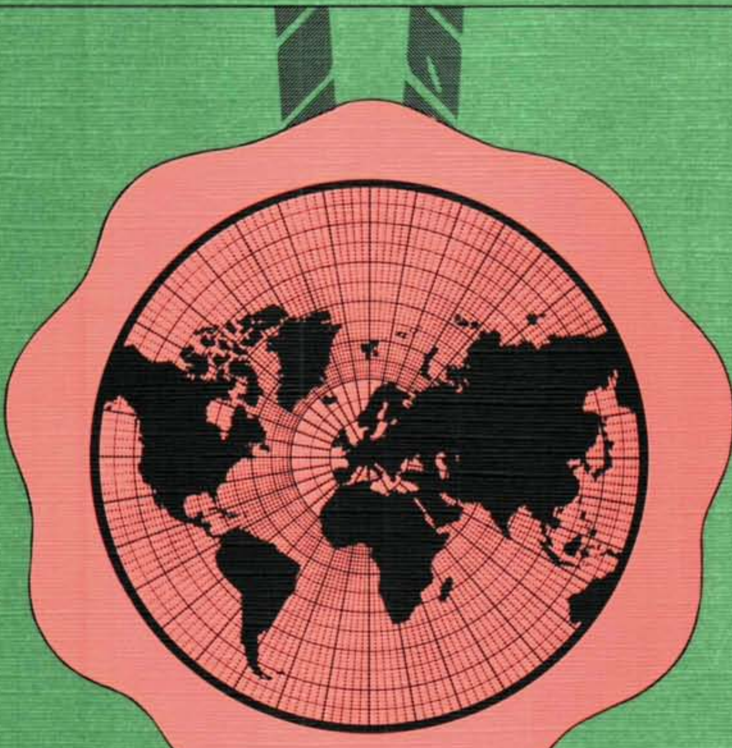
IAEA/SG/INF/3

IAEA SAFEGUARDS
AN INTRODUCTION



INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1981

IAEA SAFEGUARDS

AN INTRODUCTION

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The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

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FOREWORD

The IAEA Safeguards Information Series is intended to provide information on IAEA safeguards and related subjects. It is hoped that it will be of help to, inter alia, facility operators, design engineers and, since it is not excessively technical, also to certain civil service and external relations staff, and journalists.

The purpose of this third booklet in the Series is to give a general picture of the objectives and methods of safeguards, and of their role in non-proliferation policy.

The two previous booklets published in the IAEA Safeguards Information Series are as follows: IAEA/SG/INF/1 is a Glossary of Safeguards terms providing definitions which may be useful to the reader with a deeper interest in the subject; IAEA/SG/INF/2 is of a more specialized nature containing guidelines for States' Systems of Accounting for and Control of Nuclear Materials.

CONTENTS

NON-PROLIFERATION AND SAFEGUARDS

Historical

The concept of safeguards

Until the Second World War, agreements and treaties between nations generally rested on the good faith of the parties to the agreement, and did not provide for any means to verify that they were fulfilling the obligations they had accepted. The advent of nuclear energy changed this. Since the early 1950s, when States began to trade in nuclear materials and equipment for peaceful purposes, it has become the practice (and is today the invariable practice) for international agreements dealing with the use of nuclear energy to specify a set of 'safeguards' to verify systematically that the State or States concerned will not use the relevant nuclear materials or equipment for purposes or in a manner proscribed by the agreement. In the case of IAEA safeguards the prohibition generally relates to any explosive and any military use of nuclear material, equipment, etc.

This insistence on rigorous *verification* reflects chiefly the fact that nuclear energy can be used for military as well as peaceful purposes and, in particular, that certain nuclear materials can, in addition to their peaceful applications, be used as the explosive charge of nuclear weapons. A breach of the agreement might thus have far-reaching consequences for the parties themselves and for international security in general. The value of nuclear materials (and the radiation risks they may involve) also calls for precise accounting and other verification measures.

The first proposals

Soon after Hiroshima the United States of America proposed to the newly created United Nations that it should set up an international authority that would control all nuclear material throughout the world and all forms of nuclear activity. By its very first Resolution the General Assembly established a United Nations Atomic Energy Commission to study this proposal (known as the Baruch Plan) and to "deal with the problems raised by the discovery of atomic energy". The Soviet Union called for the destruction and prohibition of all atomic weapons before setting up a system of control.

The USA subsequently modified the Baruch Plan; only the sensitive steps in the nuclear fuel cycle (reprocessing and enrichment) should be owned and operated by an international authority while other activities should be subject to safeguards to ensure that they were not turned to military use. Despite these modifications, the Baruch Plan still called for too far-reaching a surrender of natural sovereignty to be accepted at that time.

The negotiations in the United Nations Atomic Energy Commission reached an impasse in the late 1940s and the Commission was dissolved in 1952. Prospects for a world truly free of nuclear weapons faded with the demise of the Commission and attention turned to the more restricted goal of limiting the number of nuclear-weapon States. Of the two concepts inherent in the Baruch Plan, that of safeguards to verify peaceful use survived and eventually became a cornerstone of all international agreements in the nuclear field. The concept of international operation of sensitive facilities did not bear fruit at the time but it was revived thirty years later and it is still being discussed.

The International Atomic Energy Agency

In 1953 the USA proposed the establishment of an International Atomic Energy Agency (IAEA) which would spread the benefits of nuclear technology[1] in return for an undertaking by each Member State to use it for peaceful purposes only and to accept safeguards to verify this undertaking. After three years of negotiations this concept was eventually reflected in a crucial article of the IAEA's statute which authorized it "to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose and to apply safeguards at the request of the parties, to any bilateral or multilateral arrangement or at the request of a State, to any of that State's activities in the field of atomic energy". The Statute came into force in 1957 and the IAEA began work, at Vienna, in the same year.

At the same time the USA, the USSR and other leading industrial countries began to conclude agreements for the transfer of nuclear technology, plant and material to other countries. Most of these agreements required the importing country to accept the safeguards of the exporter on the items supplied; in other words, to report regularly on the use made of these items and to accept inspectors to verify the use of the material. In 1956 the countries of the European Communities agreed to establish a regional system of safeguards ('Euratom' safeguards).

From 1957 until 1964 little was done to activate the IAEA's safeguards. By the end of that period all five permanent members of the UN Security Council, China, France, the USSR, the USA and the United Kingdom, had tested nuclear weapons. It was clear that neither strict controls on the transfer of technology

[1] Although no nuclear power plant was in operation in 1953 it was already foreseen that nuclear power would become a major producer of electricity.

nor safeguards applied by exporting countries had been effective in preventing the spread of nuclear weapons.

In 1965 the first major step was taken to develop systematically the IAEA's safeguards by adopting a safeguards system to replace an earlier one which covered only reactors. This new system, which was extended in 1966 and 1968 (IAEA document INFCIRC/66 Rev.2), is still applied in safeguards agreements with the 10 non-nuclear-weapon countries that have nuclear programmes and that have not expressly submitted all their nuclear activities to IAEA safeguards as they would have been required to do if they had been parties to the NPT or Tlatelolco Treaty (see below).

Most of the safeguards agreements with these 10 countries have resulted from decisions to transfer to the IAEA the responsibility for applying the safeguards prescribed in earlier bilateral agreements for the supply of nuclear plant and materials. In six of the 10 cases they cover all known nuclear plant in the country concerned, but unlike NPT safeguards (see below) they leave the country legally free to build *unsafeguarded* facilities and to produce *unsafeguarded* nuclear material.

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT)

Prolonged negotiations at the United Nations' Eighteen Nation Disarmament Committee finally bore fruit in 1968 in an agreement on the text of a treaty designed explicitly to prevent the spread of nuclear weapons – the Treaty on the Non-Proliferation of Nuclear Weapons (NPT). The treaty was subsequently endorsed by the General Assembly and entered into force in May 1970.

Each non-nuclear-weapon State that becomes party to the NPT binds itself not to acquire nuclear weapons or other nuclear explosives (Article II). It also binds itself to conclude an agreement with the IAEA for the application of safeguards to all its peaceful nuclear activities with a view to verifying the fulfilment of its obligations under the Treaty (Article III). In return the Treaty recognizes the right of all Parties to participate in the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy; in other words all Parties are guaranteed full access to peaceful nuclear technology (Article IV). The Parties also undertake to pursue negotiations in good faith towards nuclear disarmament (Article VI) and re-affirm their determination to achieve the discontinuance of all tests of nuclear weapons (Preamble); these commitments obviously apply principally to the nuclear-weapon States themselves, who alone, under the Treaty, may develop and test nuclear weapons.

Several of the concepts reflected in the NPT had already been incorporated into a regional Treaty for the Prohibition of Nuclear Weapons in Latin America, which the Latin American countries had negotiated and opened for signature in February 1967. This treaty is known as the Tlatelolco Treaty after the location in Mexico where it was concluded.[2]

NPT safeguards

To carry out the safeguards obligations assigned to the IAEA by the NPT it was clearly necessary for the IAEA to devise a safeguards system appropriate for the entire fuel cycle of the advanced industrial countries that were expected to join the Treaty. This NPT safeguards system,which was drawn up during 1970 and approved by the IAEA Board of Governors in the same year, is set forth in IAEA document INFCIRC/153 (corrected).

Acceptance of the NPT and the safeguards that go with it obviously entails a significant concession of national sovereignty, and during the first half of the 1970s the issue was debated extensively in the main industrial non-nuclear-weapon States. The interests of the Common Market countries and of Japan were reconciled in safeguards agreements concluded between them and the IAEA. The ratifications of these agreements followed in 1977, thus bringing the main industrial non-nuclear-weapon States under IAEA safeguards.

Meanwhile, in 1974 a nuclear device was exploded by India, which was not then and still in 1981 is not party to the NPT. Furthermore, the nuclear material used for the Indian device had not been under IAEA safeguards. Nevertheless this event led to some doubts about the adequacy of the international safeguards regime and the NPT. These doubts were reflected subsequently in an informal agreement between supplying countries to apply the so-called 'London guidelines' of 1978, and also in United States legislation approved by Congress in 1978 which sought to restrict the export (and use) of reprocessing and other technologies considered to be sensitive. In other words, supply conditions additional to the safeguards of the NPT were imposed. The United States legislation referred to also required the renegotiation of many existing supply agreements.

A division of interest between the supplying countries and receiving countries thus emerged in the mid-1970s. On the initiative of the USA it was accordingly agreed in Washington in 1977 to launch a general international evaluation, without preconditions, of the technical assumptions concerning the development of the nuclear fuel cycle on which the nuclear energy programmes of many countries had been based since the 1950s. This International Nuclear Fuel Cycle Evaluation (INFCE) came to an end in March 1980 after an exhaustive examination of all aspects of the nuclear fuel cycle. From the work of INFCE it was clear that there is no easy technical means of preventing the acquisition of nuclear explosive material nor is it possible to rank various fuel cycles according

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[2] The Tlatelolco Treaty is in some respects more comprehensive than the NPT since it is designed to ensure the *total* absence of nuclear weapons in the region that it covers.

to the risk of proliferation they entail; proliferation should rather be regarded as a political problem to be dealt with by creating new institutional and internationally acceptable measures and, above all, by improving and strengthening the international safeguards system.

