Safeguarding nuclear fuel cycle facilities

A report on new challenges and possibilities helping to define future directions

by V. Schuricht and J. Larrimore

Implementation of safeguards by the IAEA, which is now entering its fourth decade, has reached a stage of early maturity. After a period of rapid growth in the late 1970s and early 1980s, the expansion of nuclear development in the world has slowed. This has enabled the IAEA to consolidate international safeguards implementation practices and to work toward improving the level of accomplishment of its functions. This article considers new challenges and possibilities for improvement of safeguards implementation, presents recent results obtained, and concludes with a forward look at future challenges.

New challenges

The IAEA Department of Safeguards has been confronted with new challenges in implementing safeguards at nuclear fuel cycle facilities during the past several years. Not only has the number of countries and facilities to be safeguarded increased but the amounts of nuclear material under IAEA safeguards have increased even more. In addition, new types of facilities came under IAEA safeguards.

During the 1980s, the number of countries with significant nuclear activities and the total number of installations under IAEA safeguards have continued to increase slowly, reaching 905 installations in 57 countries in 1987. Since 1980, a remarkable 50% increase took place in the number of power reactors to be safeguarded by the IAEA. (A summary of the number of different types of installations under safeguards at the end of 1987 is given in the accompanying table.) The Agency carries out inspections at about two-thirds of these installations annually.

A further indicator for the magnitude of safeguards activities needed is the amount of nuclear material under IAEA safeguards. There have been considerable increases in the amounts of plutonium, low-enriched uranium, and source material to be safeguarded during recent years. *(See graphs.)* The total amount of plutonium includes that contained in irradiated fuel and separated plutonium, which constitutes only a small fraction of the total amount; currently nearly 9 tonnes of it are under Agency safeguards.

The period of the 1980s has marked a certain maturing of the world nuclear industry. On the research and development side, some small or obsolete facilities have been closed down as nuclear research in general was being consolidated or concentrated in most countries with extensive programmes. The associated reduction in Agency safeguards efforts has been more than compensated by new safeguards tasks.

Four nuclear-weapon States have signed voluntary offer safeguards agreements and placed all or part of their civil facilities under safeguards, while negotiations have started with the fifth nuclear-weapon State. The Agency has applied, *inter alia*, safeguards to the follow-

Installations in non-nuclear-weapons States under safeguards or containing safeguarded nuclear material at the end of 1987

Installation type	Number of installations
Reactor-type facilities	
Power reactors	186
Research reactors and critical assemblies	172
Bulk-handling facilities	
Conversion plants	7
Fuel fabrication plants	40
Reprocessing plants	6
Enrichment plants	6
Separate storage facilities	34
Other facilities	46
Other locations	406
Non-nuclear installations	2
Total	905

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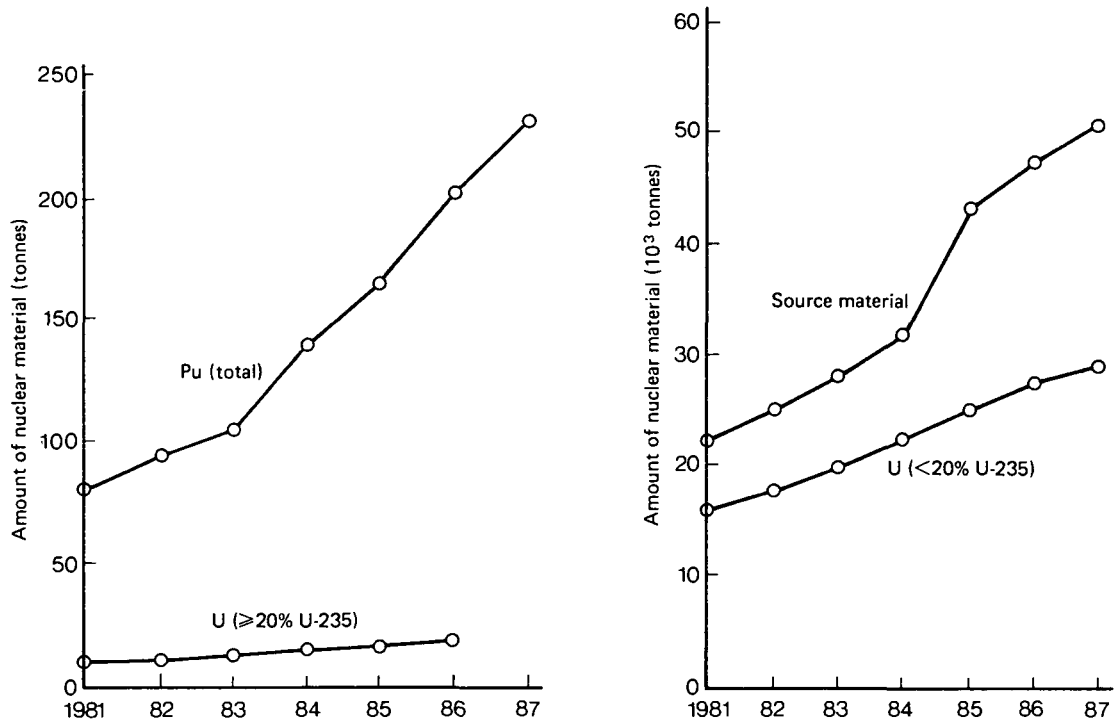
Amounts of nuclear material under IAEA safeguards
(including all safeguarded nuclear material in nuclear-weapon States)



