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ISPRA COURSES 1978

Non-Destructive Assay in Fissile Material Control **SFMM/78**

September 18-22, 1978

The Course is aimed at providing a detailed picture of the state of non-destructive assay of fissile material to-day.
The majority of the time will be spent in "hands-on" laboratory experiments in small groups. The experiments are designed to illustrate basic nuclear measurement theory and specific practical measurement problems. The course will include gamma-ray measurement experiments (e.g. U-enrichment, Pu isotopic composition, GeLi detector systems, etc.) as well as neutron experiments (coincidence counting, active interrogation, etc.). Emphasis will be placed on individual participation and discussion of the attendees specific problems.

Registration fee: Lit. 160.000

For further information please contact:

Secretariat "Ispra-Courses"
Centro EURATOM
I - 21020 ISPRA (Varese)

EUROPEAN SAFEGUARDS RESEARCH AND DEVELOPMENT ASSOCIATION
ESARDA

COMMISSION OF THE EUROPEAN COMMUNITIES
JOINT RESEARCH CENTRE

CALL FOR PAPERS

1st SYMPOSIUM ON SAFEGUARDS AND NUCLEAR MATERIAL MANAGEMENT

APRIL 25-26, 1979

The first annual symposium sponsored by ESARDA on Safeguards and Nuclear Material Management will be held in the Ravenstein Congress Hall in Brussels, Belgium.

The purpose of the meeting is to stimulate discussion about safeguards implementation problems in the European Community between nuclear plant operators, safeguards authorities and research organizations.

The JOINT RESEARCH CENTRE of the Commission of the European Communities will be responsible for the organization of the Symposium.

Original papers will be welcome from nuclear plant operators, safeguards authorities and research organizations of all countries on the following subjects:

- Safeguards concepts and regulations
- System analysis
- Nondestructive assay methods and instruments
- Destructive analysis
- Physical standards (reference materials) and normalization samples
- Interlaboratory tests
- Containment and surveillance
- Data recording, processing and reporting in nuclear installations
- Isotopic correlations
- Statistical methods for nuclear safeguards

Contributions have to be written in one of the following languages: Danish, Dutch, English, French, German, Italian. An abstract in English should always be provided. Simultaneous translation will be organized at the symposium.

Both a 50 word abstract in English. and a 500 word summary must reach the scientific secretariat not later than December 10, 1978. It will greatly assist the Commitee if the summary is also in English.

Papers will be selected by an international committee.

Final manuscripts will be required at the time of the conference.
Registration forms, programmes and additional information on the symposium will be distributed later. A copy of the proceedings of the symposium will be sent to the participants.

An instrument exhibition is being organized together with the symposium.

The organizers would like to be informed in advance by the people planning to attend this symposium with or without contributing a paper, so that official programmes can be distributed beforehand.

Please write to the scientific secretariat of the symposium:

A.S. Adamson, NMACT, AERE HARWELL, Didcot OXON, OX11 0RA, England
C. Beets, CEN/SCK, B-2400 Mol/Donk, Belgium
L. Stanchi, JRC, 21020 Ispra (Varese) Italy

A NOTE ON PARTICULAR SAFEGUARDS PROVISIONS

B. LOVE
EURATOM SAFEGUARDS
LUXEMBOURG

Regulation 3227/76 is to be implemented through "Particular Safeguard Provisions". These are mentioned in no less than 14 of the 40 Articles of the Regulation, which may be taken as an indication of the extent to which the detailed procedures for the application of safeguards to any particular installation have been seen to be necessarily tied not only to general principles but also to the particular circumstances specific to that plant. This note outlines the various aspects which may be covered in the PSP's, and attempts to give some general indication of the structure which may be adopted for them. Clearly, since the PSP is to be tailored to the particular plant, any particular operator may find only a part of what follows to be applicable in his case.

The P.S.P. has its roots in the declarations by the operator of the basic technical characteristics. These declarations should be complete and sufficiently detailed in all significant aspects. Only if this is the case can the particular characteristics of the plant be properly taken into account in specifying the detailed safeguarding procedures. If this is not the case there is a risk that the safeguarding procedures finally specified may be less economical and more burdensome to the operator then would have resulted from more complete declarations of the information on the design and operating characteristics of the plant.

