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Safeguards Verification Equipment Development Status and Looking Forward (Focus on the NDA Equipment)

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1. Introduction

International Atomic Energy Agency (IAEA) has the task of providing continuing assurance to the international community that States that have entered into safeguards agreements with the IAEA are meeting their obligations [1].

Other hands, as States utilizing nuclear power has increased and related technology has advanced, and IAEA has been made in their efforts to accomplish their role with the limited funds and resources.

South Korea is one of States conducting best practices of international safeguards from IAEA due to having many types of facilities such as PWRs, HWRs, Research Reactor, Fuel Fabrication Facility, and so on. South Korea paid attention from IAEA for a longtime. Therefore South Korea had established our own State System of Accounting for and Control of Nuclear Material (SSAC).

This paper is looking at the recent IAEA development status of verification measures and technologies in order to strengthen the effectiveness and improve the efficiency of safeguards, then suggesting some recommendation to enhance more safeguards system in South Korea

2. IAEA Status of Safeguards Equipment Implementation

In 2016, IAEA provided equipment and technical support for verification activities in the field, ensuring that instrumentation necessary for the implementation of effective safeguards worldwide continued to function as required. More than 6400 pieces of verification equipment were dispatched to support verification activities in the field [2].

Significant financial and human resources were dedicated to performance monitoring to ensure the reliability of the IAEA's equipment. At present, Non-Destructive Assay systems, digital surveillance systems, Unattended Monitoring Systems and Electronic Seals have exceeded the target goal of 99% availability. This near total availability could be achieved through preventive maintenance policies and system architecture implementing redundancy at system/component level [2].

Table 1. Utilization Status of Safeguards Verification Equipment [2]

Category	States	Facilities	Systems
NDA	N/A	N/A	1,057
surveillance (Camera)	35	266	872
Containment (Seals)	N/A	N/A	25,000
Unattended Monitoring *	24	N/A	164
Remote Transmission & Processing of Data	25	122	887

* Measure Radiation (140), Thermo-hydraulic Monitors (8), Solution Volume Measurement (16)

3. IAEA's NDA Development Status of among Safeguards Verification Equipment

3.1 Combined Procedure for Uranium Concentration and Enrichment Assay (COMPUCAE)

COMPUCAE is used for on-site analytical measurements in support of joint Euratom-IAEA inspections during physical inventory verification (PIV) campaigns in European Low-Enriched Uranium (LEU) fuel fabrication plants [4]. This equipment has enhanced the in-situ analytical capabilities of the combined procedure for uranium concentration and enrichment assay system which were extended to uranium hexafluoride samples allowing future deployments at UF6 handling facilities [1][2].

3.2 A hand-held Raman Spectrometer

Raman Spectrometer is named after the Indian physicist, Chandrasekhara Venkata Raman, who first described "a new radiation"(later known as the Raman effect) in 1928. It is closely related to infrared spectroscopy, in that it records the vibrating, stretching, and bending movements of molecules [5]. This equipment for immediate identification of chemical substances during complementary accesses and design information verifications was authorized for inspector use [2].

3.3 Cascade Header Enrichment Monitor (CHEM)

CHEM is used to qualitatively confirm the absence of high enriched uranium (HEU) in cascade header pipes of centrifuge enrichment plants [1][6]. This equipment uses either the HPGe detector or X-ray fluorescence (XRF) source to measure the enrichment of UF6 gas in a pipe. An enhanced version of the cascade header enrichment monitor has been authorized for inspector use [2].

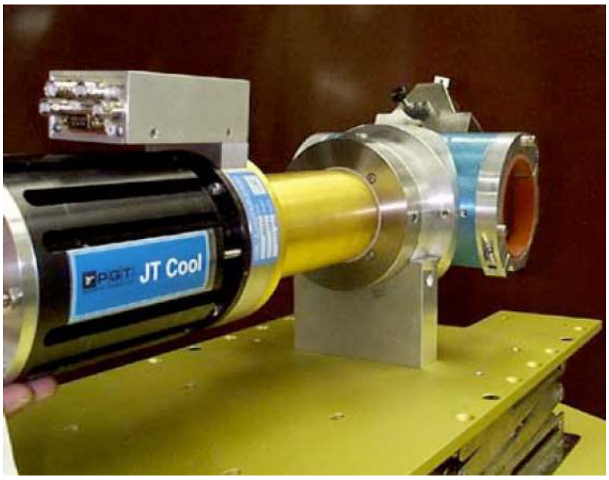

Fig 1. Detector and inserted Collimator [8]

3.4 Fork Detector (FDET)

FDET is one of the detectors for spent fuel verification that includes the detector head, a several meter long extension pipe, a miniature gamma ray and neutron detector (MiniGRAND) electronics unit and a portable computer [1]. A prototype electronic unit for MiniGRAND was designed and procured. It is now undergoing tests to authorize it as a replacement for the old units currently used with fork detectors [2].