Note: Data for plutonium refer to the total amount of plutonium, i e that contained in irradiated fuel and separated plutonium.

ing types of facilities in nuclear-weapon States: fast breeder reactors, spent fuel storage ponds, enrichment plants, reprocessing plants, plutonium storage facilities, fuel fabrication plants, power reactors, and research reactors.

Finally, new technology reached the large prototype or commercial stage in substantial measure over the period. The Agency is now applying safeguards to the following new types of facilities: commercial MOX fuel fabrication plants (producing mixed PuO_2-UO_2 fuel), high-temperature gas-cooled reactor, fast breeder reactor, and uranium enrichment plants using centrifuge technology.

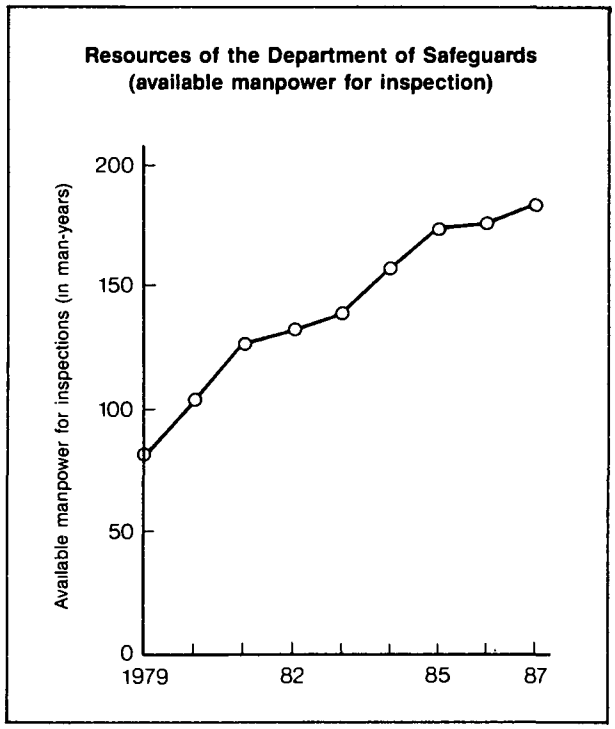
A very interesting aspect of the application of safeguards to these enrichment plants was the development of the safeguards system by the Hexapartite Working Group. For these facilities, the technology holders and the Agency together developed a safeguards system which would provide mutually acceptable assurances and which would at the same time protect the sensitive technology used in these plants. At present several enrichment plants using centrifuge technology are being safeguarded under agreements negotiated on the basis of the safeguards approach developed by the Hexapartite Working Group.

New possibilities

During the late 1970s and early 1980s, increased resources were made available which enabled the Agency to keep up with the increasing demands for safeguards implementation. Since the mid-1980s, activities have been emphasized which contribute to increasing the quality of the Agency's work. Close co-operation within the Agency and especially within the Department of Safeguards and between the Agency and States have contributed very much to the progress achieved.

The available manpower for inspections, while doubling since 1979 and now approaching 200 man-years, has leveled off in recent years. *(See graph.)* The calculation of available inspection manpower takes into account that an inspector or inspection assistant can perform inspections only after having completed the necessary training and having been approved for designation by the State to be inspected.

Increased financial resources available to the Department of Safeguards have resulted in improved support for the inspection work. Substantial advances were made in development and purchase of equipment, development of improved procedures, information treatment, evaluation of safeguards implementation, training, standardization, and administration.



A re-organization of the Department of Safeguards, initiated in 1982, resulted in an improved capability for co-ordinating safeguards implementation activities, specifically between the three divisions of operations.

Many improvements have been implemented in the preparation, performance, and evaluation of inspections. Some examples may be listed:

- A new computerized inspection reporting system for item facilities became operational at the end of 1982. In 1984 the computerized inspection report became the reporting medium for all facilities, including bulk-handling facilities.
- The IAEA Safeguards Information System is being routinely used in support of inspection activities and for safeguards evaluation and management information purposes.
- Inspection reports and statements are being reviewed using computer-assisted review procedures.
- The allocation of extra effort at Headquarters improved the timeliness of inspection reports considerably.

