PLANNING FOR FAILURE – INTERNATIONAL NUCLEAR SAFEGUARDS AND THE ROKKASHO-MURA REPROCESSING PLANT

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"No safeguards scheme, including that of the International Atomic Energy Agency (IAEA), can be effective if such sensitive materials and facilities (plutonium and reprocessing plants) are widely available in Non-Nuclear Weapon States."
U.S. National Defence Research Institute, Rand Corporation, November 1993, [2]

Confidence in the effectiveness of international safeguards on nuclear activities worldwide is central to the existence of the Treaty for the Non-Proliferation of Nuclear Weapons (NPT) and the wider non-proliferation regime. Without confidence, the commitment to non-proliferation by member states could become increasingly doubtful. This nuclear dynamic is soon to come to the fore in North-east Asia with the planned start up in 2005 of a large-scale reprocessing plant in Japan. The Rokkasho-mura facility, the most expensive plutonium facility ever, and 30 years in the planning, if operated will yield thousands of kilograms each year of nuclear weapons usable plutonium. Yet, the international safeguards system to be applied at the facility will be incapable of detecting the deliberate diversion or theft of large quantities of plutonium on an annual basis. This paper attempts to explain the evolution of safeguards since the beginning of the nuclear age, and specifically to analyze the safeguards technology to be applied at Rokkasho-mura.

The broader proliferation implications of the Rokkasho-mura facility are not widely discussed in this paper, but they will have to be in the coming months. Such a facility will not be operating in a political vacuum, but rather in one of the most unstable regions in the world, North-east Asia. All countries in the region – Japan, North and South Korea, Taiwan and China, as well as the Russian Federation, and the United States military presence, make this a region of high tension, high stakes and potentially catastrophic consequences. All of them have nuclear programs at various stages of development from the on-going modernization of U.S. and Chinese nuclear weapons, to the opaque nuclear weapons program in North Korea, as well as the continuing interest in acquiring plutonium by the nuclear establishments in Taiwan and South Korea. However, Japan is alone in the region in moving ahead with the stockpiling of large quantities of plutonium for which it has no practical peaceful use.[3]

In recent weeks tension has been ratcheted upwards with the disclosure and confirmation from Pyongyang that they have embarked upon a uranium enrichment program with the intention of securing fissile Highly Enriched Uranium (HEU) for nuclear weapons. Whatever the reality of the program, and there are certainly major unanswered questions over the ability of North Korea to successfully complete and operate a large-scale enrichment program, the effect has been to focus international opinion on the nuclear proliferation dynamics in North-east Asia. As more is understood about the planned operation of Rokkasho, the plans to use a flawed safeguards system by the International Atomic Energy Agency, and the further accumulation of weapons-usable plutonium stocks the nuclear proliferation debate in the region is guaranteed to become a central tenet of international relations both for countries in the region, and beyond.

THE EVOLUTION OF INTERNATIONAL NUCLEAR SAFEGUARDS

The need to control nuclear technology has been recognised since it became clear in 1939 that a fission chain reaction could be produced in uranium. Some of the scientists involved in the discovery of, and

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2 1 “Limiting the Spread of Weapons-Usable Fissile Materials", National Defence Research Institute, Rand Corporation, November 1993, p. xiii.

3 2 Current stocks belonging to Japan are in excess of 38 metric tons, this is set to increase to over 45 tons by around 2010, not including what is separated at Rokkasho-mura. Demand for plutonium in Japan’s Mixed Oxide Fuel, MOX, program has collapsed in recent years, with not one gram loaded in commercial reactors. Greenpeace estimates earlier this year calculated that the country’s stocks will be in excess of 140 tons by 2020, if Rokkasho operates, with at least 110 tons in excess of demand. Recent developments in Japan centred around Tokyo Electric, Japan’s largest electrical utility have already delayed the MOX program even further, with consequences for even greater plutonium surplus.

research into, nuclear fission attempted to restrict exchanges of information about fission in an effort to prevent the discovery from spreading. This restriction was seen to be necessary because it was foreseen that nuclear fission could be used to produce extraordinarily destructive weapons. The attempt at controlling nuclear information failed.

When it was realised that secrets about nuclear technology and the materials needed to produce nuclear fission could not be confined to one nation, demands grew for some assurances that any information about nuclear technology and supplies of nuclear equipment and materials provided by one country to another would be used for the purposes agreed and not diverted to the production of nuclear weapons. Demands for such assurances escalated after the awesome devastation produced by nuclear weapons in Hiroshima and Nagasaki became widely known. Soon after the end of the Second World War in 1945, the concept of international nuclear safeguards was born. Hiroshima and Nagasaki ensured that almost from the birth of the nuclear age efforts to prevent the use of 'peaceful' nuclear energy for military purposes would fail.

The term 'safeguards' was first used in this context in November 1945 in a document called the "Three Nation Agreed Declaration" on international nuclear energy policy by the President of the United States, and the Prime Ministers of Canada and the United Kingdom. The first session of the General Assembly of the United Nations in January 1946 created the United Nations Atomic Energy Commission (UNAEC), charging it with preparing proposals for "the elimination from national armaments of atomic weapons and all other major weapons adaptable to mass destruction", together with "effective safeguards by way of inspection and other means to protect complying States against the hazards of violation and evasion".

The Acheson-Lilienthal Report

Before the UN created the UNAEC, the United States established a panel chaired by US Secretary of State Dean Acheson to "study the subject of controls and safeguards necessary to protect American interests. This panel commissioned a panel of experts led by David Lilienthal, chairman of the Tennessee Valley Authority (TVA) to study the issues. In one of the most significant documents of the nuclear age, the Acheson- Lilienthal report, released in March 1946, reported that:

> ***"We have concluded unanimously that there is no prospect of security against atomic warfare in a system of international agreements to outlaw such weapons controlled only by a system which relies on inspection and similar police-like methods".***

Verifiable nuclear disarmament, according to the Acheson- Lilienthal panel, would require that countries be completely prohibited from producing fissile materials or conducting activities supporting a nuclear-weapon programme. All such activities would be conducted by an international agency created for the purpose. The agency would provide nuclear fuel for nuclear-power reactors.

In March 1946, President Harry Truman appointed Bernard M. Baruch to represent the US at the UNAEC. His proposal, presented in June 1946, was mainly based on the Acheson- Lilienthal report but insisted that the international control mechanism should include a provision for enforcement that would not be subject to the veto of the Security Council, a provision opposed by the Soviet Union. The USA and the USSR also could not agree on the inspection rights the international agency would have and the mechanism for enforcing the international control regime. In any case, it is unlikely that the US Senate would have ratified any such treaty even if there had been agreement between the USA and the USSR.