Article 7 of the Regulation gives a non-exhaustive list of the main procedures to be specified, after consultation with the operator and the Member State, in the PSP. The main headings are:

a) the designation of Material Balance Areas, and Key Measurement Points for Flow and Inventory,

b) the procedures for Records and for Reports for each MBA,

c) the frequency and procedures for Physical Inventory Taking,

d) containment and surveillance measures,

e) sample-taking for safeguard purposes,

f) communication of operating programmes,

g) advance notification of receipts and shipments.

Article 8 of the Regulation stipulates that the PSP shall be drawn up by means of an "individual decision" of the Commission after consultation and that both the operator and the Member State will be notified of the decision. It is expected each P.S.P. will take the form of a relatively short formal "decision", with the technical content being spelt out in detail in an Annex, which will form an integral part of the whole.

The layout to be adopted for the Annex will, for obvious reasons, have a certain similarity to the layout of the "Facility Attachment" which specifies the corresponding safeguards commitments, if any, which the Community has undertaken vis-à-vis the IAEA for implementation of the Non-Proliferation Treaty in the particular plant concerned. There are differences, however, in that, for example, various descriptive sections of the F/A are not appropriate for inclusion in the PSP whereas the effect of certain Community requirements (e.g. provisions for accounting by particular safeguard obligation) may require to be specified in the PSP but not in the F/A.

The normal sequence for the requirements in the P.S.P. is now given, together with occasional explanatory remarks.

Code 1 - **Information on the installations**

1.1 Changes in the basic technical characteristics which require to be notified in advance.

1.2 Programme of activities:
Content and mode of transmission of annual outline programme
Specific times of Physical Inventory Takings.

1.3 Conditions requiring advance notification of receipts, shipments or other Inventory Changes.

1.4 Particular requirements for advance notification of imports and exports.

Code 2 - **Material Balance Areas** and **Key Measurement Points** for Flow and for Inventory.

Code 3 - **Records Requirements**

3.1 Accounting records

3.2 Other specific requirements for accounting records, e.g. time of recording, procedures for accounting for discards, wastes and other IC's, such as New Measurement, Nuclear Transformation etc.

Specification of typical batch descriptions, and relevant source data. These are to be specified for each KMP, (F) or (I), and for flow KMP's for each type of inventory change.

Material Description Codes and Measurement Basis Codes may be specified. The specification of source data will generally follow the pattern:

for bulk material in one container :	Identification reference, Chemical composition and physical form of material Tare, gross and nett weights U-factor and U-total weight Pu-factor and Pu-weight Enrichment and U-235 weight
for fuel pins, for each pin :	Identification number, Pin fabrication data including fuel compound weight and U-factor, if fabricated in the particular MBA Weight of total uranium in pin Weight of enriched uranium, enrichment and U-235 weight for each separate enrichment.
for fuel assemblies, for each assembly :	Identification number Assembly make-up data including fuel compound weight and U-factor if assembled in the particular MBA Weight of total uranium in assembly Weight of enriched uranium, enrichment and U-235 weight for each separate enrichment.
for rebatching :	Source data for each container before and after rebatching.
for Shipper/Receiver Differences :	Source data according to shipper and according to receiver.

3.3 Operating records
3.3.1 Operating data used to establish changes in the quantity or composition of nuclear material.
3.3.2 Location of each item of inventory at any time.
3.3.3 Calibration results, including derived estimates of random and systematic errors.
3.3.4 Actions taken in order to ascertain the cause and extent of any accidental or unmeasured loss.

Code 4 - **Reports Requirements**

4.1 Inventory Change Reports
4.1.1 Particular provisions concerning non-standard form and format.
4.1.2 Particular codification arrangements concerning External Obligations.
4.1.3 Specific procedures to be applied, e.g.
- at specific MBA's
- for use declarations
- for transmission of concise notes
- for reporting nuclear transformations
- for reporting isotopic data
- for grouping at dispatch of small Inventory Changes, such as analytical samples.