In the meantime the IAEA had embarked on a number of studies on additional institutional measures to reduce the risks of proliferation. It had completed a comprehensive study of the benefits and problems involved in setting up multinational fuel cycle centres, in which certain sensitive stages in the nuclear fuel cycle would be owned and operated by groups of nations. Another ongoing study seeks to activate a safeguards measure foreseen in Article XII.A.5 of the Agency's statute under which the IAEA has the authority to require to be deposited with it any excess of plutonium over that needed by the country concerned for use in reactors or research, the object being to prevent the stockpiling of plutonium. The International Plutonium Storage System (IPS) has been studied by an IAEA expert group since 1978; if it is put into effect it will probably be an integral part of the Agency's safeguards system.

A similar study group is looking into questions of international or multinational arrangements for the storage of spent fuel.

In June 1980, after the conclusion of INFCE, the Board of Governors established a Committee on Assurances of Supply (CAS), open to Member States of the Agency, with a view to restoring the stability of the international nuclear supply system under an acceptable non-proliferation regime. The establishment of this Committee reflects the extent to which the questions of nuclear supplies and safeguards have become intimately linked with each other and the fact that today there could be no significant nuclear trade except within the framework of an effective safeguards regime.

The present position

The spread of nuclear technology

By the end of 1980 a total of 253 nuclear power reactors were in operation in 22 countries, providing about 8% of the world's electricity. By 1985, power reactors already under construction will raise this figure to about 17%. In addition, 353 research reactors are in operation or under construction in 49 countries. The spread of nuclear energy has thus been impressive despite a number of setbacks during the last decade (see Figs 1a and 1b).

At the same time the overt spread of nuclear weapons has slowed down. During the decade that began with Hiroshima (1945 – 1954) three nations became nuclear-weapon States; during the next decade (1955 – 1964) two more followed. During the third decade ending in 1974 only one additional nation exploded a nuclear device, as Fig. 1b shows. In other words, the spread of nuclear weapons

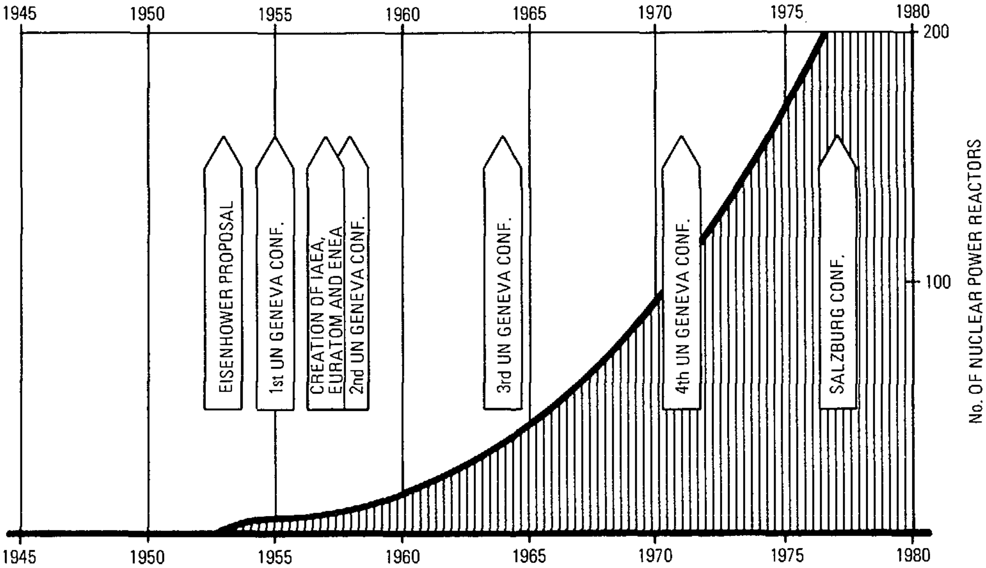

FIG.1a. Main international steps to promote the peaceful uses of nuclear energy and the growth of nuclear power.

Notes: *(1) The first UN Conference on the Peaceful Uses of Atomic Energy in Geneva in 1955 led to the first major declassification of secret nuclear information. The subsequent conferences continued this tradition, turning with time more to practical technology than to basic science.*

(2) The IAEA International Conference on Nuclear Power and Its Fuel Cycle in Salzburg in 1977 dealt with the overall role to be played by nuclear energy, making particular reference to the fuel cycle and the need for its integration on a national and international level.

(3) Euratom = European Atomic Energy Community. ENEA = European Nuclear Energy Agency: now entitled Nuclear Energy Agency (NEA) of the OECD.

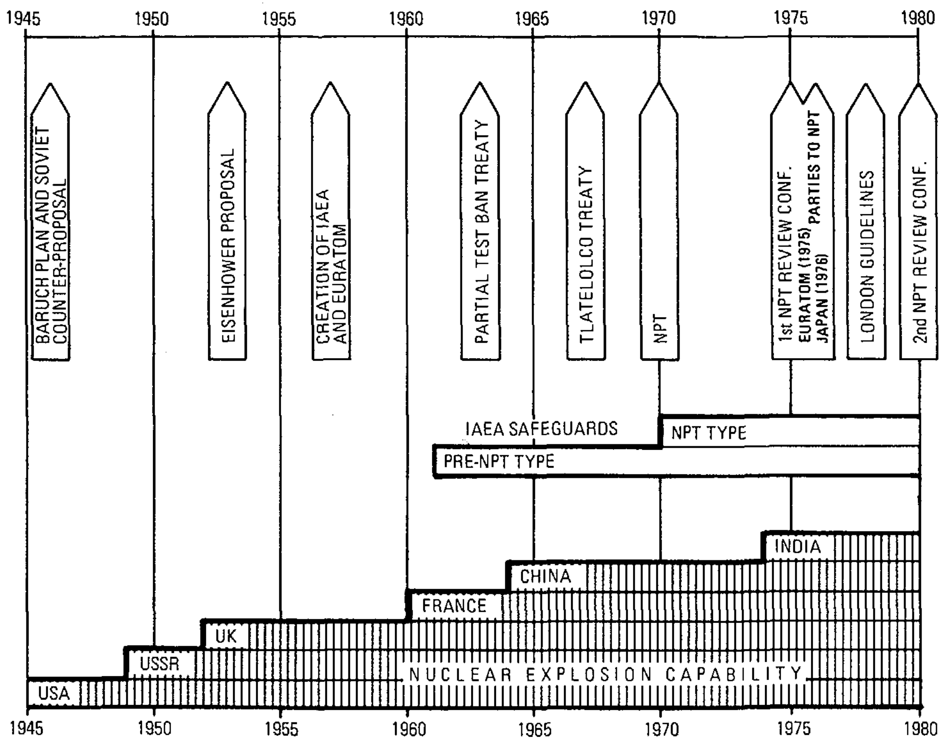

FIG.1b. Main international steps or proposals for stopping the spread of nuclear weapons.

Notes: *(1) The first IAEA Safeguards System (pre-NPT type) was adopted in 1961 to cover nuclear reactors with less than 100 megawatts thermal output. In 1964 this system was extended to cover all nuclear reactors. A second IAEA Safeguards System (also pre-NPT type), adopted in 1965, replaced the first and is still applied. It covers nuclear reactors and, by extensions in 1966 and 1968, also reprocessing, conversion and fuel fabrication plants.*

(2) In addition to the second IAEA Safeguards System there exist provisions (NPT type) for the application of safeguards to all peaceful nuclear activities in the non-nuclear-weapon States parties to the NPT.

and nuclear explosives has, at least so far, slowed down while knowledge of how to make them has become widespread.[3]

There are many reasons for this. It was for instance the Second World War that laid the basis for the US, USSR, UK and French nuclear weapons programmes and that led to the treaties and national laws which make it illegal for the Federal Republic of Germany and Japan as well as several other European countries to acquire nuclear weapons. Nevertheless it is reasonable to conclude that the political and institutional steps the world has taken to prevent proliferation – the creation of the IAEA, the formulation of the IAEA safeguards system, the NPT and the Tlatelolco Treaty[4] – have also played a useful part. They have provided the means for governments to ratify in a binding manner and for all the world to see their decisions to forgo nuclear weapons and also, by accepting IAEA safeguards, to show the world that they are carrying out their undertakings. This assurance to the international community has raised confidence, increased international security and lessened the incentive of other countries to acquire nuclear weapons.

The present safeguards situation

By December 1980 a total of 113 States, including three nuclear-weapon States (USSR, UK, USA), had become parties to the NPT.[5] The NPT covered almost all the non-nuclear-weapon States of the industrial world[6] as well as some 70 developing States (see Fig.2).

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[3] Although certain processes in the nuclear fuel cycle (enrichment and reprocessing) can be used either for peaceful purposes or to make nuclear explosives, this short summary shows that the *expansion of nuclear power has not gone hand in hand with the spread of nuclear weapons.* Indeed, most of the five nuclear-weapon States tested their first bombs several years before the entry into service of their first power reactors; in one case (China) there is still no nuclear power plant in operation or even under construction.

[4] The conclusion of an effective 'comprehensive test ban treaty', prohibiting all tests of nuclear explosives, would clearly be a further major step in preventing the spread of nuclear weapons. The 1963 Moscow Partial Test-Ban Treaty prohibits such tests in the atmosphere, outer space and under water but does not proscribe underground tests provided that the resulting debris does not cross the frontiers of the testing State. Underground testing by the nuclear-weapon States continues at the rate of about 50 tests a year.

[5] Egypt became party to the NPT on 26 February 1981.

[6] The only industrial non-nuclear-weapon State which has not yet accepted the NPT is Spain, but in March 1981 that country concluded an agreement with the IAEA which had the effect of bringing all existing nuclear activities in Spain under the IAEA's safeguards. This agreement entered into force on 11 May 1981.