In the absence of an international regime that would ban nuclear weapons in the hands of individual nations, the USA continued the development of its own nuclear arsenal. The opportunity for international control of nuclear activities was lost. The USSR detonated its first nuclear weapon in 1949; the UK did so in 1952; France did so in 1960; and China in 1964.

In December 1953, US President Dwight Eisenhower, in a speech before the United Nations, proposed, as part of his "Atoms for Peace" programme, the creation of a new International Atomic Energy Agency to take custody of nuclear material, ensure its safe keeping, and use it for peaceful purposes. In 1954, the US started to enter into bilateral nuclear co-operation agreements with other countries. These agreements included provisions, called safeguards, by which the USA could be assured that nuclear material and technology it provided to other countries was not diverted to military use. At the same time, the US began negotiations to create the International Atomic Energy Agency (IAEA). These negotiations ended in 1956 with the approval of the IAEA Statute. The mission of the IAEA, defined in Article II of the Statute, is to "accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world". In 1957, the IAEA was established as an intergovernmental organisation affiliated with the UN.

The IAEA's safeguards system

The IAEA was given the authority to enter into safeguards agreements with individual nations to ensure that any nuclear materials, equipment or facilities offered up for inspections were not diverted to military purposes. The first safeguards agreement was between the IAEA and Japan in 1959. But the IAEA did not adopt a comprehensive safeguards system – to be applied, on request, to individual nuclear activities within a state and to all activities receiving IAEA technical assistance.

The legal basis for the IAEA's safeguards system is Articles III and XII of the Statute of the IAEA and Article III.1 of the Nuclear Non-Proliferation Treaty (NPT). The Agency's safeguards system is essentially set out in two basic documents - Information Circular 61 (INFCIRC/61/Rev.2) and Information Circular 153 (INFCIRC/153). INFCIRC/61/Rev.2 was evolved by the Agency prior to the signing of the NPT. After the Treaty came into force in 1970 the system was made stricter and more rigid, to take into account the obligations assumed by IAEA Member States in respect of non-proliferation .[4] Safeguards have also been strengthened by measures designed to improve the Agency's capability to detect undeclared activities. These are defined in a Model Additional Protocol (INFCIRC/540) approved by the IAEA Board in May 1997.

The IAEA Board of Governors finalised the post-NPT safeguards system in February 1972; it has the title "The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons". Published by the IAEA as INFCIRC/153 (Corrected), it takes into account Article III of the NPT, which states that the required safeguards "shall be applied on all source or special fissionable material in all peaceful nuclear activities within the territory of such state, under its jurisdiction, or carried out under its control anywhere". All plutonium and highly enriched uranium above gram quantities are subject to safeguards. NPT safeguards focus on nuclear material, particularly weapon-usable plutonium and enriched uranium.

Although the IAEA is not a party to the NPT, the non-nuclear-weapon parties to the NPT (defined as states that had not manufactured and detonated a nuclear device by January 1, 1967) have assumed obligations vis-à-vis the Agency under safeguards agreements, which under the NPT itself they are obliged to conclude with the Agency. Nuclear-weapon parties to the NPT are not subject to safeguards under the Treaty but some have voluntarily permitted the IAEA to inspect some of their nuclear facilities.

Comprehensive safeguards agreements, which follow the standard INFCIRC/153 model, include an obligation for the state to accept safeguards on all source (natural and depleted uranium and thorium) and special fissionable materials (enriched uranium and plutonium) in all peaceful nuclear activities within its territory, under its jurisdiction or carried out under its control anywhere - so-called full-scope safeguards.

The safeguards agreements set out the Parties' basic rights and obligations relevant to the application of safeguards. Detailed implementation procedures are set out in so-called "subsidiary arrangements", referring specifically to the requirements of the facilities to be safeguarded.[5]

The application of safeguards

Under NPT safeguards agreements, the IAEA has the right and obligation to ensure effective application of safeguards in conformity with the commitments undertaken by the State in question; no distinction is made between declared and undeclared material. The Agency is obligated to make sure that all materials subject to safeguards are in fact safeguarded.

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[4] Pellaud, B., Safeguards in Transition: Status, Challenges, and Opportunities, IAEA Bulletin, Vol.36, No.3, September 1994, p.2-7.
[5] Pellaud, B., IAEA Safeguards in the 1990s: Building on Experience, IAEA Bulletin, Vol.37, No.1, March 1995, p.14-20.

This requirement means that the Agency is authorised to make special inspections in States with comprehensive safeguards agreements, if it is deemed necessary and appropriate to do so to ensure that all nuclear materials in all peaceful nuclear activities are under safeguards. The legal basis for the Agency's right to conduct special inspections is the safeguards agreements concluded pursuant to INFCIRC/153 (Corrected). (The enforced inspections of Iraq, after its military defeat in the 1991 Gulf War, are untypical.)
The activities monitored by the IAEA under safeguards are: nuclear reactor operation; the fabrication of fuel for nuclear reactors; the separation of plutonium from spent reactor fuel elements in reprocessing plants; the enrichment of uranium; and nuclear research. Safeguards are applied to nuclear materials used in the facilities involved in these activities, namely, special fissionable material and source material.

Some states that have not joined the NPT have agreed to accept full-scope safeguards under other arrangements. For example, some exporters of nuclear materials (such as uranium), equipment, or facilities demand that importing states accept full-scope safeguards. For states that have not joined the NPT or otherwise agreed to accept full-scope safeguards, Agency inspections are limited to only specific materials, equipment, and facilities. These states negotiate agreements with the IAEA but need not declare all their nuclear material.

The IAEA's safeguards budget is only about US $100 million per year. And the safeguards budget has been frozen for over a decade because of the zero real growth policy imposed on all United Nations organizations. The Agency has, therefore, to rely on "voluntary" funding to finance almost one-fifth of its safeguards activities. This state of affairs inevitably undermines the Agency's ability to conduct credible verification.

The main method used in safeguards is nuclear material accountancy. This is supplemented by containment (using seals, for example), surveillance (using video cameras, for example), and on-site inspections (the IAEA employs about 200 full-time inspectors). The importance of material accountancy is embodied in INFCIRC/153: "To this end the Agreement should provide for the use of material accountancy as a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures". Safeguards are essentially an audit system. It should be emphasised that safeguards can only detect the diversion of safeguarded nuclear materials from peaceful to military purposes. They cannot prevent such diversion.

