IAEA Safeguards – Developing in a changing world

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Introduction

This paper has two objectives. Firstly, it describes IAEA safeguards, including its objectives and its application at nuclear facilities. Secondly, and more specifically, the paper discusses the implementation of safeguards at NB Power's single-unit CANDU-600 MWe reactor at Point Lepreau, New Brunswick.

The paper first discusses current safeguards practices, and then covers current and forthcoming developments. Recent reform efforts are intended to improve the effectiveness and efficiency of IAEA safeguards. In terms of effectiveness, strengthened IAEA safeguards are broader in scope and application. In terms of efficiency, integrated safeguards attempts to both optimize IAEA inspection effort in the field and minimize intrusiveness on facility operations. As far as possible, the safeguards changes are discussed in terms of their application at Point Lepreau NGS.

1 - "Atoms for Peace" and the IAEA

The International Atomic Energy Agency or IAEA was a direct outgrowth of US President Dwight Eisenhower's "Atoms for Peace" speech in December 1953 before the United Nations General Assembly. Following on the heels of two failed efforts to construct a post-World War II international regime to control atomic energy in both its peaceful and destructive purposes, namely the Acheson-Lilienthal Report and the Baruch Plan, Eisenhower called for the establishment of an international agency that would "devise methods whereby fissionable material would be allocated to serve the peaceful pursuits of mankind." After much debate, a statute creating the IAEA was agreed. It was given a dual mandate: both to assist recipient states in the development of their peaceful nuclear programs, and to verify through safeguards that the material in those programs was not diverted to proscribed military activities. The IAEA came into being on 29 July 1957, and is based in Vienna, Austria.

The basic concepts behind the application of safeguards were developed throughout the 1960s, and at first the system evolved slowly. The number of inspections and facilities grew as states accepted "limited" safeguards on their material, facilities and equipment. However, this slow growth in safeguards changed dramatically with the entry into force of the Treaty on the Non-proliferation of Nuclear Weapons, the NPT, in 1970. The NPT requires non-nuclear weapon state (NNWS) parties to conclude a comprehensive safeguards agreement with the IAEA that covers all the state's nuclear material in all its peaceful nuclear activities. As of the end of 1999, 223 agreements were in force with 139 states. The five nuclear weapons states (NWS) under the NPT have also concluded voluntary-offer safeguards agreements with the IAEA that cover some of their peaceful nuclear activities.

It should be remembered that safeguards is not the only activity of the IAEA. The founding objectives covered the complete scope of nuclear activities. The IAEA has five other major program areas: Technical Co-operation, Nuclear Safety, Nuclear Energy, Sciences and Applications, and Management.

2 - Fulfilling Canada's Nuclear Non-proliferation Commitments through IAEA safeguards

IAEA safeguards are technical means of verifying compliance with legal obligations relevant to the non-proliferation of nuclear weapons. While the means are technical, the objective of safeguards is political. Specifically, IAEA safeguards serve two political purposes. First, safeguards offer assurances to the international community of the peaceful uses of safeguarded nuclear material. Second, they serve to detect facilities, equipment and activities, and therefore deter the diversion or misuse of material from peaceful uses to non-peaceful uses. Safeguards are not intended to prevent diversion or misuse. In this regard, IAEA safeguards serve as an early warning system. In accordance with its statute, once a serious violation of a safeguards agreement is detected by the IAEA, and the Member State has been unable to give sufficient explanation, the non-compliance is to be reported to the United Nations Security Council for appropriate action.

Since the inception of the NPT in 1970, IAEA comprehensive safeguards are embodied in INFCIRC/153, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-proliferation of Nuclear Weapons (1972), and have become the basis on which to judge state compliance with their nuclear non-proliferation commitments under the NPT. Canada reinforced its commitment to the non-proliferation of nuclear weapons by ratifying the NPT on January 8, 1969. It fulfilled its obligation under Article III.2 of the NPT by concluding a comprehensive safeguards agreement (INFCIRC/164) with the IAEA on February 21, 1972.

