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INTERNATIONAL ATOMIC ENERGY AGENCY SAFEGUARDS

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INTRODUCTION

The International Atomic Energy Agency (IAEA) is unique among international organizations in its use of on-site inspections to verify that States are in compliance with the terms of a negotiated agreement. These inspections are applied in 52 countries at nearly 500 facilities to assure that uses of nuclear materials and facilities are limited to peaceful purposes. The legal basis for the inspections is agreements between the IAEA and the State, concluded in the framework of the Nuclear Nonproliferation Treaty, for full scope safeguards on all nuclear materials. In addition, other more limited agreements for safeguards on a portion of a State's nuclear material are also concluded with States not party to the Treaty. In either case, the role of the IAEA is to verify compliance with the terms of these agreements by auditing facility operating records and reports submitted to the IAEA by the State; by independent measurement of nuclear materials by IAEA inspectors; and by emplacement of surveillance devices to monitor facility operations in the inspector's absence.

Although IAEA safeguards are applied only to peaceful nuclear activities and do not attempt to control or reduce the numbers of nuclear weapons, there are aspects of the IAEA methods and technology that may be applicable to treaty verification for arms control. Among these aspects are (1) the form of the IAEA's agreements with States, (2) the IAEA approach to inspection planning, and (3) the instrumentation employed by the IAEA for monitoring facility activities and for measuring nuclear material.

General Agreements

General agreements between the IAEA and a State describe in broad terms the obligations and privileges of the two parties with respect to implementation of safeguards. The general agreements are approved by the State's parliament and the IAEA Board of Governors.

Under agreements drawn up in accordance with IAEA document Information Circular 66, materials, equipment, and facilities may be subject to safeguards to assure they are not used for a military purpose. In these cases, IAEA activities are applied only to specific items placed under safeguards. In contrast, agreements under IAEA document Information Circular 153 emphasize that safeguards is on nuclear material, and the scope encompasses all nuclear material used by the State in its peaceful activities.

Noncompliance with the terms of the agreements would be reported through the IAEA Board of Governors to the United Nations Security Council. Because the IAEA has no power to enforce compliance, it must rely on the political and economic sanctions that might be applied by other States in response to evidence of a violation of agreements with the IAEA.

Facility Attachments

For each facility under safeguards, the IAEA and the State negotiate a Facility Attachment describing the inspection activities permitted and the States obligations for cooperation. A typical facility attachment includes (1) facility design and process operating descriptions, (2) safeguards measures that the IAEA is permitted to apply at the facility, (3) records of facility operations to be maintained by the operator, (4) a description of the State's System of Accounting to be maintained by the State, and (5) materials accounting reports to be submitted by the State to the IAEA.

IAEA inspection procedures applied under these agreements include examination of facility records and State reports for completeness, correctness, and consistency; measurement of materials to confirm that the amounts are consistent with those declared by the State; and the use of containment and surveillance to confirm in the inspector's absence that material amounts remain unchanged and that there are no undeclared movements of material.

INSPECTION GOALS

The general IAEA objective of the timely detection of the diversion of a significant quantity of material from peaceful purposes is quantified in the inspection goals that specify (1) a significant quantity as the amount of special nuclear material required for manufacture of a nuclear device (for example, 8 kg Pu, 25 kg of contained U^{235} in uranium enriched to $\geq$20%, and 75 kg of contained U^{235} in uranium enriched to <20%); (2) the detection time, estimated as the time for conversion of the material to a weapon (1 month for direct use material such as plutonium or highly enriched uranium, 3 months for direct use material in irradiated fuel, and 1 year for indirect use material such as low-enriched uranium); and (3) a probability of 0.9 to 0.95 for detecting the loss of a significant quantity of material within the detection time period.

In practice, these idealized goals are not strictly adhered to but may be modified according to the size of the facility inventory and throughput, the material type, whether the material is in item or bulk form, and the measurement uncertainty of the methods available to the IAEA for verifying material amounts.

SAFEGUARDS APPROACH

A safeguards approach is a coordinated system of inspection activities consisting of materials accounting and containment/surveillance methods, which are designed to confirm a State's compliance with safeguards agreements. Factors considered in developing the approach are the inspection goals; design characteristics of the facility to be inspected; terms of the safeguards agreements with the State; effectiveness of the State's System of Accounting; technical limitations of the IAEA measurement and surveillance technology; inspection manpower available to the IAEA; and technically credible scenarios for misuse of facility materials or equipment.

Although IAEA safeguards are applied in a collaborative spirit with the State cooperating in the implementation of inspections, the development of the safeguards approach is adversarial in its assumption that violations of safeguards agreements may occur. This assumption is essential in planning safeguards activities to assure other States that IAEA safeguards conclusions are valid.

For each facility type, IAEA systems studies have identified potential scenarios for undeclared removal of material from a facility or from its assigned location in the facility, undeclared introduction of material into a facility, and undeclared modification of material. These scenarios are specified in terms of the material types and amounts, physical paths for movement of the material, methods for modification of the material, and methods for concealing evidence of treaty violations.

The Safeguards Approach is designed to detect anomalies in facility operations that would be created by the postulated scenarios. Facets of an approach are identification of key points within a facility for application of safeguards measures; a set of inspection activities that includes examinations of facility records and State reports; verification of material inventories and transfers, and containment/surveillance measures; and the frequency and intensity of applying these activities.

