Field experience of safeguards inspectors

by F. Klik*

The IAEA has been applying safeguards since 1962 and, so far, there has been no case of safeguarded nuclear material, facilities, or equipment, being used for unauthorized purposes. There have, of course, been many cases of detected anomalies, but it has always been possible to account for them satisfactorily.

The work of the Agency's Department of Safeguards has changed over the last decade. In the main, this is due to the Treaty on the Non-proliferation of Nuclear Weapons (NPT) which entered into force in 1970. This treaty assigns to the Agency the job of safeguarding all the nuclear material in peaceful nuclear activities in those countries which are party to the treaty. Many new safeguards agreements had to be concluded and then implemented as a result of the NPT coming into force. Moreover, many new nuclear facilities were being built in the 1970s.

The workload of the Inspectorate has increased greatly in the period 1970–1980, as illustrated in Figure 1. However, the negotiation and then implementation of so many new safeguards agreements, subsidiary arrangements and facility attachments – mainly based on the requirements of the NPT – has shown that the IAEA and the states can meet the twin objectives of developing nuclear power for peaceful ends and preventing the proliferation of nuclear weapons.

The number of power reactors under safeguards has risen from 10 in 1970 to 126 at the end of 1980 (Fig. 2). The number of bulk-handling facilities rose from 4 to 49 (Fig. 3). Figure 4 shows the growing amount of highly enriched uranium and plutonium under IAEA safeguards, and Figure 5 shows the increase of natural and low-enriched uranium under safeguards.

Reflecting these developments, the professional staff of the Department of Safeguards has increased from 54 in 1970 to 206 in 1980, of whom 138 are full-time inspectors. They performed about 1100 inspections at more than 500 facilities in 1980.

Consequently the safeguards inspectors have now accrued a great deal of field experience, but the Agency's experience in safeguarding some types of facilities is considerably greater than for others. For example, the Agency has extensive experience in safeguarding thermal power reactors, particularly light-water reactors; on the other hand, it has so far only limited experience in safeguarding fast-breeder reactors and their support facilities, since such facilities have only recently begun to come under safeguards. In the case of bulk-handling facilities, the Agency has considerable experience in safeguarding conversion and fuel fabrication plants and limited experience with reprocessing and enrichment plants.

The IAEA conducts three types of inspection. ad hoc, routine, and special. The greater part of the inspection effort is made on routine inspections, which may include the following activities:

- Examining the records kept at a facility to establish the book inventory of nuclear material present and its flow through the facility;
- Comparing these records with shipping documents, facility operating records, and with the state's reports to the Agency to establish that shipments and receipts are consistent with each other and with the records of companion facilities,
- Verifying the stated nuclear material inventory, in many instances by statistical sampling and non-destructive analysis (NDA);
- Confirming that previously verified material remains undisturbed, by installing and servicing containment and surveillance devices.

Safeguards agreements require that the state makes available to the Agency specific information on nuclear materials and facilities. Amongst other things, the state is required to: maintain records for each facility or material-balance area, and provide the IAEA with reports on the nuclear material, based on the records kept.

The existence of a state system of accountancy and control of nuclear material (SSAC) is a prerequisite to the application of an effective international safeguards system, but cannot replace the latter. In practice this has been somewhat of a "what came first – the chicken or the egg? " situation, since at the beginning of the 1970s only a very few states had well-developed domestic accountancy and control systems. Happily, established domestic systems are now becoming more the rule than the exception. In several states, highly developed and very efficient SSACs are in operation. There is no doubt that the Agency's guidance and recommendations, provided both through Headquarters and field training courses and through practical suggestions and recommendations made during IAEA inspections, have contributed to this positive development in the states.

