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Implementation of the NPT Safeguards Agreement in the Republic of Korea

Report by the Director General

A. Background

1. The Agreement between the Republic of Korea (ROK) and the IAEA for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (the Safeguards Agreement)¹ entered into force on 14 November 1975. The Additional Protocol to the Safeguards Agreement (the Additional Protocol)² was signed on 21 June 1999 and entered into force on 19 February 2004.
2. On 23 August 2004 the ROK, in connection with the submission of its initial declaration pursuant to the Additional Protocol, informed the Secretariat that the ROK Government had discovered, in June 2004, that laboratory scale experiments involving the enrichment of uranium using the atomic vapour laser isotope separation (AVLIS) method had been carried out, in 2000, by scientists at the Korea Atomic Energy Research Institute (KAERI) in Daejeon. The ROK explained further that the uranium enrichment experiments had taken place in the context of a broader experimental effort to apply AVLIS techniques to non-nuclear materials such as gadolinium, thallium and ytterbium. The ROK stated that only about 200 mg of enriched uranium were produced, following which the experiments were terminated, and the installation where these experiments had been carried out had been dismantled.
3. Following the ROK's submission of its initial declaration and explanation concerning the discovery of certain experiments as noted in paragraph 2 above, the Agency promptly despatched an inspection team to the ROK to verify this and other related information. From 30 August to 4 September 2004, the Agency inspection team visited the KAERI site where these experiments and associated physics measurements of uranium were stated by the ROK to have taken place, and also

¹ The Safeguards Agreement is reproduced in document INFCIRC/236.

² The Additional Protocol is reproduced in document INFCIRC/236/Add.1.

visited the manufacturers of laser components. In its investigation of the origin of the nuclear material used in the AVLIS experiments, the Agency visited: the Youngnam Chemical Plant in Ulsan; the Korea Institute of Science and Technology (KIST) in Seoul; related facilities at the KAERI site in Daejeon; and, in a follow-up verification mission, the former Goesan coal mine.

4. Subsequent Agency verification missions were carried out from 20 to 24 September and from 3 to 6 November 2004.

5. During the Agency verification missions, the ROK stated that its scientists had conducted uranium conversion activities in the 1980s which involved the production of about 154 kg of natural uranium metal, a small amount of which was later used in the AVLIS experiments.

6. The Agency inspection team also visited the TRIGA Mark III (TRIGA III) research reactor at the KAERI site in Seoul. Environmental samples, collected previously at this site, had revealed the presence of slightly irradiated depleted uranium (DU) with associated plutonium. In response to an Agency enquiry, the authorities in the ROK stated that in the early 1980s laboratory scale experiments had been performed at this facility to irradiate 2.5 kg of DU and to study the separation of uranium and plutonium. The authorities in the ROK have stated that all the above experiments were performed without the knowledge or authorization of the Government.

7. In response to an enquiry by the Agency, based on open source information, the ROK provided information on 21 October 2004 on an experiment carried out during the period from 1979 through 1981 to assess a chemical exchange process to confirm the feasibility of producing 3% U-235.

8. At the Board of Governors meeting on 13 September 2004, the Director General informed the Board that an inspection was under way, and noted that it was “a matter of serious concern that the conversion and enrichment of uranium and the separation of plutonium were not reported to the Agency as required by the ROK Safeguards Agreement”. The Director General undertook to report to the Board regarding this matter as appropriate and not later than at its meeting in November 2004, and asked the ROK “to continue to provide active cooperation and maximum transparency, in order for the Agency to gain full understanding of the extent and scope of these previously undeclared activities, and to verify the correctness and completeness of the ROK’s declarations.”

9. With the active cooperation of the ROK, the Agency inspection team has been able, at each of the facilities and locations visited, to examine associated records that were made available, perform measurements, take photographs, collect samples, interview a number of the scientists involved, and view the dismantled equipment that the ROK stated had been associated with the experiments. The team was also able to place Agency seals on major components of the dismantled equipment and associated nuclear material.

10. This report provides information on the nature of the safeguards issues involved, the Agency’s findings and the corrective actions that have been taken by the ROK.

B. Atomic Vapour Laser Isotope Separation (AVLIS)

11. On 10 December 2002 and again on 1 April 2003, the Agency requested permission from the ROK as a transparency measure to visit KAERI’s Laser Technology R&D Centre in Daejeon, in order to confirm the nature of activities undertaken at the Centre. Both requests were refused by the ROK. Following the entry into force of the ROK’s Additional Protocol, the Agency was allowed to visit the Centre in March 2004, but the ROK did not permit the Agency to take environmental samples. The

ROK stated that samples could be taken only after it had submitted the Article 2.a declaration under the Additional Protocol. At the same time, the ROK continued to affirm that its laser enrichment technology R&D programme did not involve the use of any nuclear material.