4.1.4 Specific provisions regarding timing or frequency of reports.

4.2 Physical Inventory Listings
- Headings similar to those for ICR's.

4.3 Material Balance Reports
4.3.1 Particular provisions concerning non-standard form and format
4.3.2 Categories of nuclear material for which MBR's are to be established
4.3.3 Timing of reports

4.4 Special Reports
Circumstances requiring the establishment of a special report, together with content and form of report, e.g.
- loss of nuclear material
- change in containment
- interference with surveillance system
- delay in transport, or other suspicion of possible loss.

4.5 Initial Inventory.

Code 5 - **Operator's engagements** (undertakings/commitments)

5.1 Physical Inventory Taking
5.1.1 Frequency and timing
5.1.2 Procedures

5.2 Containment devices

5.3 Surveillance system

5.4 Provisions relating to the verification of the operator's measurement system, e.g.
- Submission of analytical samples for destructive analysis
- Submission of samples for non-destructive analysis on the operator's instruments
- Advance notice concerning special calibrations.

5.5 Provisions relating to the verification of the quantities of nuclear material, e.g.
- Sampling for destructive analysis
- Sampling for non-destructive analysis.

Code 6 - **Financial Provisions**

This may seem all a formidably long list of contents for each PSP, but it reflects a framework into which the safeguarding requirements appropriate to a single plant can be fitted. Consultations with operators have been in progress and will require to continue until PSP's have been established for all the installations subject to safeguards in the Community.

For those operators who are not currently in consultation with the Commission about their PSP's, this "breathing space" gives them an opportunity to look again at their Declaration of basic technical characteristics in the light of the use to which it will be put for drafting the PSP, and to see whether it includes descriptions of those features of their plant or operating procedures which they would wish to see reflected in the PSP. Similarly these operators can usefully give thought to the variety of different "typical batch descriptions" and typical Inventory Changes which occur in their plant, and assure themselves that the necessary source data are being both generated and recorded in an appropriately systematic manner.

SAFEGUARDING A FUEL ELEMENT PRODUCTION PLANT

– the use of an automatic in-line sampling device and measurement system –

GENERAL

An interesting problem in safeguarding techniques was posed by the need for a method for independent verification by Euratom Safeguards of the total quantity of U-235 leaving a fuel fabrication line in the form of AVR or THTR fuel spheres. This was solved by the design and development of an automatic in-line sampling device, and an associated measurement system, which have now been in routine operation for over two years.

The material to be measured consists of 60 mm diameter graphite spheres, each having a central core of 50 mm containing a mixture of graphite and graphite-coated particles of highly-enriched (U, Th) oxides. Each "pebble" contains 0.96 g of 93 % enriched uranium and 9.62 g of thorium.

The finished pebbles are fed directly from the production line at a maximum rate of one element every 14 seconds to the shipment drums, which can contain up to 1000 elements. The smallest homogeneous production batch is normally composed of 2000 elements.

A study was first made in the Euratom Safeguards Directorate of the statistical sampling effort taking into account the safeguards requirements, the fuel specifications, and the production practices. The basic requirements for the apparatus were then established with specialists of the Joint Research Centre at Ispra, who carried out the design and development of the equipment.

Requirements from the operator as well as from the Safeguards Authority, which influenced the choice of the verification system are as follows:

- the system should give the minimum inspection time and effort at the plant;
- no intrusiveness: automatic sampling and measurement should be used, and as far as possible on end products;
- no access to the pebbles should be possible after the pebbles have passed the operator's quality control and are fed toward the shipping drum, in order to prevent any substitution of sampled and verified elements by other elements before shipment;
- no alteration of the production rate: for in-line measurement of the U-235 content of each individual pebble a fast response and a high level of reliability and automation of the apparatus must be reached;
- no damage to the product: the pebbles sampled and measured by the Safeguards Authority have already passed the final quality control;
- the origin of the selected elements must be retraceable to avoid mixing up the selected pebbles when they are fed back to the shipment drums;
- no delay to production or shipment.

SAMPLING DEVICE

To meet these specifications, an in-line automatic sampling device (the Fuel Pebble Sampling Device) was designed to be fitted directly on top of the shipment drums. This device had to perform the following functions:

- count in a tamperproof way all pebbles for shipment (only a pebble should trigger the counter);
- sample pebbles automatically according to a preselectable programme;
- provide containment for all the pebbles that have passed through whether into the shipping drum or into the sample container.