* Mr Klik is Director of the Division of Operations (A) in the Agency's Department of Safeguards

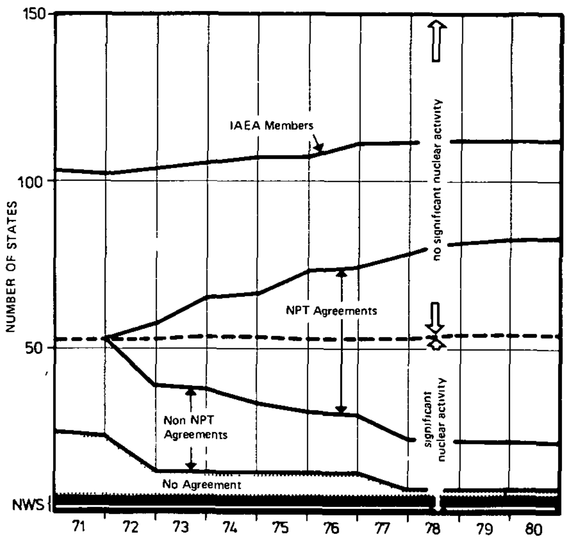

Figure 1. Evolution of safeguards agreements 1970–1980.

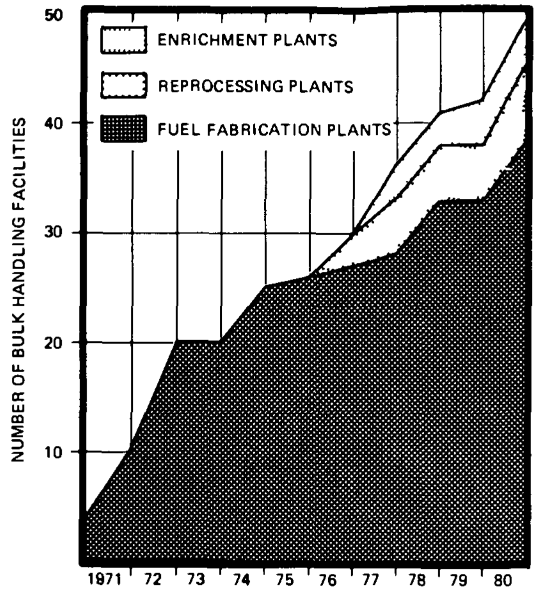

Figure 3. The number of bulk-handling facilities under safeguards.

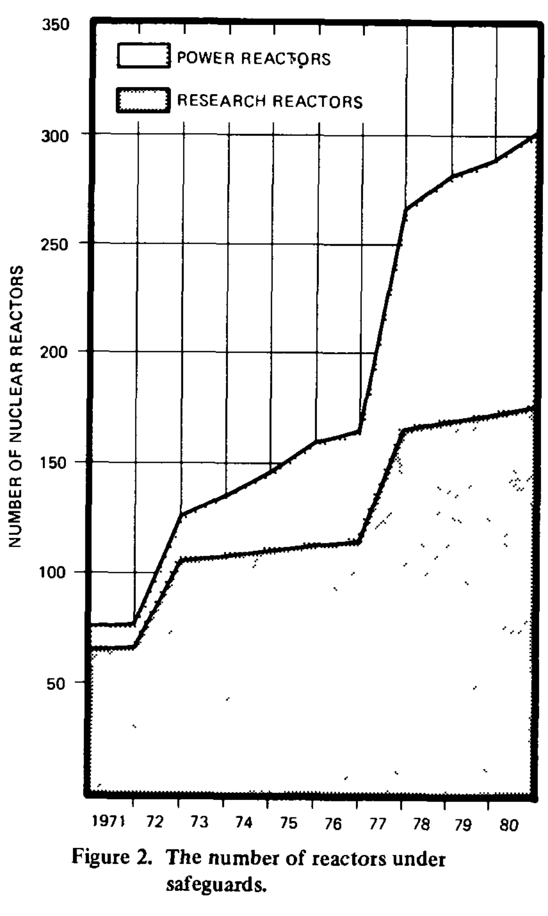

Figure 2. The number of reactors under safeguards.