Canada's safeguards agreement with the IAEA, which is based on the model agreement mentioned above (INFCIRC/153), provides the general framework for the implementation of IAEA safeguards in Canada. The agreement creates an interlocking system involving facility design information, nuclear material accountancy and auditing, containment and surveillance, installed equipment, on-site inspection, destructive and non-destructive analysis, and information management and analysis. Assessed together, the IAEA draws annual conclusions on the non-diversion of nuclear material.

3 - At the Station: Safeguards at Point Lepreau

Upon concluding its safeguards agreement, Canada negotiated a set of subsidiary arrangements with the IAEA. These arrangements specify in detail how the procedures laid down in the agreement are to be applied. One important aspect of the subsidiary arrangements is the requirement for Canada to submit and to maintain up-to-date design information on its nuclear facilities relevant to the application of safeguards.

Like all other nuclear facilities in Canada, the 600 MWe CANDU reactor (heavy water moderated, pressurized heavy water cooled, on-load refueled reactor using natural uranium oxide fuel) at Point Lepreau provided design information to the IAEA. According to a standardized "Design Information Questionnaire" (DIQ) administered by the Atomic Energy Control Board (AECB), which is itself discussed below, it specified the following elements:

- The identification of the facility, including its general character, purpose, nominal capacity and geographic location;
- A general description of the arrangement of the facility with reference to the form, location and flow of nuclear material;
- A description of the features of the facility relevant to material accountancy, containment and surveillance; and
- A description of proposed procedures at the facility for nuclear material control and accountancy, with special references to the "material balance areas," measurements of flow and procedures for physical inventory-taking,

and the IAEA used the information to develop a safeguards approach and a "facility attachment" for the Station.

The technical objective of IAEA safeguards is the "timely detection of diversion of significant quantities of nuclear material." The values currently in use for "significant quantity" (SQ), relevant to the CANDU 600 at Point Lepreau, are:

- 8 kg of plutonium; or
- 75 kg of U-235 contained in natural or depleted uranium.

The associated guidelines for "timely detection" are:

- detection within 3 months of a diversion of plutonium contained in irradiated fuel bundles; or
- detection within 12 months of diversion of natural or depleted uranium.

Using these objectives and guidelines, the IAEA analyses the facility-type and the associated design information to postulate possible diversion scenarios (i.e., means by which nuclear material could be removed from declared uses at the facility) and to develop a safeguards approach covering inspection goals and procedures designed to detect such diversions. For Point Lepreau NGS, the diversion scenarios focus on diversion of both fresh and irradiated fuel bundles, with greater emphasis on the latter due to their greater strategic value, and on the possibility of undeclared nuclear production in the reactor through plutonium breeding. The assessment translates into safeguards measures that form a tight boundary around the irradiated fuel flow path.

The cornerstone of the safeguards approach for all nuclear facilities in Canada, including Point Lepreau NGS, is nuclear material accountancy. Specifically for Point Lepreau and other nuclear reactors in Canada, it is based on "item accountancy", or verification of the flow of fuel bundles at the station. Information on these flows is essential for effective IAEA safeguards, and it is essential that the facility operator maintain detailed accounting and operating records on the internal flows of nuclear material. The parameters of accounting and operating records are clearly delineated in the facility attachment described above and through the regulatory process described below.

Building on nuclear material accountancy, the safeguards approach for irradiated fuel at Point Lepreau incorporates permanently installed safeguards equipment. Spent fuel bundle counters (SFBCs) installed at the entry points to the discharge bay continuously monitor the flow of irradiated fuel bundles between the core and the spent fuel bays. A tight system of containment and surveillance (C/S) measures helps to assure that no irradiated material is removed from the core by circumventing the SFBCs. The inventory of irradiated fuel in the spent fuel bays is under C/S to reduce measurements of the inventory. It should be noted, however, that, unlike safeguards approaches for light water reactors, the reactor design does not allow for core inventory verification. Instead it concentrates on the detection of undeclared removal of irradiated fuel from the core or the spent fuel transfer route, thereby enabling detection of the diversion and unreported production scenarios described above.