VERIFICATION METHODS

Within the facilities inspected by the IAEA, which include light-water reactors (LWRs), research reactors, CANDU reactors, conversion/fabrication facilities, and reprocessing facilities, safeguarded material containing uranium and plutonium appears in a variety of forms. Among these forms are uranium and plutonium oxides in pellets, fuel rods, and fresh and irradiated fuel assemblies; UF_6 in cylinders; and nitrate solutions of uranium and plutonium in process vessels. These materials are independently verified by IAEA inspectors through analysis of samples sent to an analytical laboratory or through in-situ measurements with nondestructive assay (NDA) techniques.

The IAEA maintains a laboratory where about 2000 samples per year are analyzed by destructive analytical methods to determine the chemical concentration and isotopic composition of uranium and plutonium. This laboratory is equipped for wet chemical analysis, mass spectrometric analysis, radiometric measurements, and emission spectrography.

The laboratory facility for analysis of material samples from inspected facilities is complemented by an IAEA capability for in-situ nondestructive analysis of nuclear material. Development of these NDA techniques was motivated in part by difficulties in shipping samples of radioactive material and in destroying the integrity of valuable items such as fuel assemblies to obtain samples.

Applications of nondestructive assay instruments to measure the total amounts of uranium and plutonium or their isotopic composition are based on the unique characteristics of the radiations emitted by these materials. NDA devices may be characterized as passive methods based on the detection of radiation emitted by the material itself without external stimulation; and active methods based on the irradiation of the material with neutrons or photons to induce atomic or nuclear reactions and subsequent measurement of these induced radiations. In either case, these devices measure the intensity of gamma rays at specific energies, total neutrons, or coincident neutrons from fissions.

Among the measurements routinely performed by IAEA inspectors with NDA instruments are determinations of the enrichment of uranium in pellets, rods, and fuel assemblies; concentration of plutonium and uranium in nitrate solutions; ^{235}U enrichment of UF_6 in cylinders; and total plutonium in oxide and metal forms.

Examples of the portable NDA devices developed specifically for IAEA use at facilities are a multichannel analyzer, which displays gamma-ray spectra from sodium iodide or germanium detectors for determining ^{235}U enrichment, total uranium and plutonium isotopic composition, and a neutron coincidence counter with ^{3}He neutron detectors for determining ^{235}U and ^{238}U content in LWR fuel assemblies and plutonium content in oxides. Other more qualitative methods are the gross determination that a fuel assembly has been irradiated using Cerenkov glow night vision devices, and correlations between operators declarations of spent fuel burnup and cooling time with gross gamma and neutron measurements using ion and fission chambers.

CONTAINMENT/SURVEILLANCE

Because continuous presence of inspectors at a safeguarded facility may not be practical, containment/surveillance measures were developed for assuring, in the inspector's absence, that materials previously measured remain intact, that there are no undeclared movements of material, and that there is no tampering with inspector equipment remaining at the facility. For example, a seal applied to a container ensures that the material has remained unchanged since the seal was applied, and devices for recording optical images can provide evidence of undeclared movements of fuel assemblies in a spent fuel pond.

The IAEA currently employs about 9000 Type-E metallic seals each year. These are applied to material containers such as UF_6 cylinders, containment penetrations such as reactor shields, and tamper indicating enclosures for Agency equipment such as film cameras. Because the identity and integrity of these seals must be determined by detaching and returning to IAEA headquarters for examination, other seals that are verifiable in-situ are under development.

Surveillance devices are primarily applied to detect undeclared material movements in the spent fuel storage areas of reactors and reprocessing plants. These devices are film cameras with automatic timers, a tamper-resistant sealable enclosure, and battery power; closed circuit television (CCTV) systems are employed when continuous monitoring is required and when high radiation fields preclude the use of film. Surveillance film is reviewed at IAEA headquarters and CCTV may be reviewed in-situ or at headquarters.

Other surveillance devices in use by inspectors include radiation dosimeters to detect the passage of irradiated fuel, reactor power monitors to measure the power level from a reactor, and spent fuel bundle counters to monitor the flow of fuel bundles from a CANDU reactor to the spent fuel area.

TECHNOLOGY APPLICATIONS

Because the IAEA must account for large numbers of item and bulk quantities of nuclear material based on imprecise measurements of these quantities, it has developed procedures for making decisions with information containing statistical uncertainties. These procedures include methods for determining sample sizes and for setting decision thresholds on measured quantities so that anomalies in the observed population are detected with a specified probability. For arms control purposes, these methods could be applied to discriminate between members of the same weapons system having different performance characteristics, where these characteristics are imperfectly observed.

Verification of arms control agreements to reduce or ban the production of plutonium or highly enriched uranium could be supported by a full range of inspection procedures and technologies of the type employed by the IAEA. System analysis studies modeled on those that the IAEA uses to develop safeguards approaches could determine the inspection activities for detecting significant departures from agreed limits on production levels. Nondestructive assay measurements and containment/surveillance devices could provide a technical basis for verifying the correctness of a State's declared production of plutonium or highly enriched uranium.

Technology employed by the IAEA for nondestructive assay of nuclear material may also be applicable to monitoring of agreements that limit deployed nuclear warheads. Among the potential uses of this technology are distinguishing between nuclear and non-nuclear warheads on missiles, or monitoring for presence of nuclear weapons in nuclear-free zones. Further, tamper-protected containment/surveillance devices may be applied for monitoring weapons production and final assembly points.