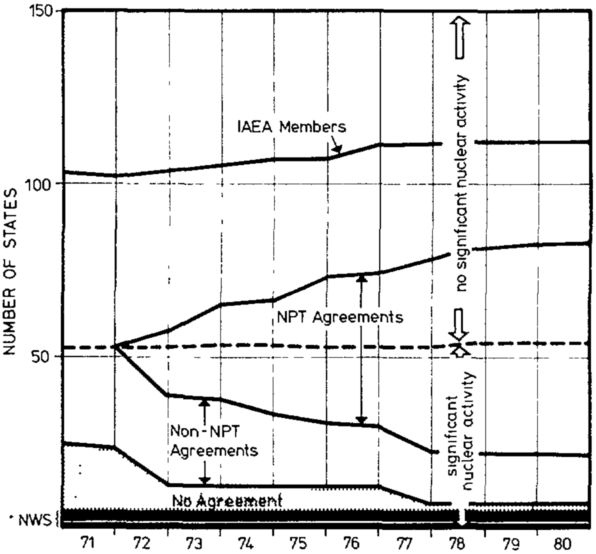

FIG.2. Evolution of safeguards agreements 1970–1980. (**Note**: *Three of the five nuclear-weapon States (NWS) are parties to the NPT).*

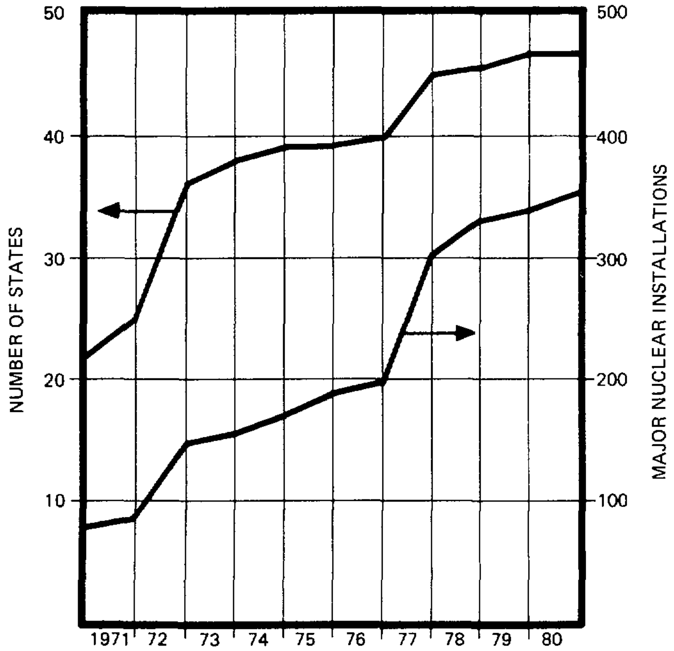

FIG.3. Number of States visited by IAEA inspectors and number of major nuclear installations under safeguards.

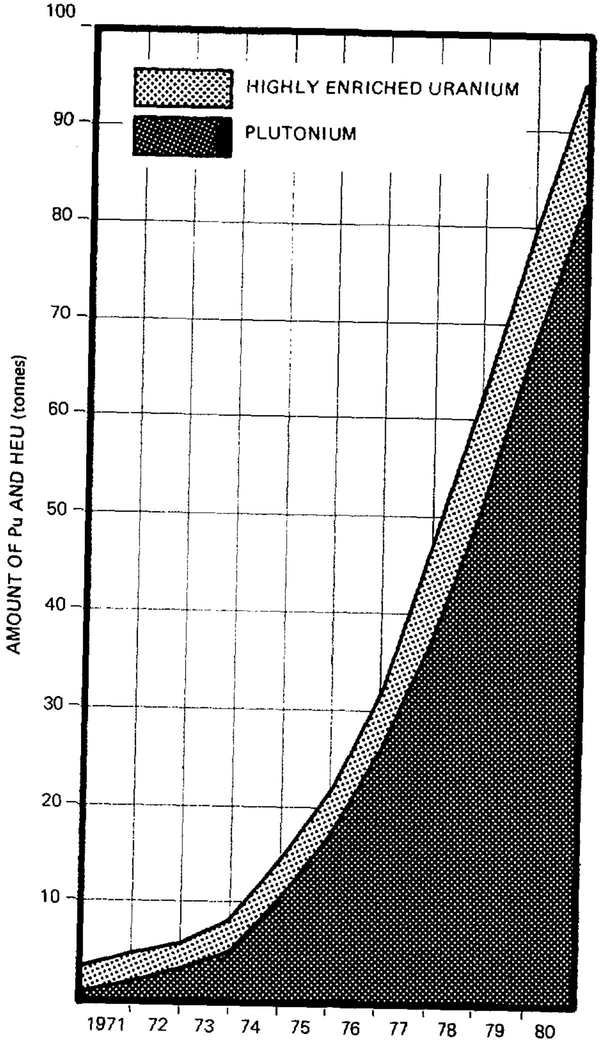

FIG.4. Amounts of plutonium and highly enriched uranium under safeguards.

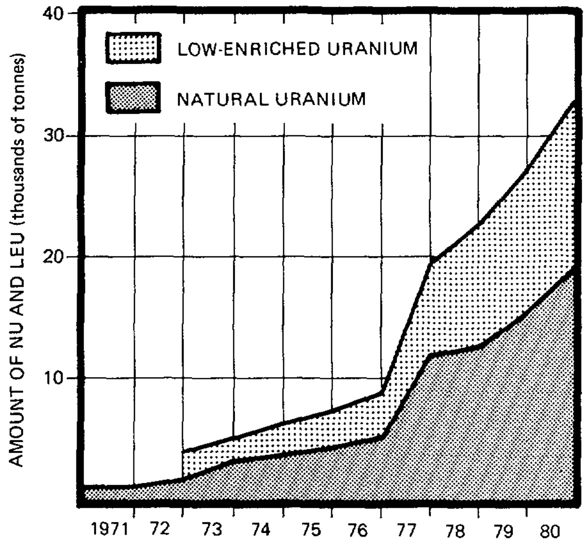

FIG.5. Amounts of natural uranium and low-enriched uranium under safeguards.

By the end of 1980 the IAEA was also applying safeguards in ten non-nuclear-weapon States which were not parties to the NPT, namely Argentina, Brazil, Chile, Colombia, the People's Democratic Republic of Korea, India, Israel, Pakistan, South Africa and Spain. In six of these countries all significant nuclear activities of which the IAEA was aware were covered by a series of individual safeguards agreements. In the remaining four (India, Israel, Pakistan and South Africa), unsafeguarded as well as safeguarded nuclear facilities were in operation or under construction and the unsafeguarded facilities were or will be capable of producing weapons-grade nuclear material.

With the four exceptions noted, almost the entire known nuclear industry outside the nuclear-weapon States is thus under the safeguards of the IAEA.[6] The growth which this has brought to the Agency's safeguards responsibilities is illustrated in Fig.3.

Figure 4 shows the growing amount of highly enriched uranium and of plutonium under IAEA safeguards. Most of the plutonium is in spent fuel from power reactors and would be usable for power production, or as an explosive, only after the fuel had been reprocessed. Figure 5 illustrates the increasing amount of low-enriched and natural uranium under safeguards.

THE OBJECTIVES OF SAFEGUARDS

The political objectives

Safeguards are essentially a technical means of verifying the fulfilment of political obligations undertaken by States in concluding international agreements relating to the peaceful uses of nuclear energy. Today most of these obligations flow from the NPT and similar agreements.

The main political objectives of safeguards are:

To assure the international community that States are complying with their non-proliferation and other 'peaceful use' undertakings;

To deter (a) the diversion of safeguarded nuclear materials to the production of nuclear explosives or for other military purposes and (b) the misuse of safeguarded facilities with the aim of producing unsafeguarded nuclear material.

The assurance given by safeguards

States conclude safeguards agreements voluntarily and the IAEA has no authority to apply safeguards unless the State concerned so requests (as it is obliged to do if it is a party to such legal instruments as the NPT). In view of the voluntary nature of this acceptance of safeguards, and for other reasons, it is reasonable to expect that the normal results of applying safeguards will be to confirm that there has in fact not been any diversion. Confirmation that this is so results from independent verification by the IAEA inspectorate. The assurance thus obtained from the IAEA's activities as an independent and objective auditor increases confidence between States and helps to diminish political insecurity which is normally the main motivation for acquiring nuclear weapons.

The deterrent effect

Deterrence is aimed at dissuading any State that might contemplate diversion of nuclear materials or the misuse of nuclear facilities. It follows that, to constitute an effective deterrent, safeguards must be technically capable (and be *seen* to be capable) of promptly detecting the diversion. Detection of diversion must also be seen to entail effective penalties for the diverting country.

Penalties or sanctions

The IAEA Statute and safeguards agreements specify a number of formal sanctions against the breach of a safeguards agreement. They consist chiefly of an alert to the international community (the UN Security Council, the UN General Assembly, all IAEA members), curtailment of IAEA assistance, and suspension of the privileges and rights of IAEA membership.

The effectiveness of these formal sanctions, should it be necessary to evoke them, will depend upon the actions taken by governments in response to the alert given by the Agency. In other words, for safeguards to be an effective deterrent it must be perceived that the international community will respond promptly and vigorously if the IAEA should ever have to 'sound the alarm'.

The extent to which the risk of detection and its consequent penalties would in practice be an effective deterrent will also obviously vary between States and according to political circumstances.

The technical instrument

The technical instrument for achieving the political objectives defined above is the safeguards arm of the IAEA, particularly the Safeguards Department. This is designed to provide continuing assurance to the international community that any diversion would be promptly detected. At least equally important is that it should also provide assurance that if, as has up to now always been the case, no diversion has occurred, the IAEA will be able to verify the correctness of the statements it has received from the State concerning its safeguarded nuclear material and facilities. The political value as well as the effectiveness of the IAEA's safeguards work thus depends significantly on the way in which its detection capability is perceived by those States which expect the IAEA to provide assurance as well as by any State which might contemplate diversion and wished to know how much risk there is of being detected.

Limits to the system

It should be clear that no international safeguards system can physically prevent diversion. The IAEA could not of course prevent any NPT party from exercising its legal right to withdraw from the NPT[7] nor could it prevent countries that have not accepted NPT or similar obligations from building unsafeguarded facilities.[8] Unfortunate as this may be, the IAEA's system can do no more than detect diversion of safeguarded material or misuse of safeguarded plant, and trigger

[7] For many reasons, withdrawal from the NPT is nevertheless very unlikely. There is no provision for withdrawal from the Tlatelolco Treaty but States may under certain circumstances cease to be bound by certain crucial articles.

[8] Hence there can be no question of the IAEA 'imposing' its safeguards on a reluctant State. The question is sometimes asked: Why doesn't the IAEA step in and place a particular facility under its safeguards? Such action is neither politically nor legally feasible.

international action. This can, however, be seen as progress since the acceptance of safeguards always involves for the State concerned giving up a measure of national sovereignty.

Safeguards and physical protection

The protection of nuclear materials and facilities against forcible seizure, theft, terrorism and other criminal activities is the responsibility of the State.[9] This is not the objective of international safeguards, which are directed against the risks of proliferation (or other proscribed activities) *by States.* It follows that the authority and measures required for each of these two activities are different, so too are their objectives and the criteria they apply.

Thus, at the international level the Agency's rights are limited to those which are accorded by the agreement with the State concerned.