In an ideal situation, the core would be covered by core discharge monitors (CDMs). These are radiation detectors designed to note time and direction of fuelling activities and to correlate with SFBCs monitoring the movement of fuel to the spent fuel bay. In its initial design, the core approach at Point Lepreau included radiation-hardened reactor-vault cameras watching each of the reactor faces, and Yes/No detector TLDs at the fresh fuel ports and ancillary ports. Also, other closed-circuit television (CCTV) cameras in the reactor building cover the diversion of fuel through open vault doors and airlocks. Early failure of the vault cameras resulted in reconsideration of the core approach. Core fuel inventory in a single unit reactor is determined by the difference between spent fuel and fresh fuel inventories and relies on the integrity of operator records and the SFBCs. Ultimately, CDMs with vault cameras are expected to be installed at Point Lepreau.

The timeliness criteria specified above require the IAEA to perform interim inventory verification (IIV) inspections four times per year. Every three months, therefore, IAEA inspectors visit Point Lepreau NGS to examine operator records relevant to fuel flow and to perform criticality checks on the reactor. During these IIV inspections, IAEA inspectors perform a book audit which involves a comparison of the state reports prepared by the AECB on inventory changes at Point Lepreau NGS, with the Station's own records. They audit the operating and accounting records, review the bundle counter records and compare results with fuel loading records. The IAEA inspectors also service all the surveillance and bundle counter equipment.

Each July as part of the Simultaneous Physical Inventory Verification or SIM-PIV inspections at all the Canadian nuclear facilities, the IAEA performs a physical inventory verification (PIV) inspection at Point Lepreau. This involves the book audit functions as listed above, as well as physical verification of the fresh fuel inventory (by item-counting of boxes and bundles, as well as measurements of selected bundles using non-destructive techniques), and of the spent fuel inventory using an underwater television camera. The PIV inspection activities typically last 3 - 4 days and involve 2 IAEA inspectors, an AECB safeguards officer and an equivalent amount of Point Lepreau personnel time.

The use of Dry Spent Fuel Storage (DSFS) at Point Lepreau adds an element of complexity to the safeguards approach. In DSFS the spent fuel is withdrawn from the spent fuel bay, loaded into baskets, and transported approximately a mile to the canister site where it is placed in concrete silos. The nuclear material is deemed to be "difficult-to-access" upon final sealing in the concrete silos, and therefore can be left under dual seals without continuous visual surveillance. However, IAEA inspectors have to be present throughout the entire transfer campaign because the transport is outside the area covered by Station C/S. The inspectors verify the transfer out of the spent fuel bay by item counting and gamma-monitoring: they witness the transport; and they observe the loading into the canister. Thus, IAEA inspectors are present at Point Lepreau NGS for most of the summer months when DSFS transfer campaigns take place. Moreover, because IAEA presence is required, operator scheduling of dry storage transfer campaigns is not completely independent.

4 - IAEA Safeguards and the AECB's Regulatory Process

Canada's safeguards agreement with the IAEA requires the establishment of a state system of accounting and control (SSAC) for all nuclear material subject to safeguards. Under the subsidiary arrangements, the Atomic Energy Control Board (AECB) has been designated the responsible government authority for ensuring that Canada meets its international nuclear non-proliferation commitments under its safeguards agreement with the IAEA. The AECB administered these responsibilities in the past through the Atomic Energy Control Act and will do so in the future under the Nuclear Safety and Control Act.

Through its regulatory authority, including licence conditions, the AECB ensures that licensed nuclear facilities in Canada, such as Point Lepreau NGS, perform the following tasks:

- submit necessary reports (such as monthly Fissionable Substance Reports in accordance with AECB-1049 and design information) to the AECB for creation of state reports;
- maintain source records at the facility (such as fuelling records);
- install permanent safeguards equipment at the facility (such as the bundle counters and C/S measures described above); and
- permit physical access to IAEA inspectors as required to fulfill Canada's international nuclear non-proliferation commitments.

For the most part, the AECB serves as the facilitator and liaison between the IAEA and the facility for the implementation of safeguards in Canada. It attempts to serve the interests of both parties as well as the Government of Canada. This means that it endeavours to ensure that the IAEA is able to perform all necessary activities under the agreement, the subsidiary arrangements and the facility attachment in order to draw successful conclusions on the non-diversion of nuclear material at Canadian nuclear facilities. The AECB also works to ensure that the IAEA's activities are applied in ways that avoid undue interference in the operations of Canadian nuclear facilities, such as Point Lepreau NGS, that are consistent with prudent management practices required for the economic and safe conduct of nuclear activities and that protect all commercial and confidential information coming into the knowledge of the IAEA. It also works to ensure that safeguards are applied in a consistent manner across relevant nuclear facilities in Canada.

