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Application of Nondestructive Assay Techniques in Kazakhstan*

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Abstract

As Kazakhstan has transitioned from being part of the Soviet Union to a nonweapons state (Treaty of Nonproliferation of Nuclear Weapons [NPT] signatory) under International Atomic Energy Agency (IAEA) inspections, significant changes have been required. Some of these changes have occurred in nuclear material protection, control, and accounting at the four nuclear facility sites in the Republic of Kazakhstan. Specifically, the Republic of Kazakhstan has changed from relying primarily on a subset of physical protection methods to a graded safeguards approach using a balance of material control, material accounting, and physical protection. Once more intensive material control and accounting procedures and systems are in place, a necessary step is to supply the accounting systems with measured values of high quality. This need can be met with destructive and nondestructive methods. Material control systems can also use qualitative nondestructive assay information as input. This paper will discuss the nondestructive assay techniques and systems the US Department of Energy (DOE) is providing to Kazakhstan under both DOE programs and the Cooperative Threat Reduction Act as part of the nuclear material control and accounting upgrades at four facilities in Kazakhstan.

Introduction

As Kazakhstan has transitioned from being part of the Soviet Union to a nonweapons country, significant changes have occurred in nuclear material protection, control, and accounting (MPC&A) at the four nuclear facility sites in the Republic of Kazakhstan.

Kazakhstan signed the Treaty of the Nonproliferation of Nuclear Weapons (NPT) in 1993 and since 1994 has worked with several countries, including the US, Sweden, Japan, and the UK to modernize its system of MPC&A for nuclear materials. The Republic of Kazakhstan now has a national agency, the Kazakhstan Atomic Energy Agency (KAEA), that regulates the four sites that work with special nuclear material. The four consist of

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- a low-enriched uranium (LEU) pellet fabrication plant that makes half of the pellets used in Soviet-style reactors (both VVER and RBMK), part of the Ulba Metallurgical Complex,
- a research reactor in the town of Alatau near Almaty,
- three nuclear research reactors on the Semipalatinsk testing site, and
- a BN-350 liquid-metal-cooled fast breeder reactor in the city of Aqtau.

All four sites in Kazakhstan now undergo regular International Atomic Energy Agency (IAEA) visits. Three of the four are negotiating facility attachments and undergo routine inspections.

In the early 1990s, Kazakhstan was faced with the problem of creating the governmental structures previously supplied by the Former Soviet Union (FSU). After drafts of the law were discussed in interagency conferences in the national government, Kazakhstan passed a law on the use of atomic energy in April 1997. Kazakhstan also has draft laws on radiation protection of the population and nuclear waste management. Under the umbrella of these general laws, Kazakhstan is creating the regulations and the regulatory structure needed to license and operate nuclear facilities in a manner that the public finds acceptable. Meanwhile, the Republic of Kazakhstan has changed from relying primarily on a subset of physical protection methods to a graded safeguards approach using a balance of material control, material accounting, and physical protection. As more intensive material control and accounting procedures and systems are put into place, the accounting systems need measured values of high quality. This need has been met with destructive and nondestructive methods.

Nondestructive Assay Applications at the Ulba Metallurgical Facility in Ust-Kamenogorsk

This facility is one of four production lines collocated at the Ulba Metallurgical Facility, a large manufacturing facility in northeast Kazakhstan. The other three production lines are not operational. This site was the location of the US/Kazakhstan SAPPHIRE operation under which highly enriched uranium (HEU) was purchased from the Republic of Kazakhstan. The fuel fabrication facility at Ulba fabricates LEU fuel pellets for RBMK & VVER reactors. It is a large plant with a capacity to fabricate 2000 tons of fuel pellets per year. It has historically generated about half the fuel for Soviet-style reactors. The typical special nuclear material is LEU (below 5%) in bulk form or pellets. It was the first site offered to the international community from the Republic of Kazakhstan as a demonstration site for MPC&A upgrades in 1994. The primary safeguards need at this site was to create and to start using an accounting system based on measured values to establish and monitor the special nuclear material inventory. Ulba was the first site in the FSU to undergo Initial Inventory Taking by IAEA, which occurred in 1995. It was also the first site in Kazakhstan to receive a nondestructive assay (NDA) training seminar (Fig. 1).