The introduction of new safeguards equipment and procedures is essential to make safeguards implementation more effective, more efficient, and less intrusive. Experience has shown that the introduction of new equipment from the development of a prototype through the approval for the routine use of commercially supplied equipment is a lengthy process. Furthermore, considerable time may be needed to get the approval from States' authorities and operators to use a new type of equipment routinely during inspections.

Nevertheless, a notable characteristic of recent years is the increase in the field use of new safeguards equipment, as well as a considerable increase in the programme for performance monitoring, procurement, documentation, maintenance, repair, and distribution. Associated with this have been increased requirements for routine services including the provision and verification of seals, film processing, the analysis of gamma spectrometric data, and arrangements for shipping and for the destructive analysis of inspection samples.

New surveillance television and recording systems have been installed in an increasing number of facilities as an alternate to the well-established photo surveillance systems. Bundle counters have been installed in on-load refuelled reactors and put into use. Portable multichannel analysers have replaced the stabilized assay meters which the IAEA had been using for more than a decade. A photo surveillance enclosure which is more tamper-resistant than its predecessor and has provision for conversion to video was procured and is now in use.

Procedures for routine use of K-edge densitometers and electromanometers have been tested and introduced. Furthermore, the Cerenkov viewing device and the high-level neutron coincidence counter have been steadily improved and are being used more extensively.

The Agency has continued to place emphasis on achieving progress in safeguards implementation by improving the co-operation between the IAEA and States. Liaison committees established according to the relevant agreements have continued their work. These committees and other regular forms of contact with facility operators have continued to make significant contributions to the solution of general and specific problems relating to safeguards implementation.

The establishment of IAEA offices in certain States has assisted the co-operation between the IAEA and these States. In May 1984, the IAEA office in Tokyo was formally established, after the successful experience with the IAEA field office in Toronto, Canada which came into existence in September 1980. These offices provide logistic support to the IAEA staff on duty in Canada and Japan and have led to a considerable improvement in solving safeguards problems through day-to-day contacts between the IAEA and State officials.* They also contribute to a more efficient utilization of inspection manpower. Resident inspectors are able to perform about twice as many man-days of inspection as do inspectors stationed at Headquarters in Vienna. In addition, these offices make it possible to carry out inspection activities at short notice, which could not be performed by headquarters-based inspectors, thus improving safeguards effectiveness.

The support provided to the Department of Safeguards by a sizeable number of Member States in the framework of their safeguards support programmes has become an essential element in improving safeguards implementation. Many successful projects

* Agreement has recently been reached to extend the functions of the Toronto office, renamed the "IAEA Regional Office in Toronto". Inspectors posted to that office will also inspect nuclear installations in the United States, Mexico, and Jamaica.

Safeguards implementation

	1980	1981	1982	1983	1984	1985	1986	1987
Surveillance systems in operation	140	160	190	230	240	290	325	320
Seals used	7 700	10 500	16 500	21 000	21 400	21 500	19 600	25 000
Plutonium, uranium samples analysed	780	890	870	1 150	1 080	1 270	1 030	1 360
Discrepancies or anomalies	200	230	406	420	400	150	270	290

have been completed, providing useful equipment or information serving the immediate needs of safeguards operations.

Results of safeguards activities

The main result of the safeguards activities of the IAEA is expressed as the "Safeguards Statement" in the Annual Reports and the Safeguards Implementation Reports (SIRs) of the IAEA: "It is considered reasonable to conclude that nuclear materials under Agency safeguards remained in peaceful nuclear activities or were adequately accounted for." The level of assurance associated with this statement should be seen in the light of the safeguards activities carried out, and the sensitivity of inspection and evaluation activities, the level of assurance associated with the Secretariat's findings and the findings of the Safeguards Implementation Report.

The overall result represented by this "Safeguards Statement" arises from both the efforts of the Department as a whole and the co-operation with and support of the Member States. Reporting on advances of safeguards implementation means at the same time acknowledging this strong support and this close co-operation. In the following paragraphs some selected results will be presented which provide support for the content of the safeguards statement.

Information on inspection effort. The number of installations inspected by the Agency has increased by more than 50% since 1980 (393 installations in 1980, 631 in 1987), while the total inspection effort in non-nuclear-weapon States and nuclear-weapon States has more than doubled (3985 man-days of inspection in 1980, 9556 in 1987). Inspection effort is being concentrated on those stages in the nuclear fuel cycle involving the production, processing, use or storage of nuclear material from which nuclear weapons or other explosive devices could readily be made. The IAEA gives highest priority to the most sensitive facilities and to direct-use materials. In 1987 about 46% of the total inspection effort was spent at bulk-handling facilities although these installations represented only about 7% to the total number of installations; for power reactors these percentages were about 31% and 21%, respectively.