The information available to the IAEA comes from declarations made by States subject to safeguards, information found by inspectors, reports by countries exporting nuclear facilities and materials, and information provided by third parties. Inspections may be ad hoc, routine, or special. The frequency of inspections depends on the nature of the activities and form of nuclear material where safeguards are applied; in general, it is between once a year and a continuous inspection presence.

About 60 per cent of the Agency's safeguards budget is spent on inspecting facilities in Canada, Germany, and Japan. This is a reflection of the scale of these 'non-nuclear weapons states' peaceful nuclear activities, the Agency's inadequate budget and an indication that the Agency has to limit its activities. But it is also a historical legacy given long-standing concerns that at least in the case of Germany and Japan nuclear material could be diverted to military purposes. It has, for example, decided not to carry out significant safeguards activities in the nuclear-weapon states, even though it could do so if it so chose.

Safeguards agreements do not allow inspectors to inspect any location at any time unless the Agency has evidence of suspicious activities. Even then, the Agency must consult with the country concerned to obtain access to make a "special inspection". Otherwise, during routine inspections, Agency inspectors are limited to inspecting designated areas in declared facilities. In spite of the discovery that Iraq had a clandestine nuclear-weapon programme while an NPT party routinely inspected by the IAEA, many IAEA Members are unhappy about the idea that the Agency should be able to make special inspections and certainly do not encourage such inspections.

Any non-compliance discovered by the inspectorate is reported to the Director General who makes a report to the Board of Governors. The Board will call on the country concerned to remedy any non-compliance it has found to occur and reports the matter to the UN Security Council and the General Assembly of the UN. These reports are confidential and not disclosed publicly.

The goal of IAEA safeguards

The goal of the IAEA, in theory at least, is to verify that for a given period "no significant quantity of nuclear material has been diverted or that no other items subject to safeguards have been misused by the State". A 'significant quantity' is the amount of nuclear material for which "the possibility of manufacturing a nuclear explosive device cannot be excluded". For plutonium, a significant quantity is defined as eight kilograms; for highly enriched uranium (enriched to 20 per cent or more in the isotope uranium-235) it is defined as 25 kilograms; for low-enriched uranium (enriched to less than 20 per cent in uranium-235) it is 75 kilograms; and for uranium-233 it is 8 kilograms.

Nuclear weapons can be manufactured from plutonium containing almost any combination of plutonium isotopes, although plutonium containing high percentages of the isotope plutonium-239 is more suitable than plutonium containing more than 10 per cent or so of the isotope plutonium-240. Except for plutonium containing 80 per cent or more of the isotope plutonium-238, all plutonium is considered to be of equal sensitivity for the purposes of IAEA safeguards in non-nuclear-weapon states.

The significant quantities were set by the Director General's Standing Advisory Group on Safeguards Implementation (SAGSI) as long ago as 1977 and are, on today's standards, far too high. There is no difficulty in fabricating a nuclear weapon with an explosive power equivalent to that of 20,000 tonnes of TNT using about 4 kilograms of weapon-grade plutonium. A country with access to technology of only a medium level could do so.

A good designer could get an explosive power equivalent to that of about 1,000 tonnes of TNT with just one kilogram of weapon-grade plutonium. To be credible, the 'significant amounts' used by the IAEA should be redefined and considerably reduced. In the concept of IAEA safeguards, the timeliness of detection of the diversion of nuclear material from peaceful to military purposes is crucial. The Agency's objective is defined as "the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection".

The SAGSI guidelines for effective safeguards were that the diversion of a significant quantity should be detected, with a 90 to 95 per cent probability, within a 'conversion time' with a false-alarm rate of no more than 5 per cent. The concept of a conversion time is based on the time likely to be required to convert diverted fissile material into a form that could be used in a nuclear weapon. The times are: for each of plutonium and highly-enriched uranium, 7 to 10 days; for plutonium in spent nuclear-reactor fuel, 1 to 3 months; for low-enriched and natural uranium 12 months; and for plutonium oxide 1 to 3 weeks. Again, on today's standards these times are too long. In fact, the cases of Iraq, North Korea, and South Africa have put paid to the expectation of timely detection .[6]

The fact is that the IAEA cannot ensure timely detection through the standard safeguards methods of material accountancy, containment and surveillance. Its goal of timely detection is "within one month for fresh fuel containing HEU, plutonium, or mixed-oxide fuel". But if a country decided to divert plutonium or highly enriched uranium from its civil nuclear programme to fabricate nuclear weapons, it could assemble nuclear weapons very quickly. The country could first produce all the non-nuclear components of nuclear weapons. The diverted fissile material could be fabricated into the nuclear components for the weapons and these components for the weapons and these components assembled into the weapons in a matter of days or weeks rather than weeks. The Agency's timeliness goal is simply not attainable, even with the best will in the world.

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[6] Leventhal, P., IAEA Safeguards Shortcomings: A Critique, Nuclear Control Institute, Washington, DC., September 12, 1994.

But undoubtedly the most serious problem facing a nuclear safeguard system is that the most sensitive plants so far as the diversion of weapon-usable materials - particularly uranium-enrichment facilities, reprocessing plants, and MOX plants - is impossible to safeguard effectively .[7] Using existing and foreseeable safeguards technology it is not possible for a safeguards agency to detect the diversion of quantities of weapon-usable fissile materials that could be used to fabricate one or more, or even many, nuclear weapons.

The Agency was lulled into a false sense of security by the assumption that any clandestine programme to manufacture nuclear weapons could be detected at an early stage by national intelligence agencies, particularly by the use of satellite surveillance. The fact that Iraq was able without detection to construct a large complex of facilities for its nuclear-weapon programme and make considerable progress in important parts of the programme, an effort which became known only after the Gulf War and only because of information provided by an Iraqi defector, was a great shock to the Agency, whose inspectors had visited Iraq regularly and made inspections in buildings next to those in which nuclear-weapon activities were being conducted.

Attempts to strengthen safeguards

In the light of the cases of Iraq and North Korea, SAGSI admitted that the current safeguards system had to be strengthened if confidence in and the credibility of the system are to be enhanced. The group recommended some additional safeguards measures; the use of techniques to monitor the environment (air, soil, and water) at nuclear facilities to detect the presence of radioisotopes and other materials typical of nuclear activities; inspecting areas beyond the strategic points within declared facilities; increasing unpredictability in the location and timing of routine inspections; and conducting special inspections at sites when there are indications of potential undeclared activities or sites, after consultation with the state concerned.