The US has provided a set of software tools for developing a site-specific automated accounting system to collect measurement data, process it, archive it, and to create reports. Ulba is proceeding quite well with the significant task of designing and implementing an automated accounting system. The possibilities offered by this accounting system for process control have also been acknowledged. Improving the process efficiency as a side benefit from improving safeguards has the facility interest. The US has provided upgrades to both destructive assay (DA) and NDA measurements. The US is supporting the facility effort to directly link the new measurement hardware into the accounting system.

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Fig. 1. Training seminar on gamma-ray measurements for LEU fabrication plants held at Los Alamos National Laboratory in January 1995. N. Mozgovoi, N. Islam (IAEA), B. Kouznetsov, and G. Sokolov are discussing a holdup measurement problem.

- 1) Enrichment Measurements - Most LEU facilities in the western world rely on enrichment and weight to generate the values for the accounting system. The US has supplied gamma-ray spectroscopy systems, scales and balances as NDA upgrades. The facility hopes to start using measured values for all feed material into the pellet fabrication process. The gamma-ray spectroscopy system is portable, similar to that used by IAEA or to be used by the national inspection agency. The portable systems can process many more samples than the on-site mass spectrometer, with much less sample handling, albeit with poorer measurement precision. The gamma-ray analysis software required some development due to excessive levels of minor U isotopes.
- 2) Process Holdup Measurements - As an accounting system is put into place and the practice of measuring all shipments and receipts is implemented, most facilities discover large or unacceptable values for (MUF) material unaccounted for. Typically, the suspicion arises that nuclear material is somewhere in the process but unmeasured. The Ulba facility has been more vigorous than facilities typically are with respect to shutdown and cleanout in support of the IAEA annual Physical Inventory Taking (PIV). Ulba is well on the way to having an excellent holdup assessment program based on measurements and cleanout.



Fig. 2. G. Sokolov performs a gamma-ray measurement on a process waste bottle containing sludge in the Ulba Metallurgical Facility in December 1994.

The US has supplied low resolution holdup and waste measurement capability and training (Fig. 2). The US has supplied an automated bar code based system for holdup measurements (HMS3).¹

- 3) Hand-held radiation monitors to be used to verify that containers stored outside do not contain nuclear material (Figs. 3 and 4).



Fig. 3. Empty uranyl nitrate shipping containers at the Ulba Metallurgical Facility in Ust-Kamenogorsk, Kazakhstan.

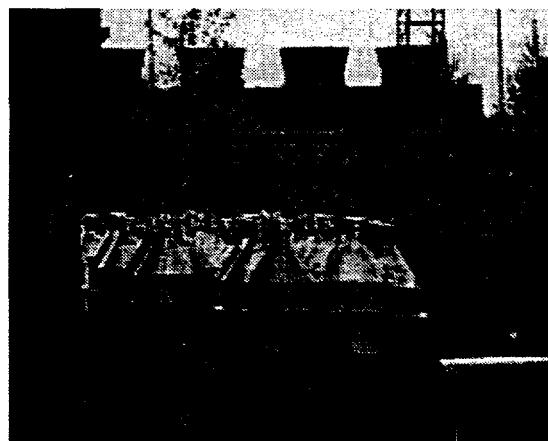


Fig. 4. Empty uranium oxide storage containers at the Ulba Metallurgical Facility in Ust-Kamenogorsk, Kazakhstan.

- 4) US-supplied low-resolution gamma-ray spectrometry systems can also be used for waste monitoring. Several hand-held alpha meters were supplied to be used in cleaning operations to verify cleaned items had contamination levels sufficiently low as to not require careful measurement.
- 5) Bar code equipment including interfaces is being implemented for material control and item identification. Ulba is a large plant with significant throughput, as much as 1200 tons of pellets were produced in a recent year, and the use of bar codes will facilitate computer input and reduce human error associated with manual or multiple entry.

Ulba underwent the second IAEA physical inventory taking (PIV) in the summer of 1996. This allowed the first MUF calculation to be made for an FSU facility. As expected, the MUF was large enough to justify further nuclear material control and accounting (MC&A) improvement efforts. It is important to note that this MUF is based on shipper's values for most if not all of the feed material, as

Ulba had no measurement capability for uranium hexaflouride. Kazakhstan has requested US assistance in assessing this MUF.