In order to reduce the time of the inspector-presence, it was decided to build ten such sampling devices, so that up to 10 shipping drums could be loaded from the production line between inspection visits.

Figure 1 shows one sampling device in use on a shipping drum; other shipping drums complete with sampling devices can be seen in the background.

At an inspection visit for measurement, the 10 sampling tubes are each disconnected by the inspector from the FPSD's, and, without any handling of the pebbles, are put in a sample tube loading unit on top of the measurement apparatus, which is installed inside the plant.

MEASUREMENT SYSTEM

The measurement of the U-235 content of each pebble is based on thermal neutron irradiation of a pebble and delayed neutron counting.

The sample pebbles are released automatically, one at a time, into the irradiation facility. In this facility, each sample is irradiated for 60 seconds in a thermal neutron flux of 5×10^5 n/sec.cm^2, producted by four Cf-252 neutron sources (4×20 μg) placed in a polythene moderator.

After transfer of the sample by gravity (distance 3m) from the irradiation facility to the counting facility (transfer + waiting time = 2 seconds) the delayed neutrons, producted by fission of the U-235 are counted, after thermalisation, by eight He^3 neutron detectors, for 40 seconds. The sample is finally released to the sample unloading unit. While one sample is counted, another sample is irradiated. This means that the total analysis time per sample is approximately one minute.

The general layout of the measurement system is shown in fig. 2. Successively from the top can be seen:

(i) the sample tube loading unit and feed mechanism
(ii) irradiation chamber
(iii) inclined transfer tube
(iv) delay chamber
(v) detection chamber
(vi) measured sample unloading unit with tube reloader.

The delayed neutron activity obtained from the sample is compared to a calibration curve established using fuel pebbles having a known amount of U-235.

Due to the small quantity of fissile material present in the sample and to the large quantity of Th-232 present, a sub-threshold neutron spectrum must be used for the assay of the U-235.

In order to minimize the error due to the inhomogeneous distribution of the U-Th particles which may exist within the fuel elements, the irradiation facility was designed to provide a neutron flux as nearly constant as possible along the radius of the pebble, by using four Cf 252 sources, and the delayed neutron response in the counting facility was arranged to be as independent as possible of the geometrical position of the U-235 in the fuel element by using eight He^3 detectors (20 cm active length).

The complete apparatus is designed for the fully automatic analysis of up to 100 samples without the intervention of the inspector. Underneath the counting facility a sample unloading unit with 10 tubes (up to 10 elements per tube) is attached. The automatic operation ensures that the elements in the unloading unit are in identified positions and in the same sequence as they were presented for analysis. This last point is of importance since its permits the return of the analysed samples to their correct output drums as was requested by the fabricator.