5 - The Future: Strengthened Safeguards and the Additional Protocol

IAEA safeguards as embodied in INFCIRC/153 (and as applied in Canada under INFCIRC/164) are based on verification of declared nuclear material and, to a lesser extent, declared nuclear activities. In practice, this had the effect of concentrating IAEA effort on what each State declared it had, i.e. nuclear material, and did, i.e. nuclear activities. The IAEA then sought to verify the declared nuclear material flow at declared nuclear facilities.

The international community's confidence in the IAEA's comprehensive safeguards system was, however, severely shaken in the early 1990s. The post-Gulf War inspections by the IAEA and the UN Special Commission (UNSCOM) found that Iraq had managed to hide the development of a complex weapons program from the international community. Underscoring the deficiencies of a system based on declared material flows, an NPT treaty state had developed and nurtured a clandestine nuclear weapons program, in spite of periodic international inspections designed to expose such illicit activities. Separately, the discoveries in Iraq were reinforced by events in the DPRK where the IAEA was unable to confirm that state's initial declaration, and in South Africa where the IAEA was asked to verify and then re-verify the initial declaration of a state that had just renounced its nuclear weapons program.

Specifically, the shortcomings of comprehensive safeguards as applied under INFCIRC/153 were three-fold. Firstly, inspection and verification activities were applied only to declared nuclear material. It was left up to the State to declare to the IAEA all nuclear material relevant to safeguards. Secondly, on-site visits were limited to designated "strategic points" where C/S measures were applied and IAEA measurements were carried out on declared nuclear material. This had the effect of limiting IAEA access to areas that contained declared nuclear material, and strictly limiting the IAEA's ability to investigate the possibility of undeclared nuclear material or activities. Thirdly, the above elements underscored that, to be effective, IAEA safeguards must be both complete and correct in their application to the state's nuclear fuel cycle activities.

This led to efforts to seriously reform IAEA safeguards. The international community demanded that if international safeguards were to retain any credibility, there would have to be changes in their application to make them more effective. These changes included:

- expanding the IAEA's access to information on the state's nuclear fuel cycle activities;
- expanding the IAEA's physical access to the state's nuclear fuel cycle;
- improving safeguards technologies; and
- allowing the IAEA the opportunity to interrogate the completeness and correctness of the state's declarations on its nuclear material and fuel cycle activities.

The reform process, which began in the early 1990s and included Program 93+2 and so-called "Trials in Canada" in the mid 1990s, culminated in May 1997 with the approval of INFCIRC/540, An Additional Protocol to safeguards Agreements, hereinafter referred to as the "Additional Protocol." This is a principal element in strengthening IAEA safeguards, as it expands the IAEA's right to information and, in turn, enhances the IAEA's physical access to the state's nuclear fuel cycle.

Under the Additional Protocol, the IAEA's right to information now covers the whole site, not just information relevant to nuclear material flow. At Point Lepreau, Station Staff are now compiling a list and a description of each building on the site, in the DSFS area, and offsite, if they are "essential services" to the operation of the nuclear facility. Point Lepreau is also required to declare activities such as D_2O upgrading and descriptions of the Off-site Emergency Centre. Preparing the information required under the Additional Protocol involves considerable work, particularly because of the numerous miscellaneous buildings, such as buildings for storage of combustible gases and chlorine, a carpenters' shop and the three pump-houses. The declaration promises to be complex in spite of the fact that Point Lepreau is in nuclear terms a straightforward facility: a single-unit CANDU generating station with no laboratories or research facilities.

Under the Additional Protocol, the expanded rights of access give the IAEA access to any location on the "site" in the declaration. This means that access is no longer restricted to strategic points and key measurement points associated with declared nuclear material. The Additional Protocol essentially allows IAEA access to any part of the station or buildings on the site.