The hardware deliveries should be completed by early summer 1997, and a commissioning ceremony is being planned for September 6, 1997. Occasional follow-up by appropriate experts is recommended to help continue the smooth transition to a material accounting system. Otherwise the MPC&A upgrade program at Ulba should be completed by the end of 1997.

Nondestructive Assay Applications at the BN-350 Liquid Metal Fast Breeder Reactor in Aqtau

The Aqtau breeder reactor was originally designed to produce plutonium for the FSU. Byproducts of this production were electricity, heat, and desalinated water for the surrounding population center. The city of 160 000 people has no natural source of fresh water.

Safeguards which has been established at the facility protects and monitors fresh fuel ranging from depleted to HEU (<30% enrichment) and spent fuel in the form of irradiated core driver assemblies and irradiated breeder assemblies. Safeguards at the facility falls into three categories: physical protection, safeguards required to demonstrate that the facility is complying with IAEA agreements, and safeguards required by the facility to track and monitor the presence of material within the reactor building in near realtime. Physical protection is being upgraded to western standards, and the US has cooperated with the Japanese support program to provide a radiation monitoring system similar to that used by the IAEA in Japanese breeder reactors. In addition, a state of the art integrated radiation-based monitoring system is being provided to the facility by the US. This monitoring system has been designed with the help and cooperation of the facility, and combines radiation sensors supported by video, sonar, and binary sensors. The system provides the facility with material control and tracking information and provides input into the physical protection system.

NDA activities include the following.

Measurements

- 1) Measurement of spent fuel in the reactor building to determine the sensitivities required for monitoring sensors at various locations within the plant. (Completed)
- 2) Measurement of spent fuel to verify reactor calculation codes provided by the US. (In progress)
See Fig. 5.

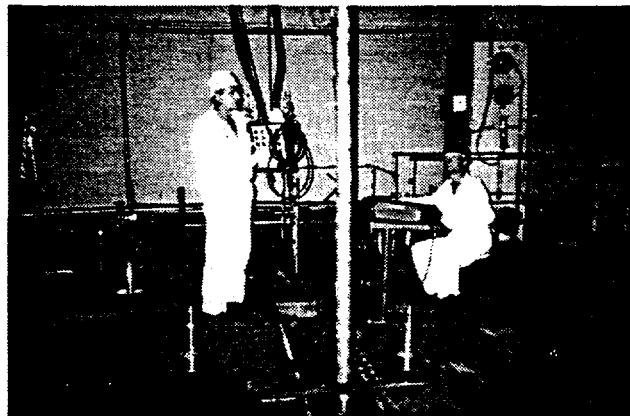


Fig. 5. Y. Ilyin and A. Blinsky operate a spent fuel measurement station at the Aqtau BN-350 reactor.

- 3) Measurement of spent fuel to demonstrate the capability to determine or verify the fissile content of irradiated driver and blanket assemblies stored at the facility. (Future) The fuel has different characteristics than fuel for which measurement techniques have previously been developed for safeguards purposes.²⁴

Training

- 1) Facility management personnel attended a course providing an introduction to MC&A techniques in February 1996.
- 2) A training seminar was provided to technical workers on gamma-ray and neutron measurement techniques used in the west for MC&A in April 1997.

Equipment Provided

- 1) A primary and backup gamma-ray assay systems have been provided by the US. These systems include:
 - high purity germanium detectors,
 - pulse-height analysis hardware, and
 - support computers including pulse height analysis software.
- 2) Hand-held radiation monitors to be used to verify that containers stored outside do not contain nuclear material.

Monitoring Capabilities

An unattended monitoring system which can track and sense radiation movement and presence is being installed for use by the facility. The system, based on proven technology developed for international and domestic DOE applications, combines radiation and various other sensors to provide a distributed sensor system and a real-time database which is accessed by a plant-specific real-time alarm program which constantly reviews the database and determines that activities or static storage of material is consistent with the prescribed activities in the plant. Anomalies are instantly brought to the attention of the facility operator and security personnel. The facility is providing personnel to develop the real-time alarm program in cooperation with US DOE laboratory staff. This system provides information for the facilities' control of nuclear material and provides input to the plants physical protection system. This system is the most advanced system of its kind, and it is based on plant designs from throughout the world with a combined total of 2.5 centuries of system operation. See Fig. 6.