According to SAGSI, these measured could be adopted without the IAEA having to revise its safeguards agreements. A standard arrangement could be made with each state accepting full-scope safeguards allowing environmental monitoring and extending access beyond that allowed under existing safeguards arrangements. It was to this end that the IAEA Board of Governors approved an Additional Protocol to IAEA Safeguards Agreements designed to enhance significantly the credibility of the safeguards system. The main aim of the Additional Protocols is to enable the IAEA to provide assurance about both declared and possible undeclared activities by providing as complete a picture as possible of nuclear activities and not limit itself to the confines of nuclear activity. The Agency is allowed adequate rights of access and enables it to use the most advanced technology. Under the Additional Protocol, states are required to provide the Agency with an extra declaration containing information covering all aspects of their nuclear and nuclear fuel cycle activities. The Agency has the right to collect environmental samples anywhere it has the right of access. It plans to use remote monitoring technology extensively to improve the efficiency of the safeguards system. Japan signed in 1998 and ratified the Additional Protocol in December 1999, in contrast to the European Union or Euratom nations which have although having signed in 1998 has yet to ratify.

In the ultimate analysis, IAEA safeguards can only be effectively applied if the country concerned is not intent on violating its obligations under the NPT or its safeguards agreement with the Agency. In other words, safeguards depend on the country behaving lawfully. The IAEA cannot be expected to discover clandestine nuclear facilities - such as a relatively small hidden nuclear reactor and a small facility to separate plutonium from spent reactor fuel - in a country that deliberately sets out to deceive the Agency.

The results of IAEA safeguards inspections are kept closely guarded secrets. The ostensible reason for it is to protect sensitive commercial information. As always, secrecy breeds suspicion. Making safeguards information publicly available would significantly improve the credibility of the international safeguards system.

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[7] Miller, M. M., Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?, Nuclear Control Institute, Washington, DC., August 1990.

As of 1 January 2001, 188 States were Party to the NPT. Of these, 51 non-nuclear-weapon States party had not fulfilled their legal obligation to conclude the required safeguards agreement. Between May 1997, when the Model Additional Protocol was adopted, and the end of 2001, Additional Protocols had been approved with only 58 countries, of these Additional Protocols, 21 were in force.

Timely detection

In the concept of IAEA safeguards, the timeliness of detection of the diversion of nuclear material from peaceful to military purposes is crucial. The Agency's objective is defined as "the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear ex-plosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection".

The IAEA guidelines for effective safeguards are that the diversion of a significant quantity should be detected, with a 90 to 95 per cent probability, within a 'conversion time' with a false-alarm rate of no more than 5 per cent. The concept of a conversion time is based on the time likely to be required to convert diverted fissile material into a form that could be used in a nuclear weapon. The times are: for each of plutonium and highly-enriched uranium, 7 to 10 days; for plutonium in spent nuclear-reactor fuel, 1 to 3 months; for low-enriched and natural uranium 12 months; and for plutonium oxide 1 to 3 weeks. Again, on today's standards these times are too long. In fact, the cases of Iraq, North Korea, and South Africa have put paid to the expectation of timely detection.[8]

The fact is that the IAEA cannot ensure timely detection through the standard safeguards methods of material accountancy, containment and surveillance. Its goal of timely detection is "within one month for fresh fuel containing highly-enriched uranium, plutonium, or mixed-oxide fuel". But if a country decided to divert plutonium or highly-enriched uranium from its civil nuclear programme to fabricate nuclear weapons, it could assemble nuclear weapons very quickly. The country could first produce all the non-nuclear components of nuclear weapons. The diverted fissile material could be fabricated into the nuclear components for the weapons and these components for the weapons and these components assembled into the weapons in a matter of days or weeks rather than weeks. The Agency's timeliness goal is simply not attainable, even with the best will in the world.

CAN PLUTONIUM BULK-HANDLING FACILITIES, SUCH AS THE ROKKASHO REPROCESSING PLANT BE ADEQUATELY SAFEGUARDED?

The most sensitive plants as far as the diversion of weapon-usable materials is concerned are facilities that handle large amounts of weapon-usable fissile materials - highly enriched uranium and plutonium, particularly uranium-enrichment facilities, reprocessing plants, and MOX fuel manufacturing plants. Applying effective safeguards to these plants presents the IAEA, and any other safeguards system, with an impossible task.[9] Using existing and foreseeable safeguards technology it is not possible for a safeguards agency to detect the diversion from bulk-handling facilities of quantities of weapon-usable fissile materials that could be used to fabricate one or more, or even many, nuclear weapons.

Safeguarding the plutonium in spent nuclear reactor fuel elements is relatively simple. It is just a matter of counting the number of the elements in their store – in a cooling pond, for example. For many years, the elements are so radioactive that they must be handled with remote equipment. Safeguarding them is a matter of unit accountancy plus surveillance with video cameras.

Once the plutonium is removed from spent reactor fuel elements in a commercial reprocessing plant, however, it is quite a different matter. Commercial reprocessing plants process a large amount of plutonium – typically, several tonnes per year. A good nuclear-weapons designer could construct a nuclear weapon from 3 or 4 kilogrammes of this reactor-grade plutonium. To ensure the timely detection of the diversion of such a small amount of plutonium in a plant where so much plutonium is handled requires very precise safeguards techniques, requiring more precision than is currently achievable.

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[8] Opcit, IAEA Safeguards Shortcomings…

[9] . Berkhout, F. and Walker, W., Safeguards at Nuclear Bulk Handling Facilities, in Poole, J. B. and Guthrie, R., (eds.), Verification 1992, Verification Report 1992, Brassey's, London, 1992, p.199-209.