A State, on the other hand, is able to use all the power and authority at its disposal, including police and military force, to physically protect nuclear facilities and material and to recover any material which may have been illegally diverted. Similarly, whereas the State may apply the full force of the law to ensure compliance with its legal requirements, the actions that the IAEA may take are explicitly limited by the relevant safeguards agreements and its statute.

The technical objective

The technical objective of safeguards in agreements concluded under the NPT 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 other nuclear explosive devices or for purposes unknown and deterrence of such diversion by risk of early detection". In safeguards agreements concluded under the non-NPT system (INFCIRC/66 Rev.2) there is no specific definition of technical objectives but in practice today essentially the same concepts apply.

This definition contains two expressions requiring quantification: 'significant quantities' of nuclear material and 'timely detection' of diversion.

It is again important to keep in mind the difference in the content of these terms when they are used in relation to national measures of physical protection and when used with international safeguards.

A national physical protection system may have to be designed to detect unlawful action within hours or even minutes. Moreover the unlawful removal or other misuse of only a few grams of plutonium could be significant because of the health hazard it may pose.

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[9] In some countries *physical* protection measures are also referred to as safeguards.

Since the objective of an international safeguards system is essentially to deter governments from making nuclear weapons or other nuclear explosives, the detection within hours or even minutes of such small amounts as a few grams is not necessary and cannot reasonably be required. For international safeguards the significant quantity is the approximate quantity of nuclear material which could possibly be used to manufacture a nuclear explosive device. It is of the order of magnitude of 8 kilograms of plutonium or 25 kilograms of highly enriched uranium.

Similarly, in the context of international safeguards 'timely detection' can be related to the time required to convert diverted material into the components of a nuclear explosive device (namely, conversion time).

Results so far

As has been said, safeguards can exercise their deterrent effect only if they are seen to be capable of early detection of a diversion. IAEA safeguards have been applied since the 1960s. No diversion of any safeguarded item has been recorded, and while the possibility of a future diversion of safeguarded material or misuse of plants cannot be excluded its likelihood will generally remain small, partly because of the operation of the system itself. While the effectiveness of a national police force can be measured in terms of its success rate against crime, that of international safeguards cannot be demonstrated by statistics showing for instance the proportion of diversions detected in relation to the total number of diversions. Other means must be used in order to give an assurance of this kind to the Agency's Member States that the IAEA safeguards system is effective.

Thus, for instance, governments are informed not only of the conclusions the IAEA reaches in implementing safeguards but also of the rationale and methods used to reach these conclusions, the approaches and procedures followed in applying safeguards and the factual material on which the conclusions are based.

To give an example: in 1980 about six million 'surveillance' pictures were taken in nuclear facilities and evaluated by the IAEA, 6000 seals were issued, and 3000 were returned for verification. IAEA inspectors and safeguarded States submitted reports on about 700 nuclear installations, and about 400 000 data entries were made in the Agency's computer. The effectiveness of inspection and evaluation activities in disclosing departures from the norm is shown by the fact that in 1980 about 200 discrepancies and anomalies were detected. Most of them were minor and in all cases they were satisfactorily explained upon subsequent appraisal and investigation. It was thus again reasonable to conclude that nuclear material under IAEA safeguards in 1980 – as in previous years – had remained in peaceful nuclear activities or had otherwise been adequately accounted for.

SAFEGUARDS APPROACHES AND IMPLEMENTATION

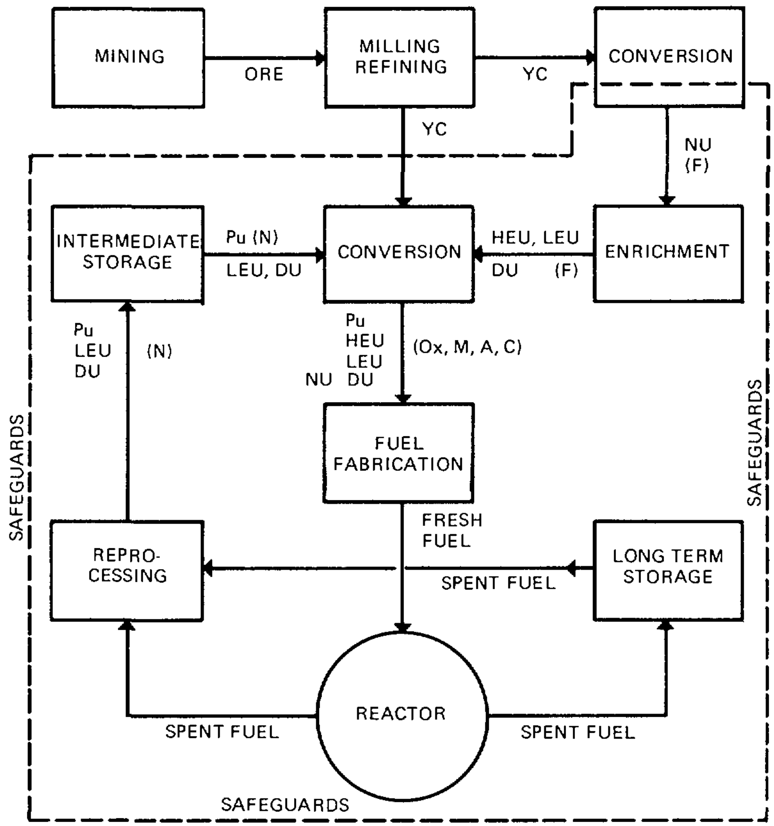
The State's system of accounting for and control of nuclear materials (SSAC)

Safeguards agreements concluded pursuant to the NPT require the State to establish and maintain a national system of accounting for and control of nuclear material within its territory, jurisdiction or control (in the case of the European community the safeguards system of Euratom fulfils this function). In fact, most States having a significant nuclear programme, whether or not they are parties to NPT safeguards agreements with the IAEA, find it to be in their national interest to establish effective means of accounting for and control of nuclear materials in their territories.

The safeguards measures applied by the IAEA will now be described in more detail. In NPT States (and increasingly in others as well), the IAEA nuclear materials accountancy and verification are based on *reports* submitted by the SSAC as well as on *records* kept at facilities. It is the responsibility of the competent national authority to ensure that plant operators comply with the requirements of the safeguards agreement. These requirements include proper and accurate keeping of records and timely and accurate reporting according to an agreed format. The national authority must also ensure that the capabilities and equipment at nuclear factilities for measuring the quantity and composition of nuclear material are maintained at the level of the latest international or comparable standards. The national authorities are also responsible for ensuring that IAEA inspectors are granted all necessary access to facilities and material and for providing the support they require effectively to discharge their duties. They must also enable and assist IAEA inspectors to apply containment and surveillance measures (e.g. seals, cameras, and other recording devices) at nuclear facilities. In some cases the same measure or device is used to meet the requirements of both domestic physical protection measures and IAEA safeguards.

Design of the safeguards approach

The material for nuclear explosives, whether highly enriched uranium (HEU) or plutonium (Pu), is produced in specialized facilities. The construction and misuse of commercial nuclear power reactors is not the easiest nor the most efficient route to acquiring nuclear material for the manufacture of nuclear explosives. However, fuel cycle facilities associated with such reactors might be used in some circumstances to produce unsafeguarded nuclear material for nuclear explosives. It is, therefore, necessary for *all* nuclear material in a country's fuel cycle to be safeguarded if the IAEA is to be in a position to give assurances of non-diversion for the State as a whole.



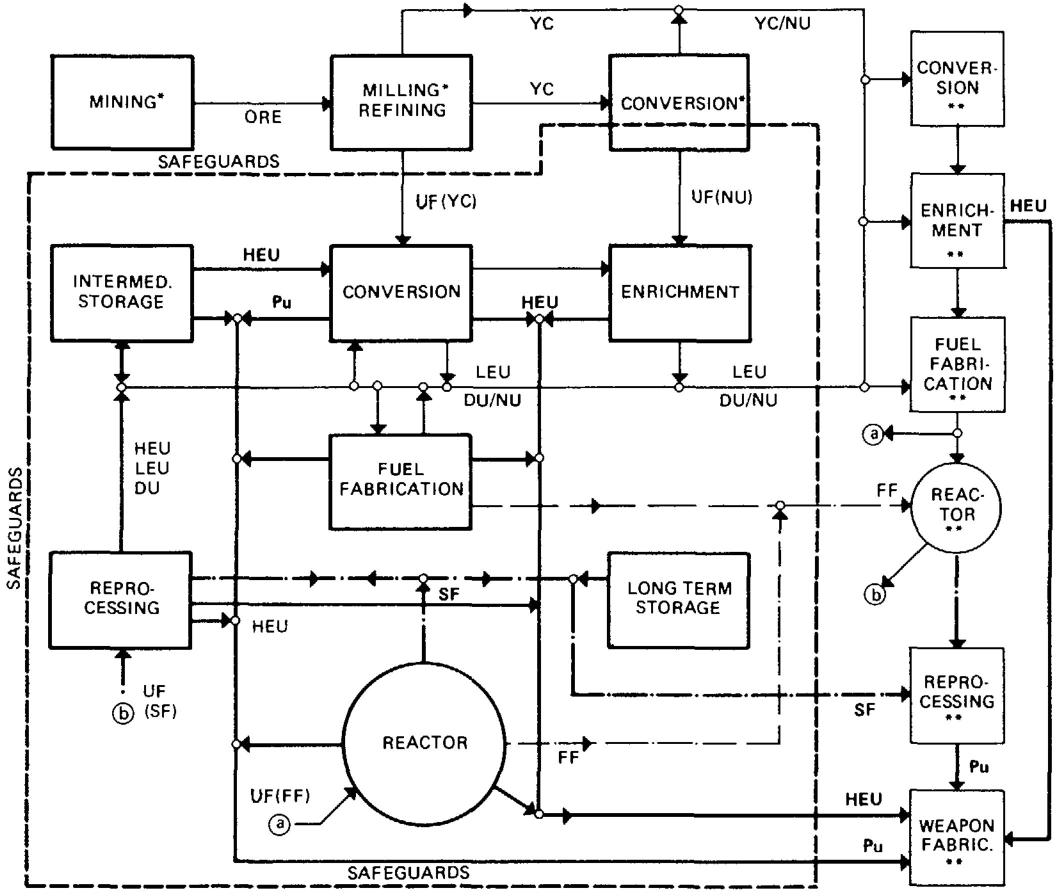
YC	yellow cake	Ox	oxide
NU	natural uranium	N	nitrate
DU	depleted uranium	M	metal
LEU	low enriched uranium	A	alloy
HEU	high enriched uranium	F	hexafluoride
Pu	plutonium	C	carbide

FIG.6. Simplified flow diagram of the nuclear fuel cycle.

The term 'nuclear fuel cycle' refers to the system of nuclear installations interconnected by a stream of nuclear material used in the production of nuclear energy.

