettes, plastic bottles, timer.

Auto titrators (commercial products) may also be employed, and are commonly used. In general, intercomparisons indicate that the manual method provides lower uncertainties for the method, while automated equipment increase throughput.

Figure 2: solution of potassium dichromate in weight burette;pH/millivolt meter in background.

2.7. Accuracy and precision

Normal level: Results are accurate to 0.1% or better and relative standard deviation is 0.1% or better.

Low-level and low-low level titrations have lower accuracy and poorer precision.

2.8. International Target Values (ITV)

In nuclear safeguards measurements, the target values for systematic (u(s)) and random (u(r)) variations in D&G titrations are 0.1%. In other words, in D&G titrations of known uranium content, the average relative deviation of a set of measurements with respect to the known value must be ≤ 0.1% and the standard deviation of the set must be ≤ 0.1% to satisfy the ITV criteria.

Figure 3: D&G titration in progress.

2.9. Comparison with IDMS

Both D&G titration and isotope dilution mass spectrometry methods have comparable levels of accuracy and precision for the determination of uranium.

The setup cost for D&G titration is less than IDMS; the latter is more expensive because a mass spectrometer is required for isotope ratio determinations.

The cost for setting up a D&G titration station is expected to be about $1,000 (excluding the cost of the chemical balance).

References

[1] W. Davies and W. Gray, Talanta, Vol. 11, 1964, p. 1203

[2] A.R. Eberle, M.W. Lerner, C.G. Goldbeck, and C.J. Rodden, "Titrimetric Determination of Uranium in Product, Fuel, and Scrap Materials After Ferrous Ion Reduction in Phosphoric Acid. Part I. Manual Titration," NBL 252, July 1970.

[3] A.R. Eberle and M.W. Lerner, "Effect of Added Vanadyl Ion on the Accuracy of the New Brunswick Laboratory Titrimetric Method (Ferrous Ion Reduction) of Determining Uranium," NBL 258, June 1971, pp. 22 25.

The cover of the Bulletin features the most frequent words in the Nuclear Suppliers Group Guidelines (INFCIRC/254, Part 1 and Part 2).
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