At a conference in Vienna in June 1997, Matthew Bunn, who chaired the US National Academy of Sciences analysis of options for the disposal of plutonium removed from nuclear weapons, made a crucially important statement, about the value of reactor-grade plutonium for the fabrication of nuclear weapons, based on recently declassified material "of unprecedented detail on this subject":

"For an unsophisticated proliferator, making a crude bomb with a reliable, assured yield of a kiloton or more -- and hence a destructive radius about one-third to one-half that of the Hiroshima bomb -- from reactor-grade plutonium would require no more sophistication than making a bomb from weapon-grade plutonium. And major weapon states like the United States and Russia could, if they chose to do so, make bombs with reactor-grade plutonium with yield, weight, and reliability characteristics similar to those made from weapon-grade plutonium. That they have not chosen to do so in the past has to do with convenience and a desire to avoid radiation doses to workers and military personnel, not the difficulty of accomplishing the job. Indeed, one Russian weapon-designer who has focused on this issue in detail criticised the information declassified by the US Department of Energy for failing to point out that in some respects if would actually be easier for an unsophisticated proliferator to make a bomb from reactor-grade plutonium (as no neutron generator would be required)."

The timely detection of the diversion of relatively small amounts of plutonium, a few kilogram, in a plant where so much plutonium is handled requires very precise safeguards techniques, requiring more precision than is currently achievable. It must be emphasized that this is not a matter of the efficiency and competence of the inspectors or of the operators of safeguards instruments. Even with the best available and foreseeable safeguards technology it is not possible to get the precision necessary.

The safeguards agencies claim that a commercial plutonium-reprocessing plant can be safeguarded with effectiveness greater than about 99 per cent. This means that, even on the most optimistic assessments, at least 1 per cent of the plutonium throughput will be unaccounted for.

Some independent experts estimate that a more realistic figure for the effectiveness of safeguards on a commercial plutonium-reprocessing plant is 95 per cent and that at least 5 per cent of the plutonium throughput will be unaccounted for.

What do these figures imply? A typical plant will have a maximum throughput of about 8 tonnes of plutonium a year. If the plant can be safeguarded with an effectiveness of about 99 per cent, about 80 kilograms of plutonium a year, enough to produce about 15 or more nuclear weapons a year will be unaccounted for.

If the plant can be safeguarded with an effectiveness of about 95 per cent, about 400 kilograms of plutonium a year, enough to produce about 75 or more nuclear weapons a year will be unaccounted for. These examples bring home the major and fundamental weakness in the international nuclear safeguards system, a weakness which cannot be rectified, and which will apply to any safeguards system. Much of this is connected with the uncertainty about the amount of plutonium entering the plant.[10]

Safeguarding a reprocessing plant

The main method used by the IAEA to safeguard nuclear facilities, including reprocessing plants, is, as described in chapter 1, material accountancy. This is supplemented by containment (using seals, for example), surveillance (using video cameras, for example), and on-site inspections by IAEA inspectors. The importance of material accountancy is embodied in INFCIRC/153:

"To this end the Agreement should provide for the use of material accountancy as a safeguards measure of fundamental importance, with containment and surveillance as important complementary measures".

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[10] Johnson, S. and Islam, N., The Current IAEA Approach to Implementation of Safeguards in Reprocessing Plants, Proceedings of the Third International Conference on Facility Operations - Safeguards Interface, 1991.

The IAEA has described inspection activities for each type of nuclear facility, including a typical reprocessing plant with a throughput greater than one significant quantity of plutonium (8 kilograms, see chapter 1). The descriptions are known as Safeguards Criteria. For a reprocessing plant, inspection activities are defined for:

(1) the verification of inventory changes;
(2) the verification of flows within material balance areas (MBAs);
(3) the verification of the interim inventory; and
(4) the examination of operator records and reports. Activities 1 and 2, involving the verification of flows, require the continuous presence of inspectors at the plant. Activities 3 and 4 are done monthly. The verification of the physical inventory is done annually.

Material balance areas

A MBA includes a specific part of the reprocessing plant, with such a plant normally divided into at least three MBAs:

MBA 1 – the input MBA or head-end - the part of the plant into which spent reactor fuel elements are received and stored and in which the cladding of the fuel elements is removed and the elements dissolved in concentrated nitric acid;

MBA 2 – the reprocessing MBA - the part after the dissolver in which the reprocessing chemistry takes place; and

MBA 3 – the output MBA - the stores in which the separated plutonium and uranium is kept.

All significant flows (inventory changes) of nuclear material into and out of the reprocessing plants and between MBAs are verified. Less significant inventory changes – like waste material and recycled material – are also verified but at a lower level.

Verification activities in MBA 1

MBA 1 contains the spent fuel pond, used to store spent-fuel elements until they are required for reprocessing, the mechanical cell and chopper and the dissolver. Verification points include the spent fuel receipts, the spent fuel inventory, the transfer from the pond to the mechanical cell, and the chopping and dissolution of fuel.

Inspectors observe the opening of the cask lid, count the fuel elements, and randomly select elements for identification using Cerenkov radiation or gamma-ray detection. Automated verification may be used involving a counting-surveillance system or a non-destructive analysis system. Measures are taken to make sure that elements are not reloaded into the cask before it leaves the area. Video surveillance is used to observe the empty cask when it leaves the pond.

The verification of spent fuel receipts is the verification of an inventory change; the verification of the spent fuel inventory (performed by surveillance) is the verification of an inventory; the verification of the transfer to the mechanical cell is the verification of a flow within the MBA (performed by CCTV and gamma-ray monitors); and the verification of the chopping and dissolving of the spent fuel is the verification of a flow within the MBA (performed by measuring the levels and densities of the fluid in the dissolver).

Verification activities in MBA 2

MBA 2 is the chemical reprocessing section in which the plutonium, uranium and fission products are chemically separated. The chemistry is not simple and there are many changes during the process in the chemical composition and concentrations of the materials. Complex and changing mixtures of nuclear and non-nuclear materials are involved.

The nature of the operations in MBA 2 adds to the problems of safeguarding them. The operations are largely automated; the computers deal with large amounts of data. The materials are normally highly radioactive and must be handled with remote-handling equipment. The heavy radiation shielding around much of MBA 2 makes large parts inaccessible when the plant is operating.

Each transfer of solution from the dissolver into the reprocessing MBA, via the input accountability tank, is verified by volume or weight measurement, sampling and analysis for plutonium and uranium. The input accountability tank contains instrumentation to measure solution levels and density and temperature. The calibration of the vessels used is observed. The calibration of the input accountability tank is checked or a recalibration is done annually. Input accountability involves the verification of an inventory change.

All samples are analyzed for plutonium and some chosen randomly for uranium analysis. The preparation of samples, shipping them (to an IAEA laboratory) and analyzing them can take up to three months. A quicker estimation and evaluation of the input to MBA 2 is performed by estimating the concentration of uranium in the sample using density correlation and then using the ratio of plutonium-to-uranium, provided by the reactor operator, to estimate the amount of plutonium in the sample. Verification in MBA 2 is inventory verification using accountancy and sample taking.