Such a system may consist of uranium mines, ore-processing plants, conversion plants, enrichment plants, fuel fabrication plants, reactors (where the energy is extracted), spent fuel storages, reprocessing plants and associated storage. The fuel cycle can be 'closed' in various ways, e.g. by recycling of plutonium and uranium through reactors, by re-enriching the uranium recovered as a result of reprocessing, or by using the plutonium in the fast breeder reactor fuel cycle. All these stages taken together are illustrated schematically in Fig.6.

YC	*yellow cake*
NU	natural uranium
LEU	low enriched uranium
HEU	high enriched uranium
Pu	plutonium
DU	depleted uranium
FF	fresh fuel
SF	spent fuel
UF	undeclared fuel



* These facilities are normally not under safeguards.

** These facilities might exist as undeclared facilities under a full scope agreement.

FIG. 7. Simplified flow diagram of proliferation paths.

Of course, only a few countries have facilities corresponding to all the installations shown in the figure. In most countries only part of the fuel cycle exists – in the minimum case only a power reactor supplied from abroad, or an R & D laboratory.[10]

An important step in the analytical process leading to adoption of a specific safeguards approach is a careful analysis of hypothetical 'diversion strategies' that could be used by a diverter. Figure 7, in contrast to Fig.6, does not show the legitimate paths normally followed by nuclear material in a commercial fuel cycle, but surveys the diversion paths along which nuclear material could be diverted. The possibility of unsafeguarded facilities[11] must be assumed in any safeguards study and this is also reflected in Fig.7, which shows the confusing variety of 'diversion paths' for different kinds of nuclear material that have to be analysed. This diagrammatical representation must of course be extended or simplified in each individual case to reflect the actual fuel cycle of the country concerned. The set of diversion paths which is assumed to be part of plausible diversion strategies forms the 'diversion assumption' and is taken into account in designing, implementing and evaluating safeguards in a given situation.

Safeguards practices can be summarized in one word: verification. To verify means 'to establish the truth of'. In safeguards, to verify is to establish the truth of statements regarding the amounts, presence and use of nuclear material or other items subject to safeguards as recorded by facility operators and as reported by the State to the IAEA. Accountancy, taken together with containment and surveillance, is the fundamental basis on which verification rests.

The verification process can be described as consisting of three distinct stages:

(1) The *examination* of the information provided by the *State* in:
- Design information describing installations under safeguards
- Accounting reports listing, inter alia, nuclear material inventories, receipts and shipments
- Documents amplifying and clarifying reports
- Advance notification of international transfers.

(2) The *collection* of information by the *IAEA* as a result of:
- Inspections for the verification of the design information
- Inspections to examine records and reports and inspection of nuclear material
- Special inspections in case of unusual findings.

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[10] A more detailed description of the fuel cycle facilities can be found in the IAEA publication 'IAEA Safeguards: Glossary' (IAEA/SG/INF/1, published 1980).

[11] The existence of such facilities may or may not be acknowledged. In the case of NPT States such facilities would of necessity be 'undeclared', i.e. clandestine.

(3) The *evaluation* of the information provided by the State and of that collected by inspectors, to determine the completeness, accuracy and validity of the information provided by the State.

Statements are provided by the IAEA to States, recording the results of safeguards activities in the State concerned. Mechanisms are in existence for the resolution of anomalies and discrepancies which may be detected by the IAEA.

Nuclear materials accountancy [12, 13]

It is the purpose of nuclear materials accounting[13] to establish the quantities of nuclear material present within defined areas and the changes in these quantities that take place within defined periods of time. The essential elements of such accounting are:

The operator identifies and counts or measures the material in the area concerned

The operator keeps records of all transactions involving this material

The operator prepares accounting reports on these transactions and submits these reports via the State to the IAEA

The IAEA verifies and analyses the data in these reports to determine their correctness and to assess the amount of any material unaccounted for and evaluate the causes of any such material unaccounted for.

To make these tasks more manageable, material balance areas (MBAs) are established in nuclear installations. These MBAs are areas into and out of which all transfers can be determined and in which physical inventories can be taken to establish a nuclear material balance. The MBAs are agreed between States and the IAEA and are recorded in Subsidiary Arrangements to the Safeguards Agreements which regulate in detail the implementation of safeguards agreements. Within MBAs measurements are made at key measurement points (KMPs), which are locations where nuclear material may be measured for the determination of flow or inventory.

Accountancy in IAEA terms begins in practice with the determination by the operator of the *initial physical inventory* (stock-taking) for a facility or MBA and the recording of that inventory in a book in which the operator thereafter

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[12] The explanations in this sub-section apply to the majority of Agency safeguards agreements, which are concluded in accordance with the NPT, and to some extent with other agreements as well.

[13] In safeguards a certain distinction is made in the meaning of the words accountancy and accounting (see the definitions in 'IAEA Safeguards: Glossary' (IAEA/SG/INF/1, p.28).

records subsequent *inventory changes.* The results of periodical *physical inventory takings* by the operator and their relation to corresponding book inventories are fundamental to nuclear material accountancy. Any difference between the book inventory and the physical inventory is called 'material unaccounted for', abbreviated to MUF. The reasons for MUF may be found in measurement uncertainties or other technical causes. If the size of the MUF is found to be beyond a value attributable to such identifiable causes, the possibility that a diversion has been made must be considered.

Figure 8 is a highly simplified view of the application of accountancy procedures. When closing the books in respect of a material balance period (e.g. the calendar year n−1) in an MBA, the operator takes a physical inventory (PI) at the prescribed KMPs of all nuclear material present in the MBA, by counting, identifying, weighing, etc. The resulting figures for this 'beginning inventory' (PB_n) are at the same time the ending physical inventory (PE_{n-1}) for the previous material balance period, and the beginning book inventory for the next material balance period (see top block in Fig.8). The operator reports the results to the responsible State Office in the form of a physical inventory listing (PIL) and a material balance report (MBR) for the material balance period which closed. These reports are then transmitted to the IAEA. At the same time as the physical inventory takes place, or shortly thereafter, an IAEA inspection of the facility takes place for the purpose of verifying the physical inventory taking by making independent measurements, taking samples, etc. The results of this inspection and of the analysis of any samples are evaluated and the conclusions reached by the IAEA are transmitted to the State in the form of a statement (ST).

We now turn to the middle block in Fig.8. Any changes in the balance of nuclear material (e.g. receipts (R), shipments (S) or discards) are entered by the operator in his records and up-date his book inventory (BI). The changes are also reported through the State Office to the IAEA in the form of inventory change reports (ICRs). Routine IAEA inspections may be carried out to verify these changes, and the records are examined and compared with the reports sent to the IAEA. The results of these inspections are evaluated and the conclusions reached are communicated to the State.

The material balance period is closed by activities schematically represented in the last block in Fig.8. After verification of the ending physical inventory (PE_n) the difference (MUF) between the book inventory (BE_n) and the physical inventory (PE_n) is determined and evaluated and a statement is formulated. Once each year the IAEA submits a safeguards implementation report (SIR) to the Board of Governors. The SIR contains an overall assessment of safeguards effectiveness during the previous year and an analysis of the effectiveness and efficiency of safeguards implementation.

In his independent verification activities the inspector uses several methods which have been mentioned already in general terms. Figure 9 shows a simplified description of such methods used, inter alia, in a nuclear power reactor. A power

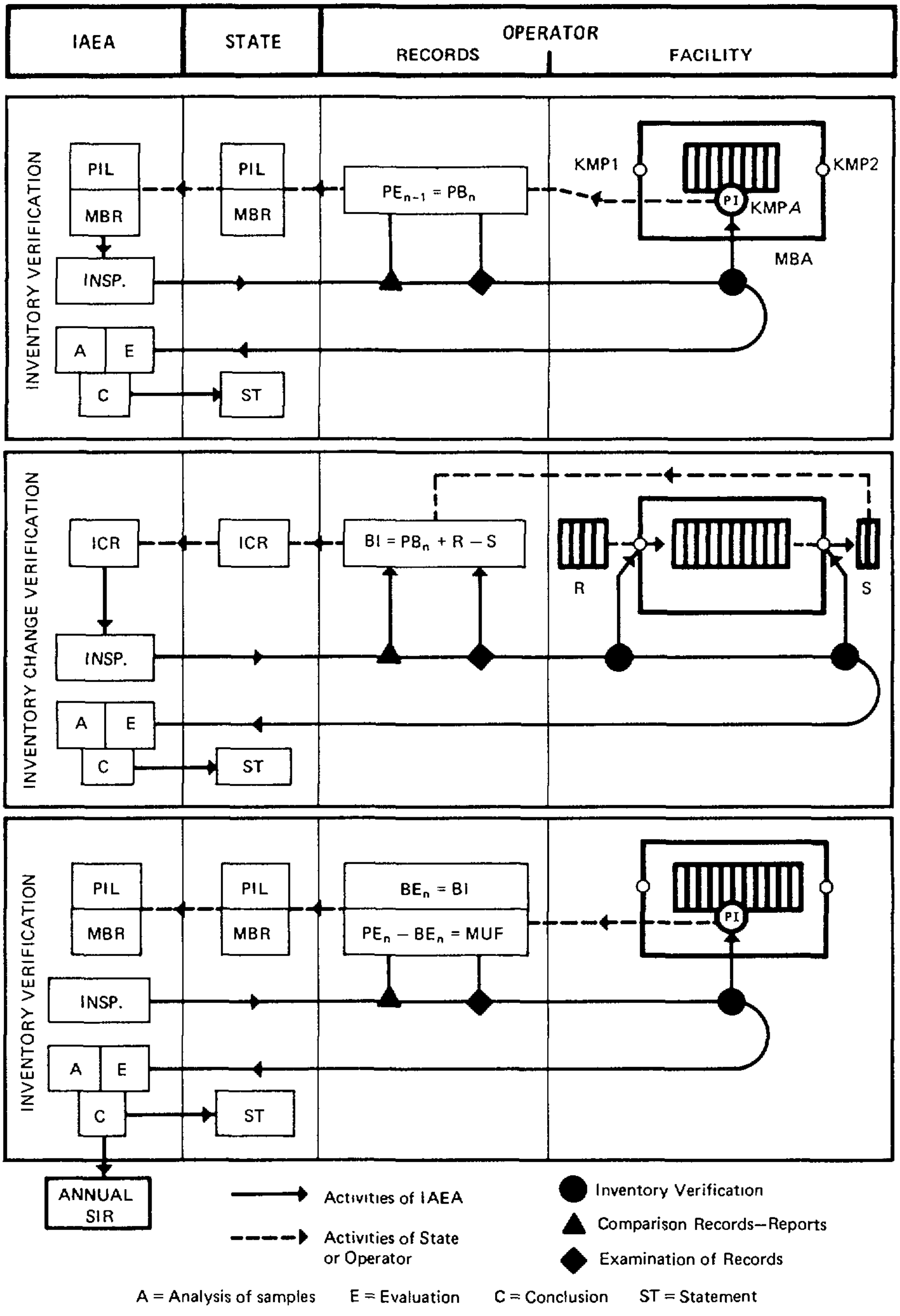

FIG.8. Simplified scheme of nuclear material accountancy (explanation in the text). A – Analysis of samples. E – Evaluation. C – Conclusion. ST – Statement.