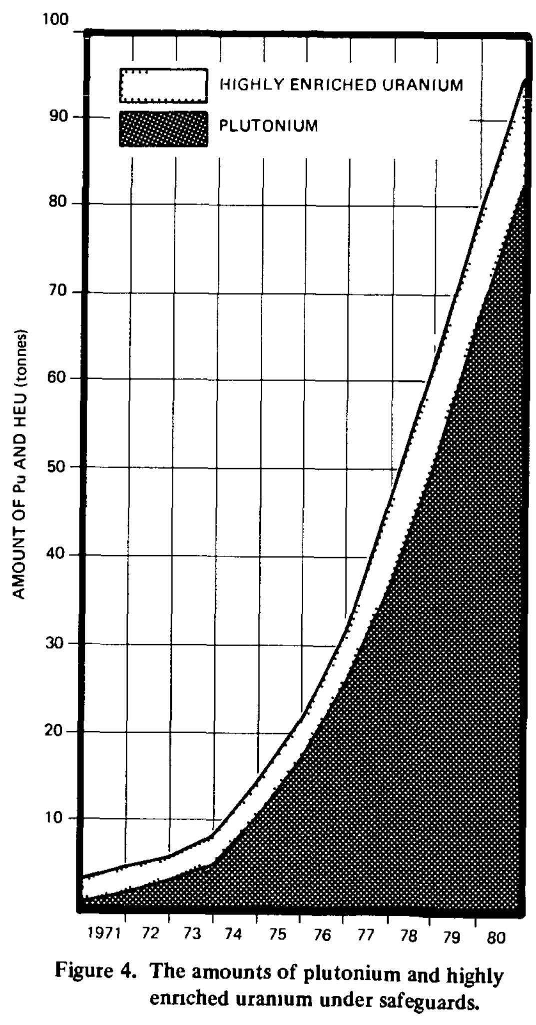

Figure 4. The amounts of plutonium and highly enriched uranium under safeguards.

The Agency takes due account of the technical effectiveness of the state systems when planning inspections. This obviously helps the Agency conserve its resources, but it also benefits the state. The co-operation of the Agency's Inspectorate with the states' systems is generally very good. Liaison committees and similar groups have been established to improve co-operation between the Agency and some states. Through these groups, several problems in implementing safeguards have been solved. A field office has been established in Canada, and arrangements for the outposting of inspectors for extended working periods agreed with Japan. Although there has been substantial progress, there is still room for further improvement of the states' systems: mainly with respect to full application of IAEA recommendations; reporting practices, closing of material balances; determination of quantity of material unaccounted for; and safeguards-oriented design.

It was recognized during the early years that safeguards could not be limited to examining and evaluating unverified reports submitted by states. The independent, physical verification of the reported nuclear material is essential. Unfortunately, it was not recognized at the same time – and it is still not as widely recognized today as might be desired – that the independent physical verification of nuclear material is not in itself sufficient. For physical verification to mean anything, there must first be recorded, reported, and audited data to be verified.

Fortunately, not only have improvements been made in state systems, but the Agency has improved its own ability to collect, sort, store, analyse, and compare data from the states' systems. The Agency's Safeguards Information Treatment Division routinely provides inspectors with accounting data for each facility, and helps them analyse the data and compare it with facility records. The auditing of nuclear material records has an important place in safeguards inspections as has been fully proved by experience. The IAEA Inspectorate has performed a great deal of auditing and this experience, together with that of the states' systems, should now be consolidated to train inspectors better in auditing. It is not an easy task to audit: while this activity is a very important one, most new safeguards inspectors have, due to their educational background (physics, chemistry, engineering) and industrial experience, little or no experience in the auditing of records and reports. An audit manual is now being prepared as one of the tasks in the support programme of one Member State. It is hoped that this, together with the emphasis placed on accounting and auditing in the inspector training programme, will improve the Agency's growing expertise.

Having confirmed the book inventory and flow of nuclear material at a facility, the inspector can start verifying physically that the declared material is really there. As a first step, items – e.g. fuel bundles – are counted, and then a portion of the inventory is non-destructively analysed.