Verification activities in MBA 3

MBA 3 contains uranium storage and plutonium storage. There is no need top verify transfers of uranium from the reprocessing area. All transfers of plutonium from MBA 2 are verified strictly. A plutonium accountability tank, provided at the end of the plutonium cycle, is carefully calibrated. Instruments in the tank measure the level, density and temperature of the solution in the tank.

The verification of plutonium storage is an inventory verification, involving sampling and analysis and the continuous monitoring of movements in and out of storage. The plutonium is produced in the reprocessing plant in the form of a plutonium nitrate solution. This is converted to solid plutonium dioxide (PuO_2) and stored in sealed containers containing up to 2 kilograms of PuO_2. The plutonium store is continuously monitored by CCTV. When moved out of the store, the plutonium containers are identified and the seals checked by radiation monitors.

Inspection of records and reports

An important part of the safeguards system is the examination of the accounting records of the plant to examine the consistency with operating records and other documents. Records of inventory changes and material balances are compared with previous accounting records. Normally, the plant records are examined at the plant monthly.

MUF – or 'Material Unaccounted For'

If the amount of nuclear material entering the MBA is I and the amount leaving the MBA is O and R is the total amount of nuclear material legally removed from I, then, if no material is lost,

$$O = I - R.$$

If an amount, X, of nuclear material is lost or otherwise unaccounted for,

$$O = I - R - X.$$

Hence,

$$X = I - R - O.$$

X is called the "Material Unaccounted For" or MUF. A main purpose of safeguarding plutonium bulk-handling facilities is to determine the value of the MUF. The problem with applying safeguards to a plutonium bulk-handling facility (such as reprocessing or MOX fuel production plants) is that it is not possible to measure any of I, R or O accurately. This means that even if there is no diversion of plutonium, values of MUF will be obtained that are not zero. Materials accountancy must, therefore, rely on statistical tests to determine whether positive values of MUF are due to diversion or to a chance combination of measurement errors.

The IAEA inspectors will work with the plant operator to estimate the values of O, I and R. If X turns out to be zero, the Agency will conclude that no diversion of plutonium has taken place. If X has a positive value there may have been a diversion of plutonium. The amount of uranium in the spent reactor fuel elements put into the reprocessing plant is calculated by the reactor operators from their knowledge of the amount of uranium originally in the reactor fuel elements and of the way in which the reactor was operated while the fuel was in it, in particular the amount of heat (thermal energy) produced by the fuel.

The estimate relies on computer calculations. The reactor operators do not state the possible error in their calculations. But independent experts calculate it to be about 5 per cent.[11]

The first measurement, as opposed to an estimate based on calculation, of plutonium in the reprocessing plant is made on samples taken from the accountancy tank. Using mass spectrometry, the ratio of the amount of plutonium to the amount of uranium is determined. From the calculated amount of uranium and the measured uranium/plutonium ratio, the amount of plutonium is calculated.

There may be errors in each stage of this operation. For example, some plutonium will remain in the parts of the fuel elements not dissolved in the nitric acid (called "the hulls"). The amount is very difficult to estimate.

Because of the errors involved, the value of the MUF will usually not be zero even if no illegal diversion of plutonium has occurred. Its value may be either positive or negative. Statistical methods must be used to work out the probability that a positive MUF means that plutonium has been illegally diverted or arises because of a chance combination or errors in I and/or O and/or R.

The magnitude of the error in the MUF is given by the square root of the error variance in the MUF - @-MUF or the measurement error standard deviation. If @-MUF is large compared with a significant quantity, SQ (defined by the IAEA as the amount of plutonium for which the possibility of manufacturing a nuclear weapon cannot be excluded, which the Agency estimates to be 8 kilograms) then the minimum diversion that can be detected by IAEA safeguards measures with a high confidence and a low false alarm rate probability will be significantly greater than a SQ. Safeguards will, in this case, not serve their purpose.

Can the IAEA safeguard a reprocessing plant effectively?

Simply put no it cannot. The IAEA's guidelines for effective safeguards is that the diversion of a SQ should detected with a 90 to 95 per cent probability and with a false alarm rate of no more than 5 per cent within a conversion time, the time likely to be required to convert diverted plutonium into a form that could be used in a nuclear weapon. The conversion of plutonium in the form of plutonium nitrate or plutonium dioxide is between 1 and 3 weeks.

If the detection of an illegal diversion is to be timely enough to allow action to be taken to prevent the use of the plutonium to fabricate a nuclear weapon, the detection time must be significantly less than the conversion time so that the authorities can make a response.

To achieve a minimum diversion of a SQ detected with a 90 to 95 per cent probability and with a false alarm rate of no more than 5 per cent, assuming that @-MUF is 1 per cent, a material balance measurement must be made when about 240 kilograms of plutonium have been separated. If a reprocessing plant produces 8,000 kilograms of plutonium a year, it will separate 240 kilograms of plutonium in about 11 days. This means that a plant material balance measurement must be made every 11 days to detect the diversion of a SQ. But to satisfy the timeliness requirement the period must be much shorter than this, every 2 or 3 days.

Conventional materials accountancy provides material balance measurement, for a typical reprocessing plant, much less frequently than once every 2 or 3 days. Can a higher frequency be achieved? According to the Office of Technology Assessment of the US Congress:

> ***"barring acquisition of additional measurements and use of more sophisticated statistical analysis - many analysts have concluded that measurements are incapable of reliably detecting diversions of one or even several significant quantities of safeguarded material from large reprocessing plants. The conventional "material accountancy" safeguards methods now in use by the IAEA appear unable to assure that the diversion of a bomb's***

[11] Barnham, Keith, Physics Department, Imperial College of Science and Technology, London, private communication, 2001.

worth of plutonium per year from a large reprocessing facility - e.g., one processing much over about 100 tons of spent fuel per year - would be detected with high confidence.