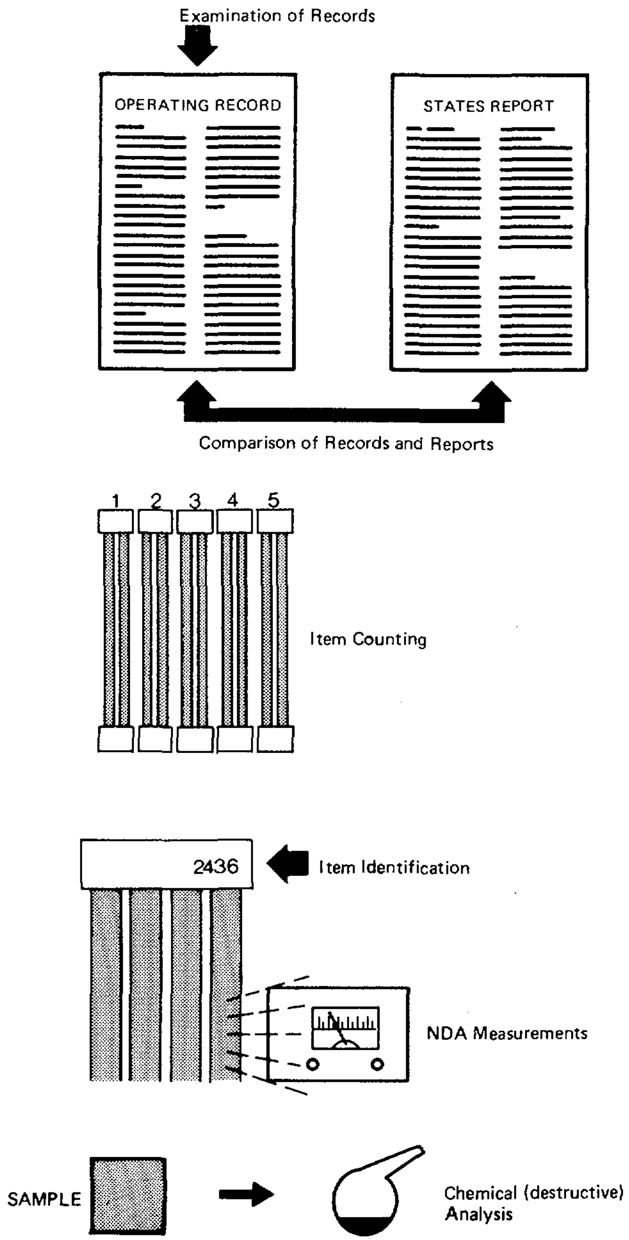

FIG.9. Verification activities of inspectors or of the Safeguards Analytical Laboratory. (NDA = non-destructive assay).

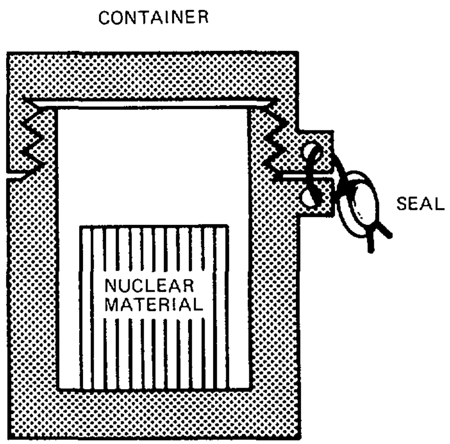

FIG.10. Containment measures: application of seal.

reactor is an 'item facility', i.e. the nuclear fuel is contained in identifiable items (fuel assemblies), the integrity of which is usually preserved during their presence in the plant. Such items can be followed through a considerable part of the whole fuel cycle, from the fuel fabrication plant, through the reactor, to the reprocessing plant or long-term storage. This facilitates the task of safeguards. Inspectors count the fuel assemblies, identify them by serial number or seals, and check on a statistical basis the fuel composition by non-destructive measurements. In 'bulk handling facilities', e.g. fuel fabrication plants, samples (pellets, powder, solutions) are taken and destructively analysed in the Agency's Safeguards Analytical Laboratory, by chemical or physical methods.

Containment and surveillance

Containment and surveillance measures take advantage of physical barriers such as walls, containers, tanks or pipes, to restrict or control the movement of or access to nuclear material. Such measures help to reduce the probability that undetected movements of nuclear material or equipment can take place. Containment/surveillance measures may involve the application of devices such as uniquely identified tamper-indicating seals to ensure that any change in the sealed inventory will be detected.

Surveillance means both human and instrumental observation in order to detect undeclared movements of nuclear material, tampering with containment, fabrication of false information or tampering with safeguards devices. Surveillance

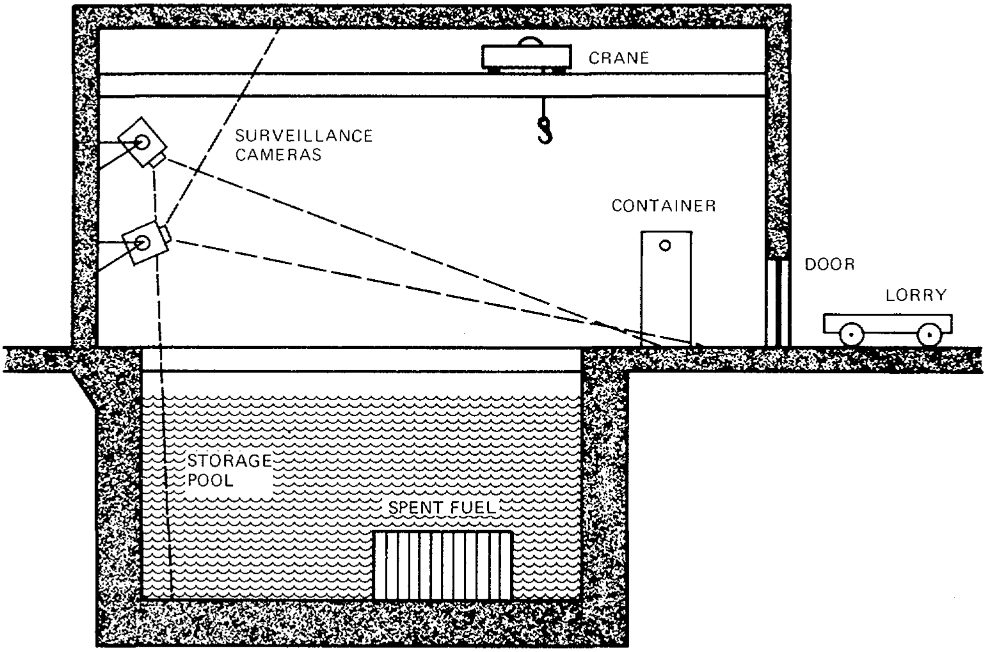

FIG.11. Combined application of containment and surveillance.

may involve the use of tamper-resistant automatic cameras or other devices to monitor changes in containment or to observe inventory changes. Personnel may carry out the same tasks by manning key observation points continuously or periodically.

For example, if a physical inventory of fresh fuel or of a new core loading in a reactor has been taken and it is possible to seal the fuel container (Fig.10) or reactor vessel, it is sufficient to verify periodically that the seal has not been tampered with in order to conclude that the inventory has not changed since the time when the seal was applied or last verified.

In the spent fuel storage, inspectors may make use of a combination of available containment/surveillance measures as shown in Fig.11. In this case, containment is provided by the walls of the building while surveillance is carried out by twin cameras which, during the absence of inspectors, take pictures at intervals shorter than the time needed to remove any fuel. Periodic evaluation of the films would thus reveal any removal of spent fuel.

The IAEA containment/surveillance measures are designed in such a way as to minimize intrusion in the work of a nuclear facility operator.

Inspections

Inspection is essential to implement the safeguards measures described above. Its aim is to verify the validity of information in the possession of the Agency. The maximum intensity and frequency of inspections are specified in the safeguards agreements and vary with the type of facility inspected. A proportion of routine inspections may be unannounced.

The NPT safeguards system distinguishes between three types of inspections.

Routine inspections are made to verify that the information contained in reports submitted by the State is consistent with the accounting and operating records kept by the operator. Routine inspections also verify the amount, the location and the identity of nuclear material, investigate shipper/receiver differences (in other words any differences in reports about the same item which may occur in notifications received from the shipper and the receiver of the item), uncertainties in book inventories, and MUF.

Ad-hoc inspections are made to verify information submitted by States regarding the design of new nuclear facilities, the first report made by the State after the conclusion of the safeguards agreement and changes between the submission of that first report and the beginning of routine inspections. Inspections made to verify material before it is sent abroad or after it is received from abroad are also classified as ad-hoc.

Special inspections are made in addition to routine inspections when unusual circumstances occur and are notified to the Agency in 'special reports', or in order to collect information in addition to that which the State routinely provides or which is obtained by routine inspections but is found to be inadequate. Special procedures must be followed for special inspections.

During inspections the IAEA's inspectors carry out numerous tasks; for instance they:

- Examine pertinent records
- Make independent measurements of safeguarded nuclear material (they may use the IAEA's own equipment or the State's or operators' equipment)
- Verify the proper functioning and calibration of equipment
- Obtain samples and ensure that they are properly collected, tested, handled and shipped
- Use and service IAEA surveillance equipment
- Affix, inspect and remove IAEA seals.

Verification is concentrated on the stages of the fuel cycle that involve the production, processing, use or storage of nuclear materials from which weapons could be readily made. The verification effort must however in all cases be sufficient to enable the IAEA to meet the defined objective of safeguards: the timely detection of the diversion of a significant quantity of nuclear material.

ORGANIZATION OF IAEA SAFEGUARDS

In discharging the safeguards responsibilities of the Secretariat, the Director General is supported by the Department of Safeguards and the Department of Administration. The former department deals with the implementation of safeguards and their development and evaluation; the latter provides assistance in the drafting and negotiating of safeguards agreements and in policy matters. The place of the Department of Safeguards in the framework of the Agency can be seen from Fig.12 and its internal structure from Fig.13.