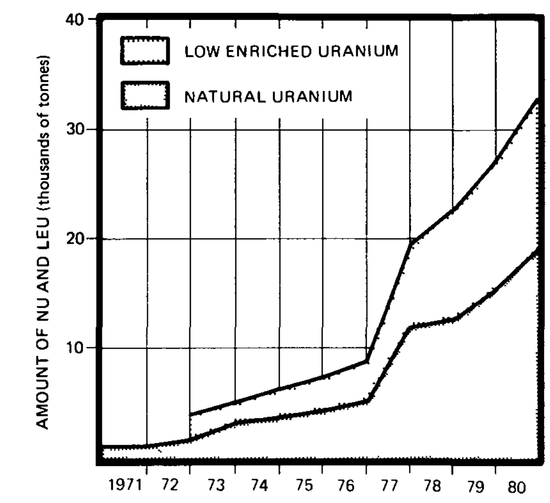

Figure 5. The quantities of natural and low-enriched uranium under safeguards.

The importance of non-destructive analysis (NDA) in the field continues to increase. There will, of course, always be a need for samples to be taken and transported to the main IAEA Safeguards Analytical Laboratory at Seibersdorf, Austria. There the samples are exhaustively analysed and the results compared against NDA methods. But the cheapness and easier logistics of field NDA, coupled with the increasingly stringent transport requirements for even small samples of nuclear material, will continue to make field NDA more attractive. The NDA measurements must, of course, be precise and accurate enough to allow the inspectorate to decide whether or not to accept an operator's statement.

For many years the Agency has used the SAM-II as one of its most important NDA field instruments. This portable, two-channel, gamma spectrometer can be used as an assay meter to confirm the presence of uranium, and to measure its degree of enrichment. SAM-IIs are now well-tried instruments and, indeed, are often used by plant operators for their own measurements. They are thus accepted and understood in nearly all facilities.

In the course of time other more sophisticated instruments have been developed: the most successful being the Silena (Fig. 6). This instrument, like the SAM-II, measures gamma-ray intensity, but the spectrum can be broken down into many more channels (1024 instead of 2) and so the precision and accuracy are higher than with SAM-II. Furthermore, readings from the Silena can be recorded directly onto a casette tape and taken back to Headquarters for playback and analysis. Naturally these improvements do not come without some drawbacks: for example, the inspector has to be more highly trained if he is to take advantage of the full capabilities of the instrument.

These two instruments are widely used to verify enriched uranium (and, at a lower confidence level,