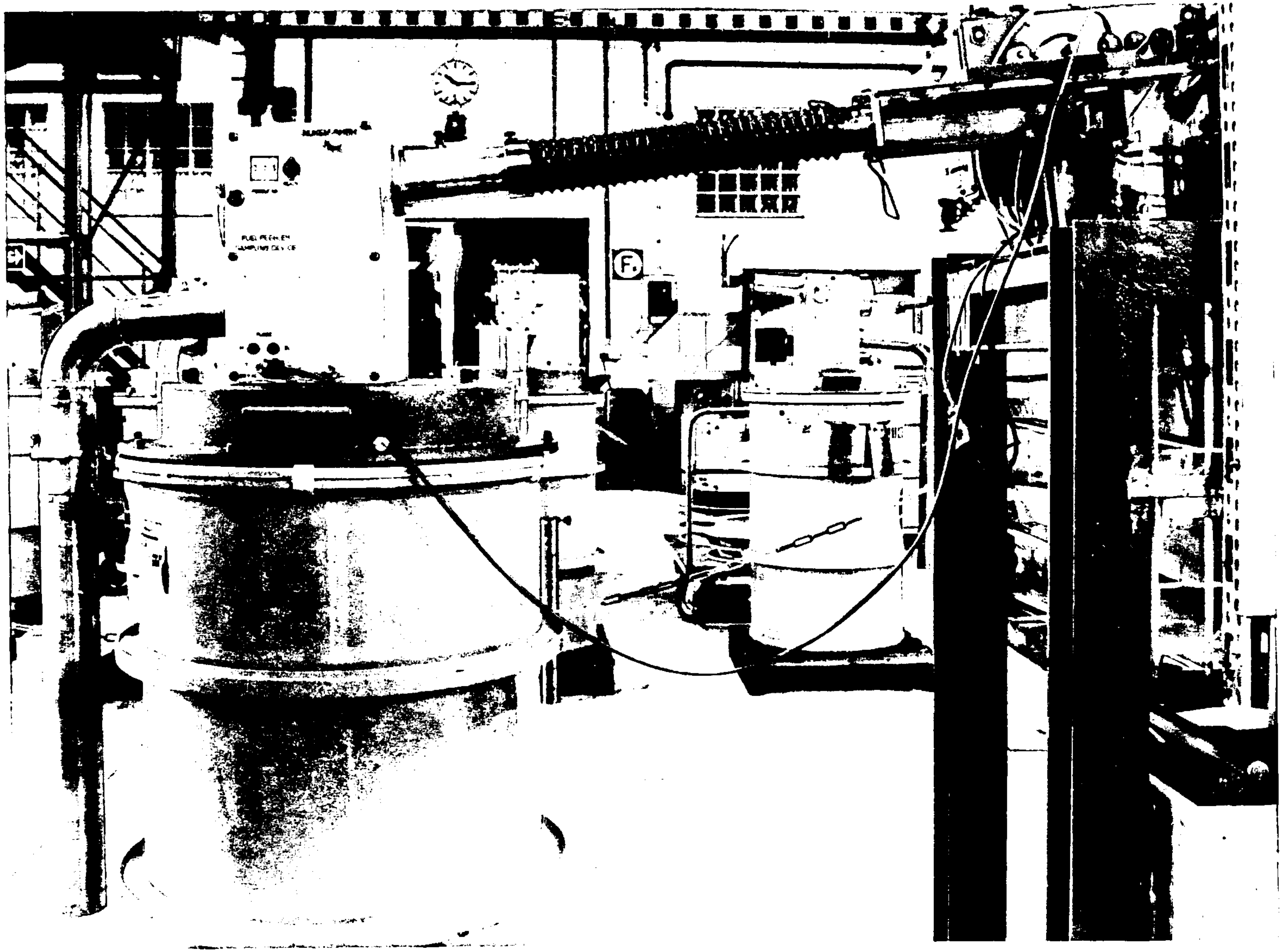

Figure 1

Fuel Pebble Sampling Device in use on a Shipping Drum
(Other Devices mounted on unfilled Shipping Drums are visible in the background)