New techniques such as "near-real-time accountancy" - unproven at this scale by the IAEA - must be adopted for large reprocessing plants, and even these techniques may not be able to measure material flows and inventories accurately enough to detect the absence of one bomb's worth of plutonium per year. In that case, if the IAEA could not demonstrate that safeguards methods other than the material accountancy techniques that form the core of its current safeguards approach can be relied on to detect diversion with a high degree of confidence, it would have to conclude that it could not safeguard such a plant to the same standards it applies at smaller facilities. To date, the IAEA has not considered the possibility that it may be unable to safeguard large facilities but neither has it been able to demonstrate that it can".[12]

Near-Real-Time-Accountancy (NRTA)

Basically, in NRTA, the in-process inventory of plutonium is monitored at frequent intervals, daily or at least weekly. The inventory is measured using direct measurements from in-process instruments, off-line analysis and data from computer simulations of the chemical process area (MBA 2). The idea is that, because the throughput over a short period of time is much smaller than that over, say, a month or a year (traditionally, the period used for material balance measurement in reprocessing plants), the effects of measurement uncertainties are generally proportionally reduced. Moreover, many more measurements are taken, so that various statistical tests can be used to increase the timeliness of detection compared with that resulting from inventories taken at, say, monthly intervals.

The use of NRTA at reprocessing plants in general, and at the Rokkasho reprocessing plant in particular, will be discussed in more detail in the next section of the paper.

SAFEGUARDS IN THE ROKKASHO REPROCESSING PLANT

Operated by Japan Nuclear Fuel Limited (JNFL), the Rokkasho-Mura Reprocessing Plant (RRP), with a planned operating capacity of 800 tonnes of spent nuclear power reactor fuel per year, is the largest and most complex nuclear installation so far subjected to IAEA safeguards. The spent fuel reprocessed will come from both pressurised- and boiling-water reactors.

RRP is a special reprocessing plant for two main reasons. First, Japan is a non-nuclear weapon country, whereas Britain and France, the two countries currently operating commercial reprocessing plants are nuclear-weapon powers. Because civil plutonium can be used to produce effective nuclear weapons, civil plutonium produced in Japan is of international interest. Second, for this reason, Japan has decided that the output of RRP should not be plutonium dioxide, as would normally be the case, but that the plutonium dioxide should be mixed with uranium dioxide in the plant so that the output is mixed-oxide (MOX) nuclear fuel.

IAEA safeguards at RRP

The extent and importance of the Rokkasho safeguards operation is indicated by the fact that the IAEA has established, with the Japan Safeguards Office, the JNFL Project to ‘plan, coordinate and integrate all activities necessary to design and implement an effective and efficient safeguards system’, related to safeguarding the RRP. The IAEA, the Japan Atomic Energy Bureau (JAEB) and JNFL are, and have been for a number of years, collaborating on the Project.

According to the IAEA, the objectives of the Project are:

- to establish a safeguards approach;
- to carry out the design information examination and verification;
- to design procure, and qualify all safeguards equipment including an on-site laboratory;
- to develop the necessary methods and software for data collection and evaluation;

[12] Office of Technology Assessment, Nuclear Safeguards and the International Atomic Energy Agency, Office of Technology Assessment, Congress of the United States, Washington, D. C., 1995.

- to draft the facility attachment; and,
- to arrange the training of inspectors and laboratory analysts for on-site verification.

The safeguards system is being designed to have a capability to detect the diversion of one SQ or more of nuclear material within successive one-month intervals and to detect the protracted diversion of one SQ of plutonium or uranium within one year. The approach is, and has been, to integrate, to the fullest possible extent, the safeguards systems into the plant design. From the beginning, design information has been comprehensively verified.

The IAEA hope that the JNFL Project will enable it to develop an effective and efficient safeguards system, that can be used for large-scale reprocessing plants, by preparing safeguards arrangements and procedures during the design, construction, commissioning and start-up of the plant. Although the IAEA has safeguarded reprocessing plants for at least 30 years now, the RRP is the first opportunity it has had to design a safeguards approach to a large commercial facility from scratch, incorporating design information and verification systems at all stages of construction. Having said that, the IAEA in the mid-1990's admitted the scale of the challenge faced by Japan's plans for Rokkasho,

"the major challenge facing the IAEA in the next years is to prepare for and implement effective safeguards at a large commercial reprocessing facility."[13]

Routine safeguards activities in RRP will depend on accountancy, conventional and near-real-time; monitoring systems (mainly unattended); containment and surveillance; non-destructive assay and solution monitoring. Unattended monitoring systems are used as much as possible to improve safeguards and reduce as much as possible requirements for inspectors and operators.

All important vessels containing solutions relevant to the verification of in-process and stored inventories and flows of nuclear material through the plant will be equipped with unattended systems to measure volume, density and temperature. Information about static inventories will be continuously available from containment or surveillance (or preferably, if applicable, dual containment and surveillance) measures.

Measures will be included in the safeguards system to detect, by periodical or random verification of the design, undeclared use of the plant. The flow of material through the plant will be continuously monitored for the same purpose.

The Main Balance Areas (MBAs)

The elements of the RRP are: the Spent Fuel Receipt and Storage are, which is now operating; the head end; the main chemical process area, that uses a PUREX separation process to remove the fission products, unused uranium and plutonium from the spent fuel elements; a MOX conversion area, in which uranyl nitrate and plutonium nitrate are co-denitrated and converted to MOX powder produced; waste treatment and storage areas; and an area for the storage of MOX powder and uranium trioxide (the uranium not used for the production of MOX is due to be converted to the trioxide and stored in the storage area).

The safeguards system is described in some detail in a paper co-authored by staffers from the IAEA Department of Safeguards, the Japan Safeguards Safeguards Office and Japan Nuclear Fuel Limited (1). The plant is divided into five MBAs for accountancy purposes. The addition of MOX production within the plant introduces another MBA. The MBAs are:

- MBA-1 – the spent fuel receipt and storage area plus the head-end area that uses a continuous dissolver;
- MBA-2 – the main chemical processing area;
- MBA-3 – the main treatment and storage area;
- MBA-4 – the MOX conversion area; and
- MBA-5 – the MOX and uranium storage area.

The five MBAs are subdivided into:

[13] See, Activities of the international Atomic Energy Agency Relevant to Article III of the Treaty on the Non-Proliferation of Nuclear Weapons, NPT/CONF/1995/PC.III/7, Document presented to the Third Session, Geneva, September 12-16, 1994.

"Inventory Key Measurement Points" (IKMPs) based on types of material and the verification approach to be applied to the Interim Inventory Verifications (IIV) for timely detection purposes and Physical Inventory Verification (PIV). Flow Key Measurement Points (FKMPs) have also been identified for all nuclear material streams or routes which cross MBA boundaries.

