Verification of the Correctness and Completeness of Initial Declarations

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Introduction

The requirement to verify the correctness and completeness of the information provided by the State in its initial declaration arises from the comprehensive safeguards agreement between a State and the Agency. According to Paragraph 1 of INFCIRC/153, the State undertakes to *accept safeguards, in accordance with the terms of the Agreement, on* ***all source or special fissionable material in all peaceful nuclear activities within its territory, 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.* According to Paragraph 2, the Agency is provided a right and an 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 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.*

The events in Iraq demonstrated to the international community that the Agency's capability in early 1990's for assuring the correctness and completeness of State's nuclear material declarations, for example assurances regarding the absence of undeclared nuclear material and activities, was limited. To improve the Agency's capabilities, a number of initiatives was launched and new measures have been introduced. These include the early provision of design information and the introduction of the voluntary reporting scheme covering production, exports and imports of nuclear material, and exports and imports of non-nuclear material and equipment. In 1993 Programme 93+2 was launched to strengthen further the effectiveness and improve the efficiency of the IAEA safeguards system. In May 1997 the Board of Governors approved the text of the Model Protocol additional to safeguards agreements (INFCIRC/540), which provided the Agency with additional access to information and to sites, more use of unannounced inspections, multiple entry visas, remote monitoring and wide area environmental monitoring. In 1995 the Board had already taken a note on the Director General's note on the implementation of Part 1 measures of Programme 93+2, such as additional information on the State system for accounting and control, information on closed down or decommissioned facilities and locations outside facilities, environmental sampling and remote data transmission.

Parallel to the introduction of new tools the Agency has enhanced the verification of the initial declarations when new safeguards agreements were concluded. South Africa signed a comprehensive safeguards agreement with the Agency in September 1991. A few days later, the General Conference of the IAEA adopted a resolution, GC(XXXV)/RES/567, requesting the Director General to ensure early implementation of the safeguards agreement and to verify the correctness and completeness of the inventory of South Africa's nuclear installations and material. During the first half of 1990's a number of new safeguards agreements was concluded with states having substantial nuclear activities: Argentina, Brazil, DPRK, Ukraine, Lithuania and Kazakhstan, to mention a few. In case of an extensive nuclear fuel cycle, the task of the assessment of the completeness proved to be complex, requiring considerable inspection resources and extensive co-operation from the state authorities regarding the provision of access not only to operating but also to defunct and/or supporting facilities and historical operating records. This can be seen, for example, in the paper describing the Agency's experiences in the verification of the initial report of South Africa /1/.

Correctness

Paragraph 62 of INFCIRC/153 requests the State to provide the Agency with an initial report of all nuclear material subject to safeguards, which is normally a comprehensive document and includes quantitative data on all types of nuclear material, on a facility by facility basis. Such a report is expanded by attachments that provide details on the location and number of items of nuclear material contained in each respective facility. On the basis of the data contained in the initial report and subsequent inventory changes, it is therefore possible to establish an itemized list of the nuclear material inventory of each facility. The inventory is verified, normally during the first few months of the implementation of the comprehensive safeguards agreement, in accordance with the requirements for Physical Inventory Verification specified in the Agency's 1991-95 safeguards Criteria, using established accountancy verification methods.

Completeness

To be able to draw a conclusion about the absence of undeclared nuclear material and activities in a State as a whole, the Agency must first have drawn the conclusion about non-diversion of nuclear material; in other words, the correctness of the initial declaration has been verified. The evaluation of the absence or presence of undeclared nuclear material or activities is based on the fundamental concept that nuclear activities have indicators of their existence. Such indicators include (specified) equipment, nuclear and non-nuclear material necessary for the activity, infrastructure support, and are based on the fact that activities involving nuclear material leave traces in the environment. By analyzing all information available to it for internal consistency, the Agency may infer from the absence of indications that there are no undeclared nuclear material and activities in the State.

The challenge to information analysis is both to obtain the information where the indicator of a nuclear activity is included, and to recognize the information when it is included.

Safeguards relevant information derives from:

(i) information provided by the State pursuant to the Safeguards Agreement and, where applicable, Articles 2 and 3 of the Additional Protocol;
(ii) information generated through IAEA inspections, design information verification and complementary access activities;
(iii) information collected by the Agency from its internal databases and from open sources; and
(iv) information provided by third parties.