12. Contrary to its earlier statements, the ROK informed the Agency on 23 August 2004, in its initial declaration pursuant to its Additional Protocol, that past activities had involved laser isotope separation of uranium. The ROK provided a summary of the experiments and the results on 23 August 2004, and informed the Agency that:

- a. The ROK had enriched uranium in three separate experiments between January and February 2000 using laser isotope separation (AVLIS) technology developed by KAERI at Daejeon;
- b. The amount of nuclear material used as feedstock in the enrichment experiments was 3.5 kg of natural uranium (NU) metal;
- c. The AVLIS experiments had achieved an average enrichment level of 10.2% U-235 and up to 77% U-235, and had produced 200 mg of enriched uranium;
- d. The laser equipment used for the uranium enrichment experiments had been dismantled, and this equipment, together with the associated material, was available for verification by the Agency; and
- e. The laser enrichment activities carried out at KAERI in Daejeon had only recently come to the attention of the Government of the ROK.

Assessment of AVLIS

13. Based on the information provided by the ROK to the Agency during its recent verification missions, elementary laser research at KAERI began in the mid-1960s and continued with the development of molecular laser isotope separation (MLIS) in the 1970s and 1980s, and AVLIS technologies in the 1990s. The ROK's laser technology development involved foreign assistance. The ROK continues to develop AVLIS technologies for the separation of stable isotopes, and this programme involves the development of small, high power, solid state lasers that could be suitable for uranium enrichment. The Agency has confirmed that the declared laser equipment involved in the undeclared enrichment experiments has been dismantled and the major components of the separation system have been placed under Agency seal.³

14. The ROK declared during the last Agency verification mission that spectroscopy work with uranium started in 1990. After reviewing information provided by the ROK, the Agency has assessed that in 1993 and 1994, the ROK carried out a uranium evaporation test involving the use of exempted DU, followed by further spectroscopy experiments during the period from 1994 to 1996 involving exempted DU and imported NU metal. The AVLIS experiments were conducted during January, February and May 2000 using indigenously produced, undeclared NU metal.

15. According to the information provided by the ROK, it appears that at least ten AVLIS related experiments involving exempted DU and undeclared NU were carried out at KAERI facilities between 1993 and 2000. The sequencing of these experiments was: uranium evaporation; spectroscopy; and uranium isotopic separation. The ROK has stated that these experiments were authorized only by the President of KAERI in Daejeon, involved some 14 KAERI scientists, and were conducted in the broader context of a stable isotope separation project. The Agency will investigate this matter further.

³ However, some of the dismantled equipment for the AVLIS experiments is being re-used by the ROK in its stable isotope separation programme (non-nuclear activities).

16. As a result of its verification activities at the KAERI site in Daejeon since August 2004, the Agency's assessment confirms the statement by the ROK that: (i) the AVLIS experiments were laboratory-scale; and (ii) the amounts of uranium involved and the enriched uranium produced were relatively small. The levels of enrichment reported by the ROK are consistent with the Agency's calculations based on computational modelling of the experimental configuration declared by the ROK. The Agency's preliminary sample results, from the product provided by the ROK, show that the average uranium enrichment level was about 10%. The Agency is continuing to assess the results of samples taken from the AVLIS equipment (i.e. the chamber and the collector plates) and the associated products.

17. The nuclear material involved in the experiments (DU and NU metal) was required to be reported by the ROK to the Agency as provided for in the Safeguards Agreement, including in particular the requirement to provide records pertaining to the experiments and all relevant nuclear material accountancy reports, including Inventory Change Reports (ICRs). The ROK was also required to declare the facilities where the experiments were conducted, as well as to provide their design information.

18. The Agency will study further the assistance provided by foreign sources to the ROK in the development of AVLIS technology, and will continue its investigation with a view to assessing the information provided by the ROK.

C. Uranium Conversion

19. The ROK informed the Agency during its recent verification missions that it had acquired source material from two separate origins: (a) uranium ore from a former coal mine in Goesan that was processed into about 25 kg of uranium in yellowcake at a pilot milling plant at KAERI in Daejeon; and (b) uranium bearing phosphate ore imported from abroad that was processed at the Youngnam Chemical Plant in Ulsan. The ROK stated that the uranium used in the AVLIS related experiments came from the Youngnam Chemical Plant.

Assessment of Conversion Activities

20. The declaration submitted by the ROK on 23 August 2004 did not include all its conversion activities. Some of the ROK's activities involving conversion of natural UF_4 to uranium metal were revealed only as a result of the Agency's verification activities.