Safeguards operations

The implementation of safeguards agreements is entrusted to the two Divisions of Operations. Each consists of three Regional Sections and is manned by inspectors and supporting staff responsible for the direct application of safeguards. By the end of 1980 there were about 120 inspectors in these two divisions. Each division is responsible for planning inspection programmes and performing inspections. After returning from inspections, inspectors prepare inspection reports which include the data they have collected and the conclusions they have drawn. Inspectors are supported in their work by other units in the Department (e.g. data processing, analytical and evaluation services). The results of inspections and corresponding evaluations are condensed into statements which are sent to the respective States. The Divisions of Operations also up-date design information on facilities under safeguards and participate in the preparation and negotiation of Safeguards Agreements and Subsidiary Arrangements including Facility Attachments[14] needed to implement safeguards agreements. The divisions also do valuable work in summarizing their safeguards experience and participating in the development of new safeguards approaches.

The allocation of countries to the different Regional Sections has been decided upon taking into account the geographical location of each country and the inspection effort required for the facilities in it. The present organizational structure is as shown in Fig.13. The Regional Sections of the Division of Operations A implement safeguards in countries as follows:

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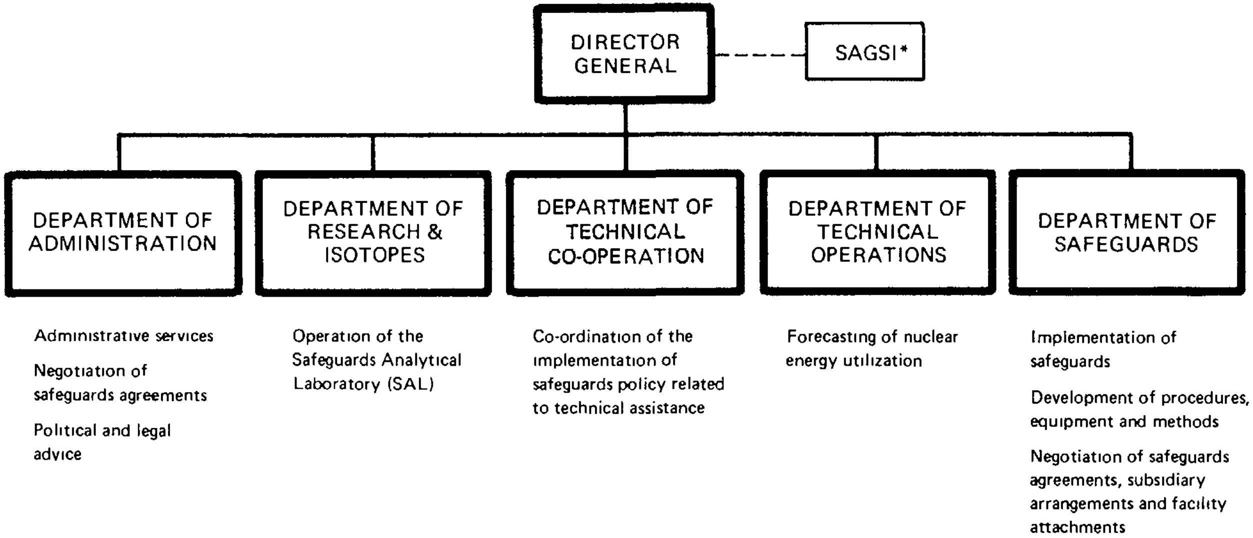
[14] Subsidiary Arrangements describe interpretations of provisions in the Safeguards Agreement as accorded between the Agency and the State(s), and indicate in detail the manner in which the Agreement is to be implemented. Details of procedures applicable to all facilities in the State are included in the General Part of the Arrangements. Procedures relating to specific facilities are laid down in the Facility Attachments.



* Standing Advisory Group on Safeguards Implementation

FIG.12. Organizational structure of the IAEA and the safeguards-oriented activities of its Departments.

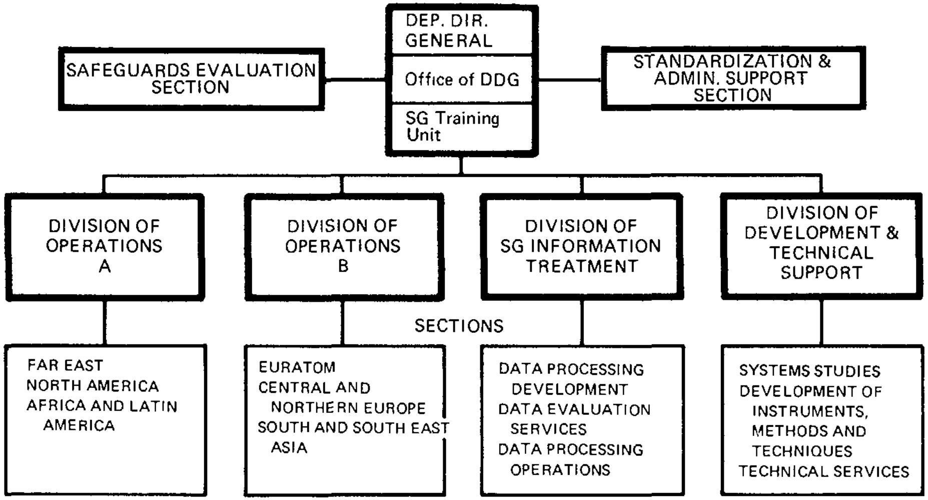


FIG.13. Organizational structure of the Department of Safeguards.

Far East Section: Japan, Republic of Korea, Taiwan

North America Section: Canada, USA[15]

Africa and Latin America Section: Argentina, Brazil, Chile, Colombia, Libyan Arab Jamahiriya, Mexico, Peru, Portugal, South Africa, Spain, Uruguay, Venezuela, Zaire.

The Regional Sections of the Division of Operations B implement safeguards in countries as follows:

Euratom Section: Belgium, Denmark, France[16], Federal Republic of Germany, Ireland, Italy, Luxembourg, Netherlands, United Kingdom[16].

Central and Northern Europe Section: Austria, Bulgaria, Czechoslovakia, Finland, German Democratic Republic, Hungary, Norway, Poland, Romania, Sweden, Switzerland

South and South East Asia Section: Australia, Democratic People's Republic of Korea, Greece, India, Indonesia, Iran, Iraq, Israel, Pakistan, Philippines, Thailand, Turkey, Yugoslavia.

The workload of inspections and accordingly the manpower and financial requirements depend in the first instance on the number and type of installations under safeguards or containing safeguarded material. The growth of this number depends on the one hand on the development of nuclear energy throughout the world, on the other hand on the increase in numbers of safeguards agreements. Figure 14 shows the growth in the number of reactors under safeguards. The number of research reactors remained rather stable during the last decade and the increase shown in Fig.14 was mainly due to the increasing number of safeguards agreements. The growth curve of power reactors however reflects also a real increase of power reactors actually in operation. All nuclear power reactors in all non-nuclear-weapon States are now under safeguards (see Footnote 6).

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[15] The agreement between the USA and the IAEA for the application of safeguards in the United States will be implemented in 1981. Under this agreement the USA permits the IAEA to apply its safeguards to all nuclear activities in the USA, "excluding only those with direct national security significance." The IAEA designates the facilities in which it will apply safeguards. Until now the IAEA has applied safeguards in the USA when so required by agreements with third countries, as well as in the USA or under special limited arrangements.

[16] The UK has similarly offered to accept safeguards on all facilities in the UK, "subject to exclusions for national security reasons only", and the relevant agreement entered into force in 1978. This agreement will likewise be implemented in 1981 at facilities designated by the IAEA. France has negotiated an agreement with the IAEA which will permit the IAEA to apply safeguards at facilities listed by France; this agreement entered into force on 12 September 1981. Until now, the IAEA has been applying safeguards in the UK and in France only in cases when so required by agreements involving third countries or under special arrangements.

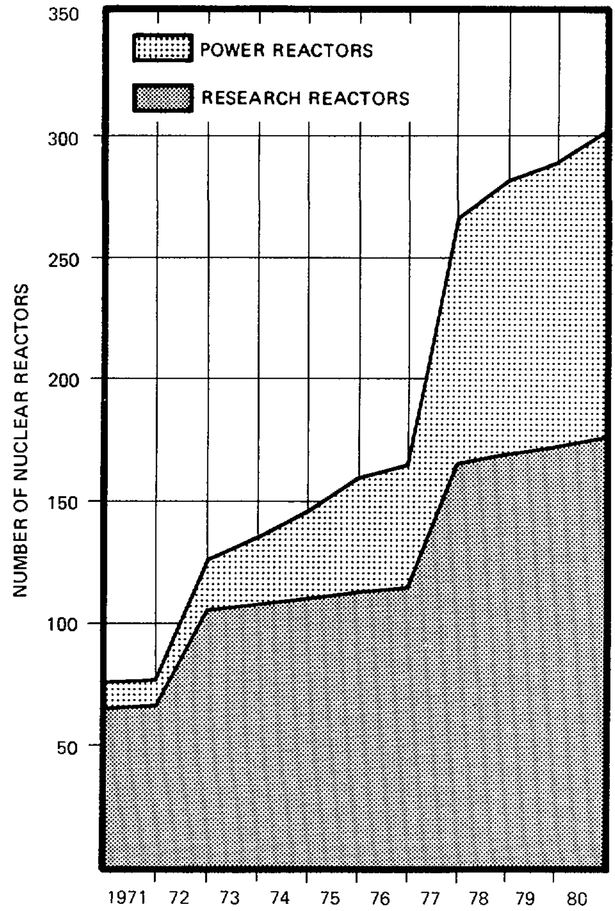

FIG.14. Number of nuclear reactors under safeguards.

As already mentioned, reactors are item facilities whose readily identifiable items (fuel assemblies) facilitate accounting for the contained nuclear material. The inspection effort needed to attain the safeguards objective depends on the type of reactor and lies between 1 and 50 man-days per year and reactor. For the light water reactors, which are by far the most common type of power reactor, about 10 – 15 inspector man-days per year are necessary.

Figure 15 shows the increase in the number of safeguarded bulk handling facilities in which nuclear material is handled in loose form (conversion plants, fuel fabrication plants, reprocessing plants, enrichment plants). Safeguarding such plants may require the presence of inspectors at frequencies ranging from 20 man-days per year up to continuous presence at the installation, depending on size and type of plant.

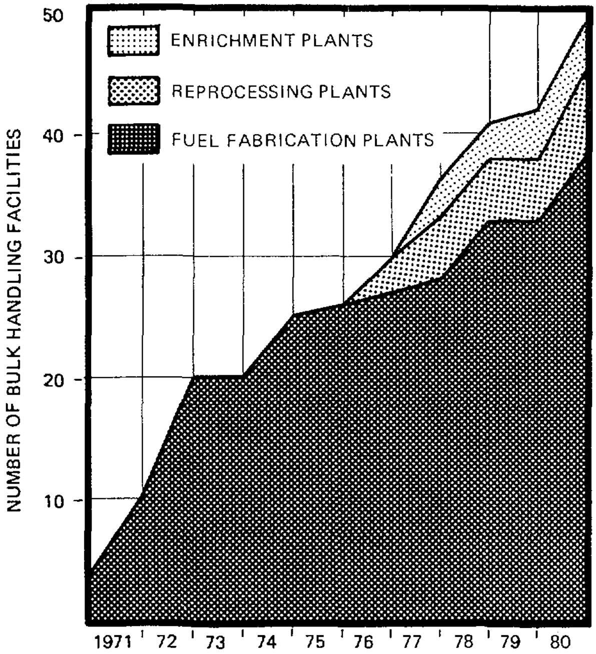

FIG.15. Number of bulk handling facilities under safeguards.