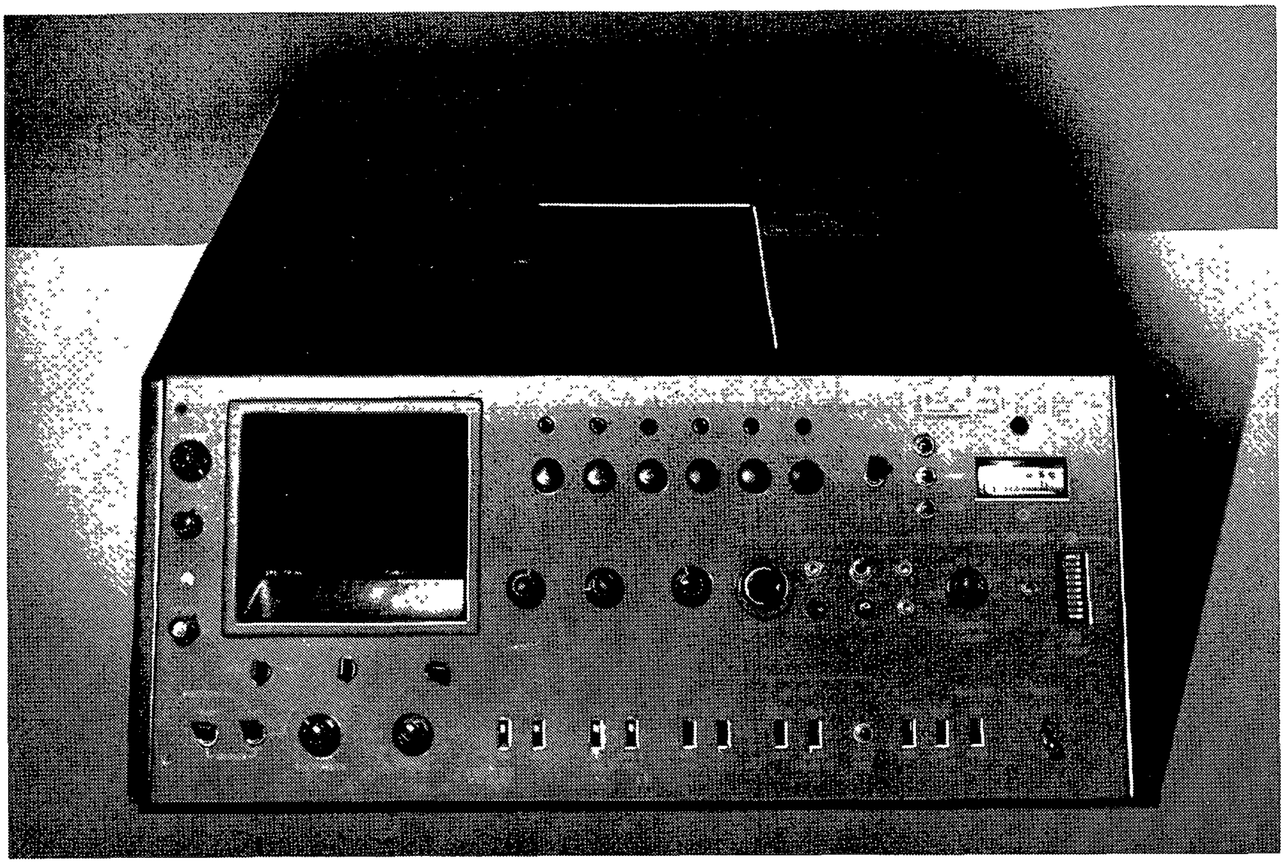

Figure 6. The portable 1024-channel gamma spectrometer, Silena.

plutonium) but, as seen from Fig. 4, the amount of plutonium under safeguards has grown much faster than that of enriched uranium. While much of this plutonium is in un-reprocessed spent fuel where verification is by containment and surveillance, there is an increasing amount of separated plutonium under safeguards in reprocessing plants, mixed-oxide fuel fabrication plants, critical assemblies, and fast reactors. There is thus a growing need for better plutonium NDA.

SAM-II cannot verify plutonium acceptably. Even the Silena requires the use of a complementary instrument, the delayed neutron coincidence counter, to get a sufficiently detailed knowledge of the fuel content. This instrument is a high-precision High-Level Neutron Coincidence Counter (HLNCC) (Fig. 7). Its detectors and electronic circuitry are designed to detect coincident neutron pulses peculiar to Pu-240, and can therefore distinguish between neutrons from Pu and those non-coincident neutrons from other sources. This enables the relative concentration of Pu-240 to be determined.

This combined technique has been very successful in measuring fast-reactor fuel assemblies. It is now a standard procedure to measure each such assembly produced at fabrication plants using a custom-built HLNCC dedicated to the plant. Other similar uses are routinely to measure the plutonium fuel-plates for fast critical assemblies. These new instruments have made a big difference in the scope of the measurements that can be, and are, routinely performed in the field.

Facilities which were considered one of the most difficult areas a few years ago, namely mixed-oxide fuel fabrication plants, are now turning out to be among those about which the greatest confidence can be obtained. This is not to say that the safeguarding of these facilities is easy. What is implied is that with the correct resources in the way of refined instruments and competent staff, high confidence can be placed in results of the measurements and safeguards. The essential point is the quality of the instruments and the competence of the staff. Whereas some time ago, the typical inspection would consist of a single inspector working for one day with a SAM-II, the most important inspections now involve teams of inspectors working for several days or a week. These types of inspections raise considerable problems of management and logistics. The personal demands on such a team are also considerable, requiring ability in human relations as well as a high level of technical expertise. How to attract, train, and keep such a team is one of the important tasks of the Safeguards Department.