The conclusion of the absence of undeclared nuclear material and activities in the State derives from determinations that:

(i) the declared past, present and planned nuclear programme is internally consistent;
(ii) the nuclear activities and types of nuclear material at declared locations are consistent with the declarations;
(iii) the overall production, imports and accounting data for inventories and flow of nuclear material are consistent with the utilization inferred from the declared programme;
(iv) the manufacture and imports of specified equipment and non-nuclear material are consistent with the declared programme;
(v) the status of closed-down or decommissioned facilities and locations outside facilities (LOFs) is in conformity with the state's declaration;
(vi) the nuclear fuel cycle-related research and development activities are generally consistent with declared plans for future development of the declared programme; and
(vii) the clarifications provided by the State have resolved any questions or apparent inconsistencies in connection with information provided by the State and all other information available to the Agency including information on the past activities.

New Measures

The introduction of the Additional Protocol has provided the inspectorate with a number of new elements, such as expanded declaration, enhanced information analysis, new technical measures, and enhanced inspector access. These include information about and inspector access to:

(i) all aspects of a State's nuclear fuel cycle from mines to nuclear waste;
(ii) short-notice inspector access to all buildings on a nuclear site;
(iii) other locations where nuclear material for non-nuclear use is present; and
(iv) inspection mechanisms for nuclear fuel cycle related R&D.

Some of the new elements can also be applied in the traditional safeguards. Since the enhanced information analysis, environmental sampling and the use of satellite imagery are dealt with in detail in this symposium, some of the new tools are described in examples below.

Mining

In the traditional safeguards the Agency did not have any verification activities related to the mining, but with the introduction of the additional protocol new tools were required. Maiorov et al /2/ have developed a method to measure the activity ratio of Th-234 (T1/2= 24.1 days) to Th-230 (long-lived nuclide) in uranium mine samples by HRGS without efficiency calibration of spectrometer to identify samples taken from non-processed uranium ore, tails or uranium product. In non-processed and undisturbed natural uranium ore this ratio should be equal to one. In the core of ore processing the bulk of the uranium decay products is separated from a uranium product and concentrated tails. Immediately after separation the Th-234/Th-230 activity ratios in a product and tails begin to change. For a product this ratio increases from one to a higher equilibrium value, and for tails it decreases also from one to a lower equilibrium value. For a fresh tail (less than 3 months after processing), the processing date can be estimated.

Use of Satellite Imagery

The Agency has had since early 1990's access to high-resolution satellite imagery. During recent years there has been an increasing amount of commercially available satellite imagery, which is used mainly as a complementary source of information in the enhanced evaluation process /3/. What has also been interesting is the increasing availability of historical images starting from 1960's, but with a reduced resolution. However, availability of commercial images from 1980's is still quite limited.

The use of commercial satellite imagery is not meant to substitute the Agency's right to have access to locations, but to enhance the evaluation of information. The benefits of satellite imagery are, therefore, in areas where it supports the implementation of on-site inspections and the evaluation of information supplied through declarations. The applications include:

(i) chronology of the construction of sites, facilities, and buildings,
(ii) structure and dimensions of sites, facilities, and buildings,
(iii) operational information on facilities and buildings, and
(iv) support for inspection planning.

Fig. 1. Shows an example of a satellite image of an uranium ore concentration plant. The 1-m resolution of the image indicates the potential of the imagery to support also design information verification activities.

Fig.1. An uranium concentration plant. IKONOS 1-m resolution.

Spent fuel verification

Most of the spent fuel verification tasks require gross defect measurement by the ICVD or SFAT, but there are cases where operator's declarations on the fuel irradiation histories need to be verified to cover a diversion scenario where spent fuel assemblies could have been diverted and replaced with fresh fuel assemblies. The replaced assemblies could have then been declared as exposed to a different number of reactor cycles than they have actually been exposed to.

Beddingfield et al /4/ modified the standard Underwater Fork Detector System (FDET) to allow the measurement of freshly discharged fuel. They used the gross gamma and gross neutron signals from the FDET to verify the consistency of the operators declarations at four reactor types: PWR, BWR, WWER-440 and WWER-1000. Fig.2. is a plot of the Kozlodoy WWER-440 measured data indicating clusters for 1-, 2-, 3-, and 4-cycle fuel assemblies and annotating where the various misdeclarations would appear.

Fig.2. Kozloduy WWER-440 measurement data /4/

Environmental sampling

Environmental sampling is one of the most powerful new tools provided to the Agency in the 1990's for the confirmation of the absence of undeclared activities. On-site sampling, combined with the particle analysis, provides information on past and current nuclear activities. An initial focus on swipe sampling has been at enrichment plants and hot cell facilities including reprocessing plants.