Besides the major types of facilities mentioned above several other installations like separate storage, other facilities and other locations outside facilities (for instance small research laboratories) have also been safeguarded (Fig.16).

The number of large installations under safeguards increased more than 4 times between 1970 and 1980 but, because of the growing unit size of installations and the increasing amount of spent fuel, the quantity of nuclear material under safeguards rose even more rapidly. During the same period the professional staff of the Department of Safeguards increased by a factor of only about 2.5. In 1980 about 1100 inspections were made at more than 500 facilities in 47 States.

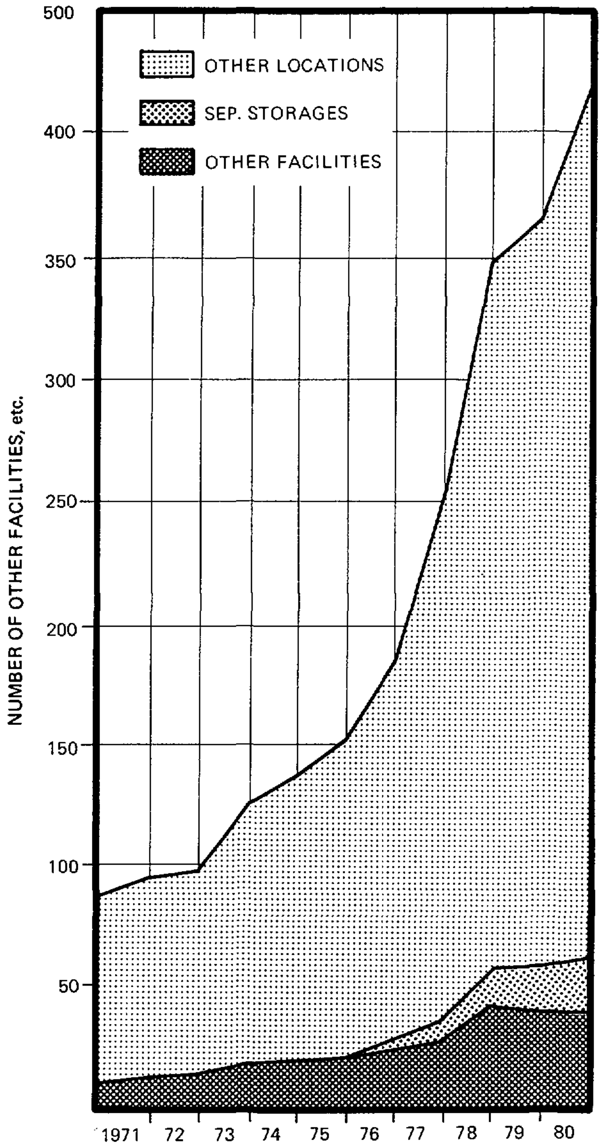

FIG.16. Number of separate storage facilities, other facilities and other locations under safeguards.

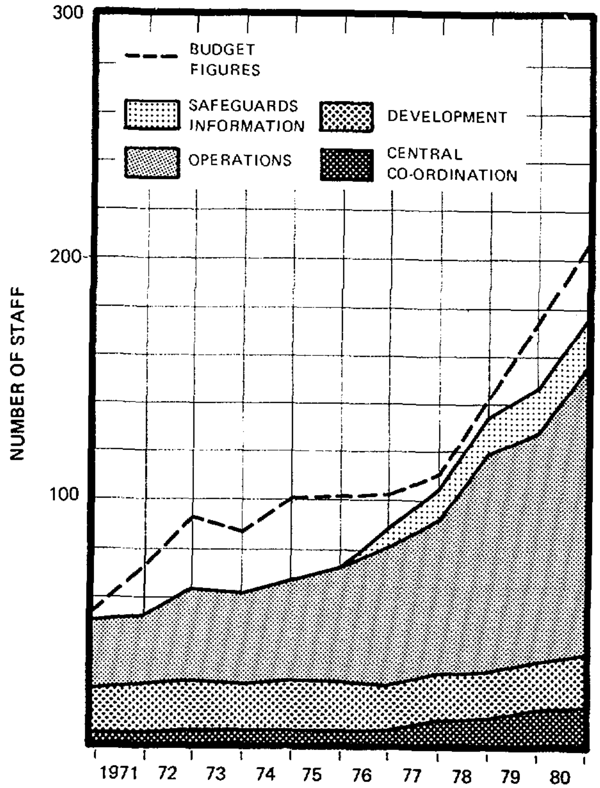

FIG.17. Increase in number of professional staff in the Department of Safeguards.

The growing safeguards workload obviously requires an increase in manpower of the IAEA inspectorate (Fig.17). The Agency recruits its personnel on as wide a geographical basis as possible. This enhances the credibility of the safeguards system in that it enables the Agency to avoid sending inspectors to their own country.

It is not always easy to recruit the qualified manpower, however. By the end of 1980 the inspectors of the Divisions of Operations came from 39 countries, including 26 developing countries.

Information treatment

Safeguards operations are supported by other organizational units, amongst them the Division of Safeguards Information Treatment (see Fig.13), handling the vast amount of safeguards information reported by States and collected by inspectors. The Division comprises three Sections.

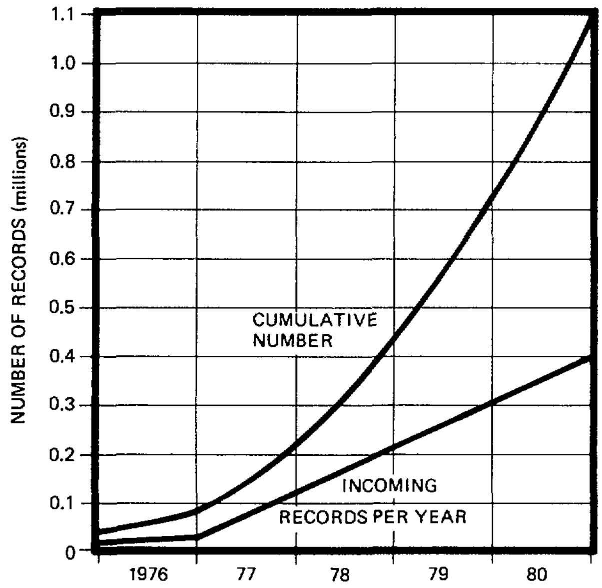

FIG.18. Increase in workload of the Division of Safeguards Information Treatment.

The *Data Processing Operations Section* is responsible for the computer processing of a variety of safeguards information including the accounting data furnished by Member States, inspection data and design data. The *Data Evaluation Services Section* provides assistance to inspectors in preparing inspections, evaluating their results, preparing inspection reports, evaluating data quality and trends, correlating data and analysing statistics. The *Data Processing Development Section* is responsible for the continuing development and evaluation of the computer techniques needed to satisfy the growing safeguards requirements.

The increasing number of records and reports which the Division of Safeguards Information Treatment processes and evaluates each year is shown in Fig.18. Several thousand questions are put to the system each year to satisfy the needs of the Divisions of Operations. Computer output data are also included in the annual Safeguards Implementation Report. Direct access to computerized data is permitted only to authorized safeguards personnel. This access is arranged by the use of computer terminals which provide immediate information on a 'need-to-know' basis. The arrangements for data stored in the computer are carefully designed to ensure their security. Established procedures are continually evaluated for their effectiveness.

Development and technical support

The Divisions of Operations require not only the support of an efficient computer unit; their activities in the field must be based on sophisticated safeguards strategies and techniques, their inspectors must be intensively trained, and they must be supplied with equipment of the highest possible standard. The resulting widely diversified tasks are assigned to the Division of Development and Technical Support (see Fig.13). There are three Sections in this Division.

The *Systems Studies Section* is the think tank of the Department. For each type of facility, plausible diversion strategies have to be postulated and safeguards approaches to defeat them have to be developed, together with methods for determining the effectiveness of the approaches.

Safeguards could not be efficiently and effectively implemented without large-scale use of all sorts of equipment and instrumentation for measurements, analyses and surveillance. This equipment must not only be accurate but also rugged, simple and portable. The main responsibility for developing, acquiring and testing the necessary equipment and instrumentation lies with the *Section for Development of Instruments, Methods and Techniques.* The IAEA does not have the financial resources to operate a special research and development laboratory and is therefore dependent on the support of Member States. At present three Member States[17] are funding research and development projects in safeguards problem areas suggested by the IAEA or in areas where existing equipment or instrumentation needs improvement or greater sophistication or flexibility. The Development Section defines the problems or specifications, co-ordinates the international efforts and performs acceptance tests.

The *Technical Services Section* is responsible for the provision of equipment, instruments and seals. This includes procurement, storage, calibration, maintenance, shipment and instruction on the use of instruments and in the application of techniques. Samples for analysis, taken by the inspector, are received by the Section and shipped for analysis to the Safeguards Analytical Laboratory, Seibersdorf, or a laboratory of the International Network of Analytical Laboratories. Seals are at present issued at the rate of 6000 a year. Optical surveillance devices such as film cameras are used in locations such as spent fuel storage ponds where sealing is impractical. More than one hundred twin-camera units are taking photos at a rate of over 20 000 per day.

[17] Canada, Federal Republic of Germany, USA. Projects with Australia, Japan, USSR, UK and Euratom are under preparation.

Conclusion

The safeguards component in the Agency's budget increased from 10% in 1970 to 27% in 1980, reflecting the growth of the peaceful uses of nuclear energy and the increase in nuclear material and installations to be safeguarded. The major part of the budget is allocated to the promotional activities of the Agency. The cost of safeguards, which is at present borne largely by developed States, is appreciable, but in perspective it is not large – of the order of the cost of a single military aircraft per year. Divided by the energy produced by nuclear reactors annually throughout the world, it represents a cost of approximately US $0.00003 per kWh of electricity. Even if one applies a factor to this figure to include the safeguards expenses incurred by States and plant operators, the resulting cost is still minor compared with the benefits derived – a considerable contribution to international security.

Until now, safeguards have been invoked only to verify agreements dealing with nuclear energy. There is no technical reason, however, why the concept of safeguards should not extend to other international agreements dealing with potentially hazardous materials and equipment, for instance in the field of arms control and disarmament.

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