Fig. 6. Training session during initial installation of unattended monitoring system software. S. Klosterbuer shows N. Bushmakina, V. Bolgarin, and O. Gomaleva the features of the software.

The IAEA currently makes monthly visits to check tamper-indicating devices (TIDs), perform item accounting, and to review radiation monitoring data. The implementation of the more advanced technology for IAEA safeguards at the facility would quite likely result in less interference with facility operations, could significantly reduce the amount of IAEA effort required to review safeguards information, and if the "remote ready" capabilities of the system were used, it would require less inspector presence. The IAEA will have to make this judgment for themselves.

Nondestructive Assay Applications at the Institute of Atomic Energy at Kurchatov

There are three research reactors in Kurchatov used primarily in support of research of space nuclear power, located on the Semipalatinsk test site. Nuclear explosives testing activities at Semipalatinsk halted in 1989. These reactors are powered with uranium. The uranium is in three general forms: bulk, fresh fuel, and slightly irradiated fuel. The need at this site is to establish an initial inventory and to develop systems to assist in periodic inventories. The site has transferred control of most of the special nuclear material back to Russia. Shipment of the Russian-owned material off site has started. The research reactors use 90% enriched uranium. As of spring 1997, all three reactors were operating. However, most of the Kazakstani-owned special nuclear material is LEU, summing to a total of less than 1 significant quantity. The inventory is predominately static. The site has developed its own accounting system for the small inventory. The site is interested in evaluating other accounting systems, if they can get the source code and make necessary changes. A modest amount of NDA equipment was supplied as upgrades by the US support program.

- 1) Two small balances for weighing of the bulk material.
- 2) Portable gamma-ray spectroscopy systems for uranium enrichment measurements.
- 3) An active well coincidence counter (AWCC) that can be configured to measure either bulk HEU or fresh fuel.

The IAEA wants Russia to complete shipping all Russian-owned material off site, then the remaining special nuclear material is less than 1 significant quantity, therefore requiring little inspection effort.

Nondestructive Assay Applications at the Institute of Atomic Energy at Alatau

The Almaty research reactor is situated outside of Almaty proper in the town of Alatau. The typical special nuclear material is 36 % enriched uranium. The need at this site is to establish the initial inventory and to develop systems to assist in periodic inventories. With the reduced technical activity, the inventory is essentially static. However the site was recently granted an operating license and began operating the reactor. The site has developed its own small accounting system, based on the Swedish reporting system. A modest amount of NDA equipment was supplied as upgrades by the US support program.

- 1) Balances for weight measurements.
- 2) Portable gamma-ray spectroscopy systems for uranium enrichment measurements and possible examinations of irradiated fuel.
- 3) Hand-held radiation monitors for use to survey containers and packages to verify they do not contain uranium.

The IAEA inspection effort is nominal due to the small quantity of nuclear material on site.

Status of Nondestructive Assay in Kazakhstan

The nuclear MCP&A enhancement program for Ulba is essentially complete. Some follow-up is expected to ensure a smooth transition to self-sufficiency. The facility or the IAEA may request additional assistance with the MUF investigation or with holdup measurement training, but funding must be identified to support such requests as this is outside the program plan developed under the Cooperative Threat Reduction Program guidelines. The BN-350 has received approximately 75% of the unattended monitoring system. It is necessary to finish the installation and then proceed with a comprehensive follow-up to ensure a smooth transition and that the system is optimized. The BN-350 has received the gamma-ray measurement systems and half of the initial training; subsequent training will be offered on site after the facility operators become more familiar with the equipment. The design of the neutron assay system for the spent fuel is well underway at Los Alamos National Laboratory. A neutron assay system should be installed by summer 1998. The IAEA inspectors will be grateful if the inspection presence can be reduced as a consequence of any of the international support activities. Activities at Kurchatov and Alatau are essentially complete. The equipment has been delivered, but the US still needs to provide some on-site training for the gamma-ray spectroscopy systems. Some follow-up is predicted as the sites adjust to new hardware, procedures, and MC&A.

All sites need calibration materials. New Brunswick Laboratory (NBL) is presently waiting for approval. NBL has received the prerequisite US approvals, now they must wait while the Kazakstanis push a request through their new regulatory process.

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