21. The approximately 2500 kg of ammonium uranyl tricarbonate (AUT) and the approximately 100 kg of U_3O_8 recovered from uranium bearing phosphate ore, as declared by the ROK, were consistent with the records provided to the Agency. However, it is not possible for the Agency to confirm the amount of uranium that was produced either indigenously from the ore or from the imported phosphate because the ROK has dismantled the relevant plant. The Agency's results of the samples taken from the material stated by the ROK to have been indigenously produced in the former Goesan coal mine show that the material is DU rather than NU as would be expected. The ROK has provided further information on 8 November 2004, which the Agency is currently assessing.

22. During the Agency's recent verification missions, the ROK stated that it previously had three laboratories capable of producing uranium metal. Two of these laboratories were involved in the production of about 154 kg of NU metal. The third laboratory, the largest of the three, was stated by

the ROK not to have been used in the production of NU metal but only for the production of DU metal. The Agency will continue to assess the total amount of the material produced in these laboratories. According to the ROK, all three laboratories were dismantled in 1994.

23. Although the records provided by the ROK are consistent with the ROK declaration, the Agency is unable to confirm the scale of NU metal production because the laboratories no longer exist. The Agency's analysis and assessment of the relatively high losses reported by the ROK in the purification and metal reduction processes are ongoing.

24. The Agency has verified the declared yellowcake and the remaining 133 kg NU metal. When the Agency has access to the dismantled conversion equipment, it will assess the capability of this equipment. In addition, the Agency is currently assessing whether the uranium recovered from phosphate ore had, upon purification to UO₂ or UF₄, a composition and purity suitable for fuel fabrication or for being isotopically enriched, before it was converted to metal.

25. The ROK was required, pursuant to its Safeguards Agreement, to report the NU converted to metal and to submit updated design information for the two facilities where the NU metal was processed. The ROK was also required to submit updated design information for the facility⁴ that was used for DU metal production. The main outstanding issues regarding the ROK's previously undeclared conversion activities include the examination and assessment by the Agency of the dismantled equipment stored as waste and the presence of DU in yellowcake samples said to be originating from the former Goesan mine.

D. Plutonium Separation

26. In November 1997, the Agency detected two particles of slightly irradiated DU with plutonium in environmental samples taken from hot cells associated with the TRIGA III reactor in Seoul. As this finding was not consistent with any declared activities by the ROK, the Agency began to investigate whether the ROK had conducted undeclared plutonium separation activities, but since at that time the routine use of environmental sampling at hot cells was a relatively new technique at the Agency, the results were treated with some caution. In December 1999, the Agency initiated consultations with the ROK, but the ROK did not acknowledge at that time having conducted any plutonium separation activity.

27. In October 2003, the results of a subsequent set of samples from the TRIGA III hot cell collected earlier confirmed the previous findings. In December 2003, the Agency requested the ROK to provide an explanation. On 31 March 2004, the ROK stated, in a letter to the Agency, that a plutonium separation experiment had been conducted at the TRIGA III hot cell. The ROK explained that, during the period from July to December 1981, a 5-pin mini fuel assembly (mini-assembly) containing about 2.5 kg of DU had been irradiated for 82 days in the TRIGA III research reactor. The laboratory scale experiments were said to be conducted to study the separation of uranium and plutonium. The ROK elaborated that the mini-assembly had been subsequently dismantled and dissolved, between April and May 1982, as part of a basic study on the chemical characteristics of irradiated nuclear material, and that, on 30 September 1983, it reported the "test specimen" (i.e. the mini-assembly) to the Agency as a measured discard of an unirradiated assembly.

⁴ DU metal production was undertaken in the "Uranium Ore Processing Facility".

Assessment of Plutonium Separation

28. The mini-assembly fabricated at KAERI in Daejeon was transferred to the TRIGA III reactor in Seoul on 20 July 1981, at which time the Agency was notified of its transfer. The ROK submitted the required Inventory Change Report (ICR) to the Agency on 31 July 1981.

29. The ROK has stated that the mini-assembly was irradiated in the TRIGA III reactor core, and then transferred to a hot cell for heavy metal separation based on the PUREX process. After dissolution of the mini-assembly, a basic solvent extraction procedure was performed on a portion of the dissolved solution, and ion exchange used in an attempt to recover a purified plutonium product. According to the ROK declaration, "Only an aqueous solution mixed with uranium, plutonium and supposedly other fission products was obtained for analysis. Quantity of the plutonium in the solution is not known," but is expected by the ROK to be less than 40 mg.

30. The plutonium separation experiment was performed in April and May 1982, contrary to the ROK's Physical Inventory Listing report, dated 31 May 1982, that the mini-assembly was still in the TRIGA III reactor core at that time. While the ROK reported to the Agency the irradiation of the mini-assembly it did not report the uranium-plutonium solution as required by the Safeguards Agreement.

31. During the recent verification missions, the ROK provided documentation regarding the irradiation history of the mini-assembly in the TRIGA III reactor. ROK officials have stated that no operating records or technical reports remain for the plutonium separation experiment.