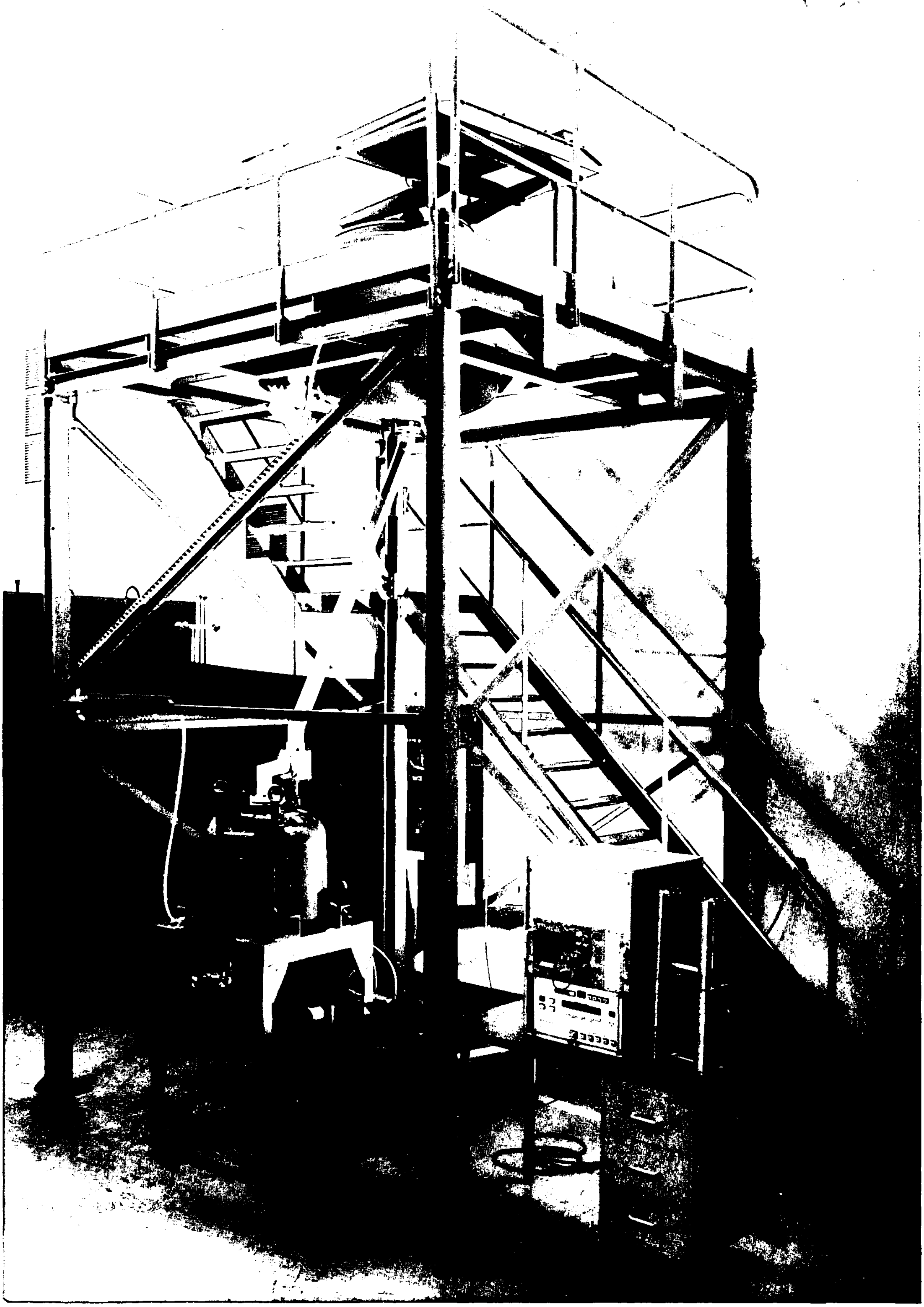

Figure 2

Measurement system during development

For a more detailed description of the system the interested reader may refer to paper SM-201/73, by Cuypers, Van der Stricht, Boursier and Corbelini, presented at the 1975 Safeguards Symposium in Vienna.

PRACTICAL EXPERIENCE

After the construction and the setting up of the apparatus by the J.R.C., Ispra, the Euratom Safeguards Directorate staff have used this safeguards system routinely in inspection from January 1976 onwards. In two years operation, 179,928 pebbles passed through the sampling device and were sampled. Approximately 1 % of them were measured.

During this period the inspection procedure fulfilled the aims mentioned above. The inspector-presence averaged 5 man-days/month. The operator's personnel work-load for preparation of drums and replacement of pebbles is two days/month.

No difficulties were experienced with the installed sampling devices and measurement system. Hence relations with the plant were always excellent, and this inspection activity is now fully accepted as a routine measure.

Using a spherical container similar in size to a pebble, the measurement system has also been used successfully to assay other types of nuclear materials, such as UO_2 powder and pellets, and U scraps, for uranium-235 content.

E. S. A. R. D. A. NEWSLETTER

In the ESARDA NEWSLETTER contained in the EUROPEAN SAFEGUARDS BULLETIN No 1, of Autumn 1976, the working groups of ESARDA were introduced.

The Steering Committee of ESARDA establishes working groups from time to time to carry out specific tasks in a joint manner. Non-members of ESARDA may attend the meetings of these groups and contribute actively. The basic objective of these working groups is to investigate technical problems relevant to safeguards and work out operable solutions which may then be recommended to safeguards organizations for routine application.