In addition to flows that cross MBA boundaries, Other Strategic Points (OSPs) are being defined for verification of flows within the MBAs. These OSPs provide confirmation of the operational status of the facility and that it is as declared." [14]

There will be nine IKMPs covering: the spent fuel receipt and storage area; the head-end area; nuclear material in the chemical processing area; nuclear material in the analytical laboratory; nuclear material in the uranium conversion area; nuclear material in the waste treatment and storage area; nuclear material in the MOX conversion area; uranium trioxide in the storage area; and MOX in the storage area.

These verification activities are designed to provide as much assurance as possible that there is no diversion of plutonium into the MUF or into the difference between the nuclear material declared in the spent fuel assemblies (calculated by the reactor operator) and the amount measured in the input accountancy tank and that estimated to be in the waste from the head-end process.

The latter difference is called the shipper/receiver difference (SRD). The SRD is an important quantity because, as discussed in section 2, it may be the source of the greatest error in the verification activities.

Methods and procedures

The aim is to use, wherever possible, unattended measurement and monitoring systems, many controlled by the safeguards inspectors. Some measurements will, however, include signals from systems controlled by the operators of the RRP. The plan is to introduce measures to check the data to enable the data to be authenticated.

Solution samples will be taken from the majority of the vessels using an authenticated, unattended sampling system. The samples will be sent for analyses in the On-Site Laboratory (OSL), which will be jointly used by the IAEA and JGSO. [15] The safeguards equipment to be used in RRP includes: time synchronised CCTV cameras, radiation detectors; to verify the reception of spent fuel elements and their transfer into the storage ponds; the transfer of solution from the dissolver to the chemical reprocessing process will be verified in batches using a Solution Monitoring and Measurement System (SMSS). The measurement of samples of uranium and plutonium will be carried out using an Automated Sampling Authenticated System (ASAS) or analysed by Hybrid K-Edge Densitometry (HKED).

The plan is to use an integrated Data Collection and Evaluation System (DCES) to collect measurements from instruments, sensors and surveillance equipment "throughout the facility and transmits them to a Raw Database (RDB)" jointly controlled and used by the IAEA and the JSGO.

A Physical Inventory Verification (PIV) will be carried out annually. The spent fuel will be verified using an Improved Cerenkov Viewing Device (ICVD). Plutonium will be assayed using spectrophotometry and uranium will be measured using Isotope Dilution Mass Spectroscopy (IDMS). Plutonium in Low Active Solid Wastes (LASW) shipped to the Waste Storage Area will be measured by neutron counting.

The MUF in MBA-2 will be evaluated sequentially by Near-Real-Time Accountancy (NRTA) using periods of between 5 and 15 days. NRTA is a crucial element in the safeguards system at RRP.

Near-Real-Time Accountancy

[14] Johnson, S. J., Abedin-Zadeh, R., Pearsall, C., Hiruta, K., Creusot, C., Ehinger, M., Kuhn, E., Chesnay, B., Robson, N., Higuchi, H., Takeda, S., Fujimaki, K., Ai, H., Uehara, S., Amano, H., and Hoshi, K., Development of the Safeguards Approach for the Rokkasho Reprocessing Plant, paper (number IAEA-SM-367/8/01) presented to the IAEA Symposium on International Safeguards: Verification and Nuclear Material Security, Vienna, 29 October 2001.
[15] Ibid.

In NRTA techniques, material inventories in MBAs and flows in and out of MBAs are monitored at relatively short intervals – weekly, for example – much shorter intervals than those used in conventional materials accountancy methods (which usually use a material balance period of a year). NRTA will be able to be applied in RRP because it is feasible to make frequent measurement of the plutonium inventory with out closing the plant down, a costly and lengthy procedure.

Because inventories are monitored more often and because statistical tests are applied to much larger data sets that are obtained, NRTA, it is claimed by those developing them, should improve both the timeliness of the detection of diversion and the sensitivity of detection compared with that obtained by monthly interim inventories.[16]

The process is evaluated by looking for inexplicable trends in the derived MUF values. NRTA depends the calibration of the system by obtaining a series of MUF values over a significant length of time when it is known that no diversion has taken place. It is assumed that deviations in this series of MUF values are caused by measurement errors and plant losses, such as plutonium retained in pipes, at the bottom of tanks and in other parts of the plant.

Systematic measurement errors are obtained from the series of MUF values, forming a baseline. During the proper operation of the plant, MUF values can be compared with this baseline. The measurement errors can be subtracted from the series of MUF values under investigation to determine if any diversion has taken place. The use of this calibration data reduces the magnitude of @-MUF, giving a higher sensitivity of detection. The baseline should be developed during the cold and hot commissioning of the plant. Statistical results obtained from the sequences of MUF data are tested against the hypothesis that no diversion has taken place. The statistical methods involved in this operation are very sophisticated and no convincing statistical method has yet been evolved that detects with high confidence all types of diversion, abrupt and protracted, and which does not give different results using different diversion scenarios.

The difficulty facing materials accountancy in RRP, with a capacity to reprocess 800 tonnes of spent fuel a year, can be explained by considering the quantities involved. The plant will reprocess spent nuclear-power reactor fuel with an average total plutonium content of up to 0.9 per cent. The main error in measuring the MUF, @(MUF), is the error in measuring the plutonium input. We can assume that this is equal to + or – 1 per cent, or more, of the amount of plutonium put into the plant.

Allowing for time taken for maintenance, the plant is likely to operate for say 200 days a year, giving a throughput of 252 kilograms of plutonium a week. The value of @(MUF) is 2.52 kilograms. The minimum amount of diverted plutonium that could be detected with a 95 per cent detection probability and a 5 per cent alarm probability is 3.3 @(MUF), or 8 kilograms – one SQ.

There are, however, a number of problems. NRTA will be labour intensive for the RRP operator and for the IAEA. A relatively large number of inspectors will have to be stationed at the plant, putting added strains on the IAEA's already meagre safeguards budget. The inspectors at the plant will soon learn the details of the plant's operation and this may conflict with demands for commercial confidentiality.

A more serious problem is that NRTA may not detect diversions of small amounts of plutonium in each material balance period so that over a long period of many weeks more than a SQ is diverted. The assumption that a diversion-free set of MUF data is available for calibration purposes is not valid if diversions began when the plant begins operating. NRTA would, under these circumstances, be ineffective. It could also be made ineffective if the operator put plutonium into the system during material balance periods.

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[16] Miller, Marvin M., Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?, Nuclear Control Institute, Washington D.C., August 1990.