Additional information on safeguards implementation is shown in an accompanying table. The number of seals used includes the Agency seals and the comparable number of IAEA/Euratom common seals used in Euratom States. The detection capability of discrepancies and anomalies is one indicator of the sensitivity of the IAEA safeguards system. Several hundred such discrepancies and anomalies have been detected and resolved each year.

In addition to the quantitative increase of inspection effort, measures have been taken to improve the effectiveness of IAEA safeguards. Examples are inspections without advance notice, and simultaneous physical inventory verification at all major facilities involved in the natural-uranium fuel cycle in one State.

Information on inspection goal attainment. The IAEA detection goals are a set of parameters (significant quantities, detection times, and detection probabilities) translating terms used in the definition of safeguards objectives into quantities. These goals are used as guidelines in designing the safeguards approach and in establishing inspection goals.

The attainment of these inspection goals is assessed on the basis of uniform criteria developed by the IAEA for internal use in connection with its annual Safeguards Implementation Report. These criteria used for the annual evaluation of inspection activities have been re-assessed and revised throughout the years to maintain high performance standards and to take account of changing demands and capabilities.

The IAEA strives to meet all relevant criteria for all material balance areas at all safeguarded facilities. Because the evaluation criteria are comprehensive, full attainment of inspection goals is not always achieved. However, it is important to understand that the IAEA carries out a broad range of inspection activities. Where the IAEA has not fully met the inspection goals for a facility, the inspection activities performed nevertheless have provided sufficient information to support the statement that "the Secretariat, in carrying out the safeguards obligations of the Agency, did not detect any anomaly which would indicate the diversion of a significant amount of safeguarded nuclear material" but at a lower level of assurance.

Inspection goal attainment has continued to improve through the many efforts described above. From 1980 to 1987 the number of facilities inspected and evaluated in the annual SIRs increased by 62%. In the same period the number of facilities where the inspection goals were

fully attained for the whole facility increased by 110%, reaching 63% of all facilities inspected and evaluated in 1986.

Looking forward

Having reported on the safeguards progress in recent years, it is appropriate to look forward to what the Agency might expect over the next few years.

An interesting future trend is the growth of more active participation in the development of safeguards approaches by operators of major facilities. As might be expected, significant participation by operators can lead to customized approaches tailored to such facilities, which guarantee at the same time effective IAEA safeguards.

Another interesting development is the tendency of new technology or of certain safeguards approaches to shift the balance of costs from one type of facility operator to another. One example is the question of verification of fresh fuel for power reactors. Should this be done at the fuel fabrication plant or at the power reactors? Another example is whether spent fuel destined for medium- or long-term storage should be verified at the reactor or at the storage facility. A third example is whether plutonium product should be verified at the reprocessing plant or at the MOX fuel fabrication plant. Although technical or commercial considerations will be taken into account in the final decisions, the Agency has to insist on guaranteeing effectiveness of its safeguards system.

It is important to note the shifting of the balance of safeguards costs between the Agency and the operator and the balance of safeguards costs between classes of operators. If the total cost of the applied safeguards is reduced in terms of combined expenditures and intrusiveness, then these trends will be of net benefit to the world's nuclear industry. Because of these trends, making judgements on the cost of safeguards and their intrusiveness will become more difficult, and will require a deeper knowledge of the details of safeguards application and a wider perspective on the nuclear industry.

A final important trend concerns the growing complexity of safeguards. As the size and complexity of nuclear facilities increase, requiring increased inspection effort, there is a related growth in the complexity of the safeguards activities carried out at headquarters by Agency staff. The number of days of work at headquarters for each day spent in the field is increasing.

Over the next few years the Agency will face significant new challenges in safeguards implementation. The entering into operation of large reprocessing plants and automated and remote-controlled facilities, the continued addition of nuclear power reactors, the growth of MOX fuel usage in the light-water reactor (LWR) power cycle, the establishment of medium- or long-term spent fuel storage facilities, the utilization of pin exchange in LWR spent fuel, and further implementation of safeguards in the nuclear-weapon States under voluntary offers will all contribute to increased demands on limited Agency manpower resources.

The Agency is called upon to maintain the effectiveness of international safeguards and continue to work toward increasing the assurance provided by the safeguards system at the same time as it is coping with an increased number of facilities and stringent resource constraints. Efforts will be made to achieve further improvements in efficiency and effectiveness. Introduction of new equipment and improved data handling can provide some help. Nevertheless, some increase in resources will be necessary. Through a combination of increased resources and improved efficiency and effectiveness, the Agency expects to meet the challenges ahead in a manner which satisfies the expectations of Member States.