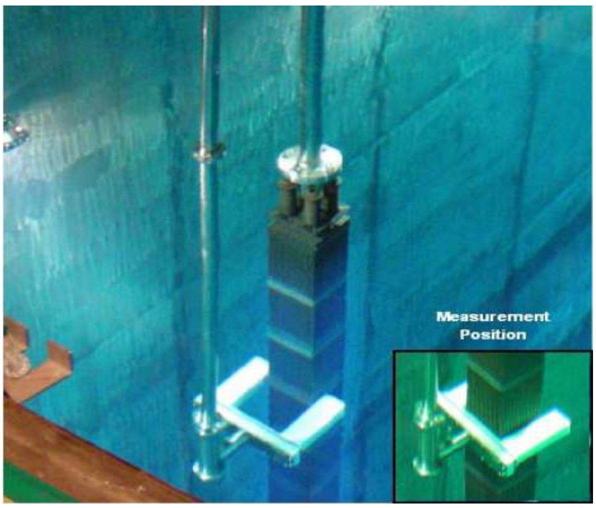

Fig 2. Fork Detector Irradiated Fuel Measurement [1]

3.5 Passive Gamma Emission Tomography (PGET)

PGET is currently the most promising method to detect the replacement of a single fuel rod in a light water fuel spent fuel assembly [7]. This equipment is to detect missing or replaced fuel rods in irradiated LWR fuel assemblies which was re-engineered using industrial grade components and successfully tested in preparation for field measurement campaigns scheduled early 2017 [2].

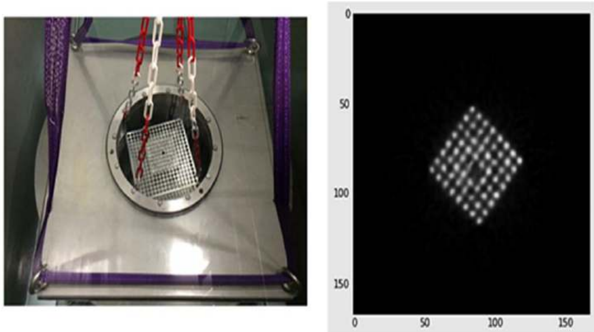

Fig 3. PGET installed and tested at the Prater Reactor in Vienna, a fist image from activated cobalt rod [2]

3.6 Others

The new CANDU bundle verifier for baskets (CBVB) was deployed at all facilities where this verification system is used [1][2].

A fast neutron collar system includes liquid scintillators and uses a mock-up of PWR fuel in different configurations with a wide range of U-235 linear mass densities and GD-burnable poison concentrations [2].

4. KINAC's Status of NDA Equipment Development for Safeguards

4.1 Spent CAAND Fuel Verifier (SCAV)

SCAV was developed to detect gamma ray intensity for spent fuel verification from 1996 to 1998. However, the scope of verification using SCAV has been limited by the detector sensibility, structure material for the ultrasonic bolt seal, distance between tray and tray, and cooling time of spent fuel, so this equipment had been replaced to OFPS as below [10].

4.2 Optical Fiber Probe Scintillator (OFPS)

OFPS was develop to complement the shortcuts existing CANDU fuel verification equipment including SCAV. The OFPS introduced gradually to Wolsung NPPs since 2007, this equipment was registered for IAEA's verification equipment (Category A) by following the IAEA QA procedure [11][12].

4.3 Quad-CZT System

Quad-CZT System is for verification of fresh fuel including in-situ analytic procedure. This equipment is a result of recent R&D activities from KINAC which started since early 2016. Now a proto-type of product was made. This equipment is replaced with alternative detector based on CdZnTe instead of NaI or HPGe which are have some shortcomings. The CdZnTe detector complements pros and cons of them [14].

5. Summary and Recommendations

One of principal cornerstones of IAEA safeguards inspectorates is to have credible and independent verification capability. Therefore, continuous R&D effort in developing verification equipment also should evolve gradually as much as.

The verification technology can be divided into NDA, Surveillance, Seals, Unattended Monitoring, and so on. Especially, most of IAEA's NDA equipment development activities focus on measuring the enrichment and amount of the uranium-235 in front-end fuel cycle facilities which is not irradiated. On the other hand, it is very interesting in that new technology is introduced to verify LWR's spent fuel such as radiation image and infrared spectroscopy.

South Korea have been conducting the R&D for safeguards verification technology. It is determined that some recommendation have to consider to enhance its performance as below.

First of all, collecting, categorizing and screening technologies capable of applying to our country's nuclear facilities should be done.

Next, Joint R&D with IAEA is strongly recommended because IAEA is the most expert group as well as will be an end user group.

Finally, it is required to have a strategy to make synergy among experts of radioactive detector, chemistry, electronics, and so on.

Through accomplishing those efforts as the recommendations, we can expect that the safeguards verification technology of both South Korea and IAEA evolve together which can make the world more peaceful as the nonproliferation is assured.

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