

Non-Destructive Assay: Instruments and Techniques for Agency Safeguards

Increasing use is being made of non-destructive assay instruments and techniques by Agency safeguards inspectors for the identification and measurement of nuclear materials. These instruments and techniques have been found to have certain characteristics that meet the needs of the Agency's world-wide safeguards inspection activities. One important advantage that non-destructive assay (NDA) offers over the traditional destructive measurement methods is that of timeliness: measurements can be made during an inspection.

In general, NDA is less expensive and less time consuming, and often may be less hazardous than destructive analysis. There are other instances when destructive sampling is unacceptable because it would destroy a valuable finished product (e.g. finished fuel pins) or would be very difficult to do (e.g. UF_6 cylinders, irradiated fuel, etc.). NDA can usually be easily repeated (this is valuable in the case of disputes) and can be made and evaluated *on-site* without the delay of international transfers of nuclear material which may be necessary for independent destructive analysis.

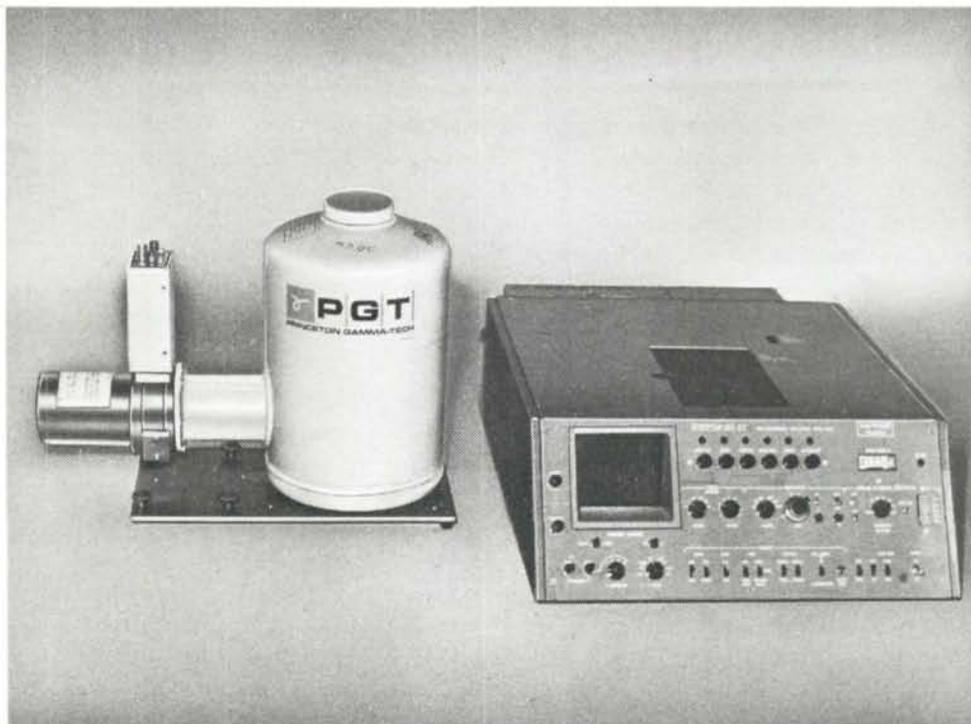
The development and selection of instruments for nuclear measurements for safeguards purposes must take into consideration the peculiar needs of the world-wide inspection activity. These include: portability, ease of checking and repair, accurate calibration using physical standards and calibration sources and the need for secured continuity of knowledge. In the Agency's development programme, emphasis is placed on compact, light-weight, rugged, portable, reasonably priced equipment, which can be carried by the inspectors and thus remain completely under their control from site to site for rapid and accurate assay of special nuclear material.

Within the Agency's Division of Development and Technical Support, the Section for Development of Instruments, Methods and Techniques (SIMT) is responsible for the development, acquisition and testing of instruments and techniques for: (i) destructive and non-destructive assay; and (ii) surveillance and containment of safeguarded nuclear materials.

SIMT conducts research and development in both these broad areas through the IAEA Research Contract Programme and by a modest, but highly important amount of development work done by Agency staff members. A useful mechanism for programme direction has been meetings of consultants and advisory groups. Recently, a programme to provide technical support to international safeguards has been initiated by the Department of Safeguards with the co-operation of the Government of the USA. Similar technical support programmes with other governments are pending. This assistance programme incorporates broad areas of technology transfer covering equipment, training and cost-free experts.

Established Equipment and Techniques

The instrument which has found greatest application is the Stabilized Assay Meter (SAM). Uranium enrichment can be determined with this compact and highly portable instrument



Silena-27 multichannel analyser and germanium detector is used to measure the fission products in irradiated fuel elements.

by measuring the intensity of gamma rays emitted specifically by uranium-235 (i.e., those having an energy of 185.7 keV since this intensity for most practical situations is directly proportional to the amount of uranium-235). For this measurement, it employs a low resolution but highly efficient sodium iodide detector.

The SAM has been routinely used for measurement of uranium enrichment (percentage of U-235 in uranium) or uranium content in fuel fabrication facilities, or at research reactors which use uranium-aluminium alloy plates as their fuel. It has also been used with a neutron sensitive detector (i.e. helium-3 type) for total neutron counting of neutrons emitted by plutonium which, with appropriate corrections, can be related to the plutonium content.

Plutonium can also be assayed by measuring the intensity of gamma rays having energies specific for a particular isotope. To resolve or separate these unique energies is more difficult in the case of plutonium and requires more sophisticated detecting and analysing equipment. However, it can be accomplished by using the Silena 27 multichannel analyser and an intrinsic germanium detector, both of which are portable, compact units used by inspectors.