32. In July 1984, the equipment used for the plutonium separation experiment was dismantled and, together with the product and waste solutions, transported in 1987 to KAERI in Daejeon for storage. The uranium-plutonium solution obtained in the separation experiment was not recorded by the ROK in the material accountancy records of the TRIGA III reactor nor was it reported to the Agency.

33. On 5 November 2004, the ROK stated that 0.7 g of plutonium was produced in the irradiated mini-assembly. The Agency's assessment is that the amount of plutonium produced would have been of the same order of magnitude with an isotopic content of about 98% of Pu-239.

34. The Agency has confirmed from sample analyses that the plutonium separation experiment could not have been conducted later than 1982. The Agency has assessed that although the separation equipment used in the experiment was rudimentary, it could have been capable of recovering pure plutonium in small amounts. The dismantled equipment and the uranium-plutonium solution have been placed under Agency seals. Based on the information available, the Agency's preliminary assessment is that only one plutonium separation experiment was carried out at the KAERI site in Seoul. The ROK has stated that the experiment was conducted solely to satisfy the scientific interest of the scientists involved.

35. The plutonium separation experiment was carried out by the ROK in a safeguarded facility and was not declared to the Agency. The ROK has not provided to the Agency updated design information of the process, including the general layout of important items of equipment used in the plutonium separation experiment, as required by the ROK Safeguards Agreement. The separation experiments, the uranium-plutonium solution and the associated waste were not reported to the Agency as required by the Safeguards Agreement. Moreover, the ROK incorrectly reported the mini-assembly as a measured discard of an unirradiated fuel assembly.

36. The open issues regarding the ROK's previously undeclared plutonium separation experiment include provision by the ROK to the Agency of: relevant operating records of the plutonium separation experiment and/or detailed information about the process; and information on the results of the plutonium separation experiment and on whether any use was made of those results.

E. Chemical Enrichment Experiment

37. In response to an enquiry by the Agency based on open source information, the declaration submitted by the ROK on 21 October 2004 included information on a chemical enrichment experiment that had not been previously declared to the Agency pursuant to the Safeguards Agreement. The experiment was carried out during the period from 1979 through 1981, and was designed to assess a chemical exchange process to confirm the feasibility of producing low enriched uranium (3% U-235) for pressurized water reactor (PWR) fuel. As stated by the ROK, the experiment was carried out using 700 g of NU (UO₂) powder, and utilized an ion exchange column process to produce a very small quantity of very slightly enriched uranium (0.72% U-235). The ROK stated that the project was terminated in 1981, and the equipment subsequently dismantled in 1982. During the Agency's 3–6 November verification mission, swipe samples were taken in the room where the ROK stated that the experiment was performed. During this mission the ROK also stated that the UO₂ was under safeguards; however, the use of 700 g of NU (UO₂) powder in the experiment was not reported to the Agency. The Agency is in the process of assessing the ROK's declaration regarding this matter.

F. Findings

38. On a number of occasions, starting in 1982 and continuing until 2000, the ROK conducted experiments and activities involving uranium conversion, uranium enrichment and plutonium separation, which it failed to report to the Agency in accordance with its obligations under its Safeguards Agreement. These failures are as follows:

- a. Failure to report nuclear material used in evaporation, spectroscopy and enrichment experiments (AVLIS and chemical exchange) and the associated products;
- b. Failure to report the production, storage and use of NU metal and associated process loss of nuclear material, and the production and transfer of waste resulting therefrom;
- c. Failure to report the dissolution of an irradiated mini-assembly and the resulting uranium–plutonium solution, including the production and transfer of waste; and
- d. Failure to report initial design information for the enrichment facilities and updated design information for the facilities involved in the plutonium separation experiment and the conversion to NU and DU metal.

39. The ROK has taken corrective actions by providing relevant ICRs.

40. Following the information provided by the ROK on its previously undeclared nuclear experiments, the ROK has provided active cooperation to the Agency in providing timely information, and access to personnel and locations, and has permitted the collection of environmental and other samples for Agency analysis and assessment. The ROK should make every effort, however, to provide the operating records for the plutonium separation and uranium spectroscopy experiments and/or detailed information regarding these experiments.

41. Although the quantities of nuclear material involved have not been significant, the nature of the activities — uranium enrichment and plutonium separation — and the failures by the ROK to report these activities in a timely manner, in accordance with its obligations under its Safeguards Agreement, is (as stated by the Director General at the Board of Governors meeting on 13 September 2004) a matter of serious concern. However, based on the information provided by the ROK and the verification activities carried out by the Agency to date, there is no indication that the undeclared experiments have continued. The Agency is continuing the process of verifying the correctness and completeness of the ROK's declarations pursuant to the Safeguards Agreement and Additional Protocol.

42. The Director General will continue to report to the Board of Governors as appropriate.