Turning from the techniques which rely upon the team approach to those suitable for individual work, mention should be made of the Cherenkov viewing device (Fig. 8). As stated earlier, verification of spent

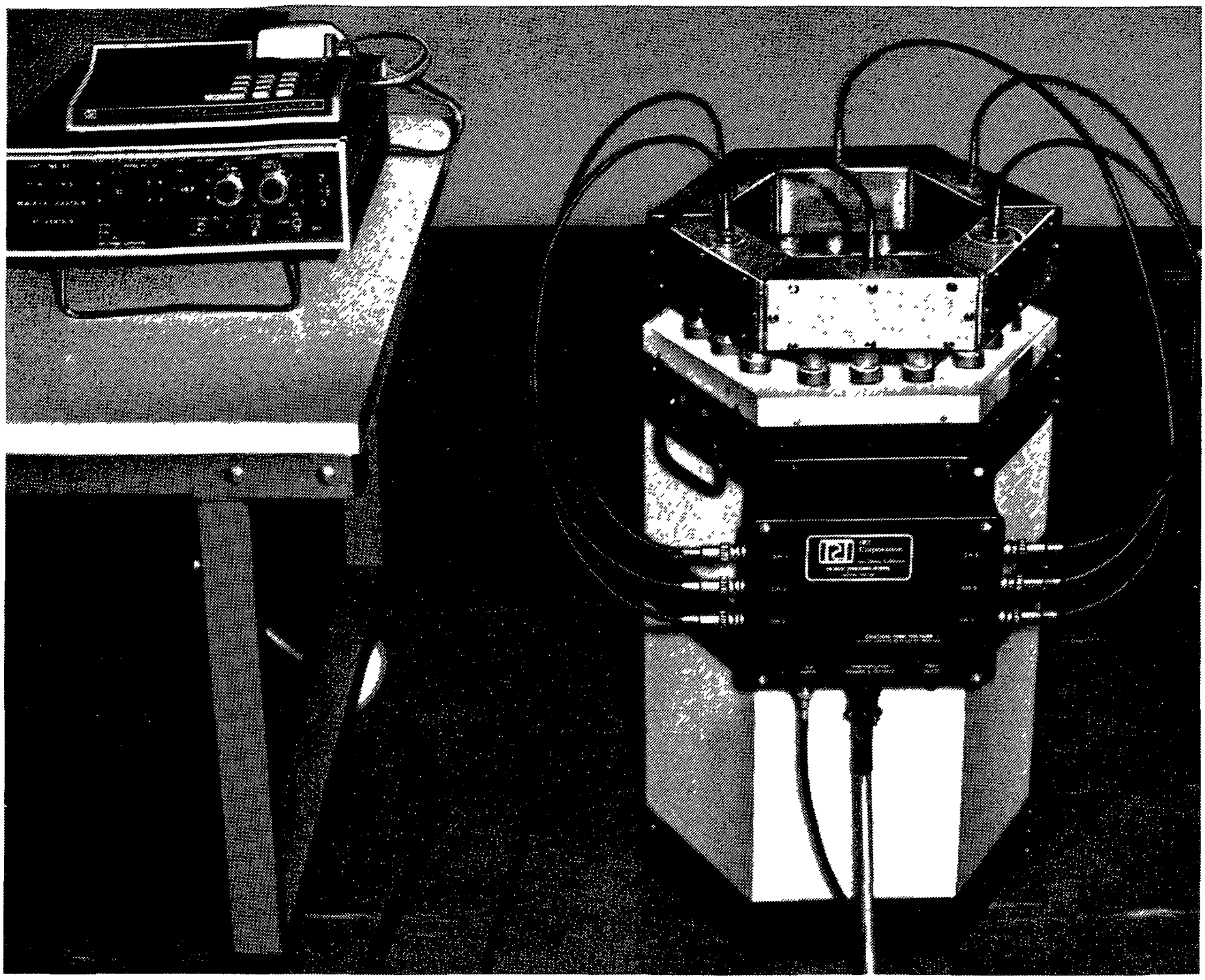

Figure 7. The High-Level Neutron Coincidence Counter (HLNCC) which can be used as a complement to the Silena spectrometer to determine the concentration of Pu-240 in a sample.