At the enrichment plants, environmental sampling is used to verify the absence of undeclared nuclear material and undeclared nuclear operations involving enrichments higher than declared by:

(i) identification of nuclear materials present, and
(ii) identification of range of enrichments.

At the facilities with hot cells environmental sampling is used to confirm the absence of undeclared operations. Depending on the declared status of the facility those could include identification of:

(i) nuclear materials present,
(ii) operations leading to separation of Pu or HEU,
(iii) undeclared irradiation of nuclear materials, and
(iv) activities in shut-down facilities.

The capabilities of the environmental sampling can be illustrated by the results of particle analysis from a Magnox research facility shown in Fig.3. The facility operator has stated that the reactor had been loaded with natural uranium fuel with typical burn-up of 5000-6000 MWD/TU. When looking at the plots in Fig.3., it can be noted that the particle analysis shows the following clusters:

(i) a "fresh" natural uranium cluster,
(ii) two clusters of irradiated fuel, and
(iii) two clusters of Pu-240 abundance.

Using the isotopic compositions observed, the irradiated fuel clusters correspond to Magnox burn-ups 5000-7500 MWD/TU and 750-1000 MWD/TU. The latter is not consistent with the statement mentioned above.

Fig.3. An illustration of environmental sampling results for Magnox hot cell samples.

Summary

During the 1990's the Agency has acquired a number of new tools for the verification of the correctness and completeness of State's declaration. Nuclear material accountancy verification remains as the cornerstone of the IAEA verification activities to confirm the absence of diversion of nuclear material from declared inventories. Enhanced design information verification, which extends over the entire lifetime of the facility, is being used to confirm the applicability of the safeguards approach and capabilities and capacities of the facilities. Environmental sampling is a powerful tool in confirming types of nuclear material present, and it can be used to detect undeclared nuclear material and activities. Universal reporting scheme provides useful information about State's nuclear infrastructure complementing the declarations. There is currently a variety of open source information available, such as scientific and other publications, annual reports, and satellite imagery, which can be used to confirm chronologies and nuclear infrastructures, including nuclear-related R&D. Complementary access is a powerful tool used to confirm the absence of undeclared nuclear material and activities.

References

/1/. G. Dillon, and D. Perricos, Verification of the Completeness and Correctness of Inventory. Experience Gained in the Verification of the Correctness and Completeness of the Inventory of South Africa's Nuclear Installations and Material. IAEA Symposium on International Safeguards, Vienna, 14-18 March,1994. IAEA-SM-333/219.

/2/. V. Maiorov, Y. Kuno, M. Ryjinski, and E. Kuhn, Th-234/Th-230 Ratio as Indicator for Uranium Mining Tails, Technical Note 99/SAL-08, IAEA,1 December 1999.

/3/. O.Heinonen, K. Chitumbo, T. Renis, S. Syed Azmi, and J. Hilliard, Satellite Imagery and the Additional Protocol, INMM, 2001.

/4/ D.H. Beddingfield , H.O. Menlove, J. Arenas-Carrasco, and I. Koulikov, Reactor Fuel Irradiation History Verification Using FDET Measurement of Fresh-Discharge Fuel Assemblies, LA-UR-01-2012.

Fig.1. An uranium concentration plant. IKONOS 1-m resolution. (not available)

Fig.2. Kozloduy WWER-440 measurement data /4/

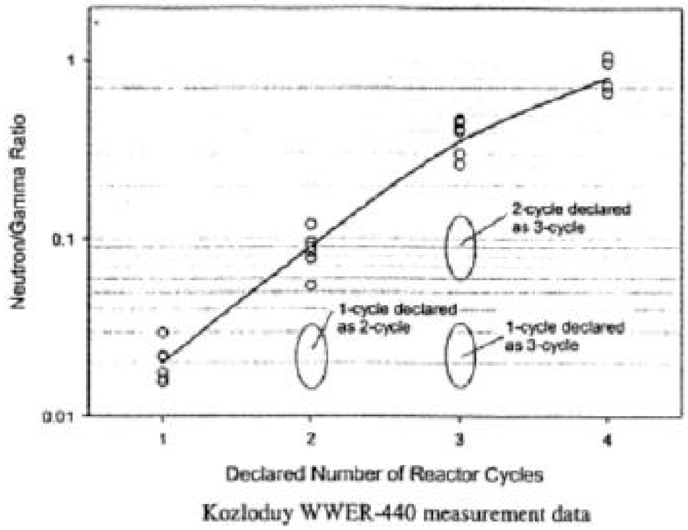

Fig.3. An illustration of environmental sampling results for Magnox hot cell samples.