Strengthened safeguards, especially the Additional Protocol, also introduces a new safeguards technique, namely environmental sampling. This new technique gives the IAEA an unprecedented opportunity to check the consistency of declared operations with signatures found in the environment. Nuclear materials have distinctive radioactive characteristics which makes the task of detecting and measuring them possible. Moreover, industrial processes involving nuclear materials leave trace signatures in the environment that can be detected with great accuracy and at much lower level detection thresholds than before using environmental sampling. IAEA inspectors are empowered to take surface wipes or samples of soil, water and vegetation that can be analyzed to confirm that the signatures found in the environment are consistent with the declared operations at the facility. Thus modern environmental sampling techniques are sufficiently powerful to reveal undeclared enrichment and reprocessing plants.

6 - Current and Future Challenges at Point Lepreau

All parties involved in implementing safeguards, including the IAEA, AECB and the facility operators, including those at Point Lepreau, are constantly looking for ways to improve safeguards efficiency. The present system is labour-intensive both for station personnel and for the IAEA. Some improvements have been made and others are being considered.

An example of this occurred when the IAEA moved from Minolta-type film cameras to a CCTV system. Previously, the IAEA had to visit the station to change the film in half a dozen cameras every month. This involved carrying cameras around the station (in and out of controlled radiation areas) with a lot of film cartridge and battery replacement. This all changed with the installation of a permanently-cabled CCTV system around the affected areas that feeds review equipment in a dedicated safeguards room at the facility. With the new system, the IAEA is able to visit less frequently. Moreover, the IAEA could easily store, print, and review the images by computer using the Multi-Optical Review (MORE) system. This new system also benefited Point Lepreau by reducing the amount of field assistance required by station personnel.

Similar to the upgrade from film to digital cameras, technical improvements are being undertaken for the Spent Fuel Bundle Counters (SFBCs) and for the TLDs that watch the new fuel load area ports, the ancillary ports, and the spent fuel bay cooling-water outflows. Presently, all of these require quarterly servicing by the IAEA, and all of them involve escorted access to, and considerable time in, the controlled radiation areas. Again, the modification entails a permanently-cabled system connected directly to digital recording and analysis equipment in the safeguards room. The TLDs are being replaced by electronic radiation detectors, which are more useful than TLDs in that they record the times, durations and energy signatures of events for future recall. Again, not only does this promise to reduce intrusion on station operations, it also translates into improved data review capabilities, and allows data to be transmitted directly off-site to the IAEA regional office in Toronto or to headquarters in Vienna.

Another potential improvement remains on the horizon but the AECB and Point Lepreau are committed to bringing it to fruition. The most labour-intensive activity in safeguards at Point Lepreau NGS is the transfers of spent fuel to dry storage. If all parties could agree on an unattended, instrumented approach to allow station personnel to transfer spent fuel from the spent fuel bay to the canister site without the continuous physical presence of an IAEA inspector, the IAEA could save a vast amount of inspector time and costs. As well, severe restraints on the station schedule planning would be alleviated. The CANDU station at Embalse in Argentina is developing a prototype approach, in cooperation with the IAEA and the United States, using unattended verification based on radio transmitters and remote monitoring; and both Point Lepreau and the AECB are currently examining the application of a similar approach to the transfer process at Point Lepreau.

7 - Conclusion

Born in the height of the Cold War, IAEA safeguards is adapting to a new international environment. Whereas safeguards was limited to detailed material accountancy on declared nuclear material, the advent of the Additional Protocol expands IAEA coverage to include undeclared nuclear activities as well as both the correctness and completeness of state declarations. These changes will affect the application of safeguards at Point Lepreau NGS. Initially, it requires greater effort on the part of station personnel. More information, covering the whole site and not just declared nuclear material flows, will be provided to the IAEA through the AECB. Greater access and improved technologies will be afforded to the IAEA to draw stronger conclusion on the bona fide nuclear non-proliferation credentials of Canada. Stronger conclusions, particularly regarding the absence of undeclared reprocessing facilities in Canada, may lead to a reconsideration of the timeliness and detection components associated with the dry storage transfer process, thus leading simultaneously to both better safeguards and less intrusion on Point Lepreau Station and other facility operations: a win-win situation for all parties.

Disclaimer –

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