Figure 8. The night-viewing device which can be used to detect the Cherenkov radiation emitted by spent fuel stored in cooling pools.

fuel has, until recently, been done by containment and surveillance. These are not always successful and other methods suitable for safeguards inspection have long been needed. A viewing device is now coming into use which enables the Cherenkov radiation characteristically emitted by irradiated fuel to be simply examined. The radiation is visible in good conditions to the naked eye as a blue-green glow. In adverse lighting conditions a night-viewing device, such as has been developed for military use, can make this glow visible even at very low intensities. As used at present, the night-viewing device takes the form of a short telescope with a wide-aperture lens. Light is amplified by a built-in electronic image convertor. When the observer looks into the telescope, an enhanced image is seen even in almost total darkness. Irradiated fuel can be examined at a distance enabling even individual pins and segments to be distinguished, according to the degree of previous irradiation and storage history.

By using such NDA devices, inspectors are able to verify uranium and plutonium during routine inspections. Several other sophisticated NDA instruments are being developed to achieve higher precision, automatic data processing, and to permit the verification of nuclear material even when bound up in complex forms.

If the Agency can be confident that the amount and condition of nuclear material is unchanged, then remeasurement is not necessary. Instead, seals can be put on containers, cabinets, valves, and enclosures, and film cameras or TV systems used to confirm operators' statements of material movement.

The Agency uses metal seals for many applications. These simple but effective devices, however, require a substantial effort at Headquarters for their preparation, recording their application, and their verification on return. Currently the Agency applies (and detaches for verification) over 3000 seals per year, and its computerized record system contains the history of more than 10 000 seals.

Where seals cannot be applied, continuity of information may be obtained by surveillance. Early experience with surveillance cameras by the Agency was not good. While in principle it would seem a simple matter to devise a camera system to take random photographs of a scene, it must be remembered that the Agency's cameras have to operate without failure, with no attention whatsoever, for a period of two to three months, sometimes in demanding environmental conditions. Such reliability has not yet been achieved, and efforts are continuing to reach the required level. Several countries are developing reliable systems in support of the Agency. These advanced systems have yet to be implemented in the field, but some are already being tested. Meanwhile, the standard camera systems have been improved by rigorous selection of individual cameras and extensive prior testing at Headquarters. Cameras fail rarely now, and simultaneous failure of both cameras in a system is even rarer. TV systems have been introduced for some surveillance tasks but cost and complexity rule them out except in special applications. Surveillance – both camera and TV systems – is very important to the Inspectorate in their safeguards work. there were more than 100 film camera units and more than 10 TV units in operation in 1980. Six million pictures were taken and evaluated in 1980.

With the large increase of inspections, rapid growth of the Inspectorate, increased reliance on records examination, and the introduction of more sophisticated NDA, training has also become increasingly important. Thus newly recruited inspectors can expect to spend three to six months in intensive training, including various field exercises, before they assume routine work as inspectors.

The field experience of the IAEA Inspectorate also provides valuable data for internal management, especially to ensure that the limited resources available to the safeguards Inspectorate are put to best use. The Agency can now form good estimates of the inspection effort required for different facilities, the number of inspection-days at facilities which an inspector can perform during one year, and the savings which can be expected from field offices and outposted inspectors. All this information has been fully employed to determine the best allocation of manpower to the operational sections of the Safeguards Department. This data is also of use in planning how many safeguards inspectors will be needed in the future.