The Silena system includes the capability to acquire and process gamma ray data and to record it on a magnetic tape cassette. The latter feature facilitates subsequent analysis of the gamma ray spectral data by computer at the Agency's headquarters. The system

is used for measurement of nuclear material containing plutonium such as powder, pellets, platelets or elements which are produced in fuel fabrication plants and used in reactors (fast critical assemblies).

There are special measurement problems involving uranium (e.g. uranium hexafluoride (UF_6) cylinders and irradiated uranium fuel) which require the high resolution capability of the Silena 27 analyser and a germanium detector. In the case of low enriched UF_6 stored in large cylinders, high-energy resolution is necessary in order to differentiate the U-235 characteristic 185.7 keV gamma rays of U-235 from other interfering energies in the background radiation. This is due primarily from the residual quantities of radioactive materials such as Thorium-234 and Protactinium-234m which may remain on the inner walls of the cylinder after a previous emptying.

The Silena 27 — germanium detector system is also used to measure irradiated uranium fuel. By means of such a high resolutions system, the gamma rays of specific energies emitted by fission products within this fuel are measured and correlated with burn-up and plutonium content. A troublesome feature of the germanium detector is that it must be cooled with liquid nitrogen during a measurement, and the liquid nitrogen has to be made available at the inspection site. The container for liquid nitrogen adds to the size of the detector unit, and time is lost while waiting for the detector to cool. To overcome these difficulties, a gamma ray detector made of cadmium telluride, which does not require cooling, can be used with the Silena 27 analyser. However, in its present stage of development, the resolution of the cadmium telluride detector is inferior to that of the germanium detector. Nevertheless, because of its small size, a cadmium telluride detector can be used in places where a larger detector cannot, for example, in narrow gaps between fuel rods in an unirradiated fuel assembly.

A high level neutron coincidence counter, designed to measure large quantities of plutonium or uranium hexafluoride having high neutron emission rates, is in field use. The counter may be used to measure bulk samples or plutonium in unirradiated fuel assemblies that contain mixed PuO_2-UO_2 . The instrument was designed in a modular form to make it portable.

New NDA Instruments and Techniques

A new stabilized assay meter called SPAM (i.e. super SAM) is nearing completion. Among its features is a built-in micro-processor for carrying out the mathematical analyses of the measurement data needed to produce preliminary assay results. SPAM is powered by a disposable battery, and will initially be used with sodium iodide detectors and later with cadmium telluride detectors. The development of this assay meter will provide a tremendous increase in capability for IAEA safeguards and a high priority has been placed on the acquisition of these instruments.

Another high priority development is the improvement and extension of the capability of a computerized segmented gamma scanner (CSGS). The instrument features new hardware and software to eliminate and correct for the measurement variations caused by non-uniform mixtures of either plutonium or uranium. CSGS will employ an intrinsic germanium detector which will enable the instrument to be used in the field.

SIMT has a programme underway on the use of calorimetry for the non-destructive analysis of plutonium. Isotopes of plutonium produce a measureable quantity of heat

primarily as the result of the alpha particles they emit. The total heat produced is proportional to the amount of the various plutonium isotopes that are present in the sample. In addition to obtaining a measurement of the heat produced (using a calorimeter), it is also necessary to determine the isotopic content and this can be done by means of a high resolution gamma ray spectroscope.

Three fast-response air-chamber calorimeters for measuring plutonium are currently being constructed for evaluation by SIMT. One is for small samples of plutonium powder or pellets, another for cans of bulk plutonium oxide and a third for plutonium fuel rods up to four metres in length. The attractive features of calorimetry are: (1) it has a high measurement accuracy, (2) it does not require the use of representative assay standards, (3) sample homogeneity and matrix does not affect the measurement.

Automatic Processing of NDA Data

In order to expedite and improve accurate analyses of NDA spectral data, collected during inspections, a new gamma ray data acquisition and processing system based on a mini-computer has been acquired by SIMT. This system is used for the systematic transfer of data from cassette tapes to a larger standard magnetic tape for permanent storage and retrieval, and for the reduction and analysis of this data to provide reports of isotopic composition and abundance. The system can also be used for the development of new gamma ray assay techniques. It will be particularly useful in the analysis and interpretation of the complex gamma ray spectral measurements of irradiated fuel to determine burn-up and plutonium content. A longer range goal is to employ this system in combination with the Agency's large IBM 370/158 computer for immediate analysis of spectral data submitted by inspectors in the field via telephone.

NDA Standards

One of the crucial points in NDA safeguards applications is the preparation, calibration and control of standards for the instrumentation. The Agency already possesses a useful range of physical standards, but success in using physical standards for field applications will depend on solving many practical problems. Although, in certain specific cases, the procurement and use of standards which are nominally identical to the measured items is possible, in general the use of calibration standards on a one-to-one basis is not feasible and other alternatives, such as the development of calculational methods, are being pursued by the Agency. In addition to meeting the urgent practical need for the reduction of the number of calibration standards, a good calculational method, once developed, would play an important role in helping to identify false physical standards. The cross-checking of NDA measurements against calculations would be an additional protection against bias in absolute measurements.

Summary Statement

The development of techniques and instruments for Agency safeguards is an on-going programme which is accomplished with the collaboration of various Member States. It is through collaboration such as this that the needs of the safeguards inspectorate are provided for and major improvement in the Agency's international safeguards capabilities are achieved.