Three working groups have been functioning on a continuous basis. They are related to :

Non-Destructive Methods

Destructive Methods

Isotopic Correlations and Reprocessing Input Accountancy

The activities of these working groups are described in the following presentations by the convenors of the working groups.

THE ESARDA WORKING GROUP ON DESTRUCTIVE METHODS

P. DE BIEVRE
Central Bureau of Nuclear Measurements
C. E. C. Joint Research Centre - GEEL (Belgium)

Destructive measurements form the ultimate basis of any nuclear material accountancy by providing the basic values for the amounts of fissionable elements and isotopes in circulation. So far they also provide the characterization values of samples and materials used to calibrate non-destructive assay. Ultimately, "declaration" values from nuclear plants and organizations as well as "verification" values obtained by Safeguard Authorities, are based on destructive measurements by laboratories.

There are therefore good reasons for a regular meeting opportunity of European Laboratories measuring fissionable material. Such a meeting forum has gradually come into being in the ESARDA Working Group on Destructive Methods. At this point in time (beginning 1978) more than 30 laboratories are represented in the Group including plant laboratories. They meet twice a year (1.5 - 2 days) on a laboratory site (Karlsruhe - Grenoble - Harwell - Berlin). This plenum is usually preceded by a one-day topical meeting where specialists treat their topic.
Examples :

- UF_6 isotopic measurements
- UF_6 element assay
- European laboratories participating in the US SALE Programme (Safeguards Analytical Laboratory Evaluation)

This flexible mode of organization minimizes travel cost and time, yet gives the opportunity to both discuss highly specialized matters with colleagues in the field and meet during the plenum many others responsible for "measuring fissionable material".

The Group has reviewed the IAEA Safeguards Technical Manual Part E Methods and Techniques and transmitted a number of comments to the IAEA.

As a forum it has discussed interlaboratory measurement evaluation programmes aiming at

- establishing the present state of the art of a given method or technique under realistic operational conditions
- attempting to establish a scientific basis for regarding differences between measurements from different laboratories as significant
- promoting improvement of precision, accuracy and reliability amongst laboratories measuring fissionable material
- determining in a uniform manner for each laboratory the reproducibility of its measurements
- allowing each participating laboratory to determine its bias.

Examples of such interlaboratory programmes are AS-76 on the determination of ^{238}Pu abundance by the measurement of the $^{238}Pu/^{239}Pu + ^{240}Pu$ activity ratio and IDA-78 on mass spectrometric isotope dilution measurements of uranium and plutonium in feed solutions of reprocessing plants.

One of the early achievements of the Group was to review the status of reference materials for safeguard measurements and discuss and approve projects for materials lacking in the field. It backed up requests for enriched ^{233}U and ^{242}Pu spike isotopes for common use so that discrepancies between declaration and verification measurements would be minimized by the use of the same spike and recommended an improvement in the existing UF_6 Reference Materials (from 0.15 % to 0.05 % total uncertainty) on the basis of the very good precisions obtained in a UF_6 interlaboratory test.

As a result there are now available from the JRC-Geel (CBNM):
233U spike solution ($^{233}U/U$ = 0.996 - 1.0 mg/g)
UF_6 with $^{235}U/U$ = 0.0044 - 0.0072 - 0.033
And in the very near future ^{242}Pu spike solution ($^{242}Pu/Pu$ = 0.998 and 0.87 - 10 μ g/g)
^{244}Pu spike solution ($^{244}Pu/Pu$ = 0.98 - 1 μg/g)
^{230}Th
synthetic U/Pu input solution.

A very important task recently started is the establishment of values of differences between measurements from laboratories to be regarded as significant. The first decisions are:
- 0.2 % of value for ^{235}U abundances in the range 0.7 - 5 % ^{235}U
- 0.2 % of value for U element content determinations.

Both are to be considered as "1977" values, i.e. generated in the year 1977.

Common stands are also taken in some situations: the European laboratories participating in the US SALE Programme for example came to a unanimous request that, in view of the high percentage European participation in the programme ($\simeq$ 12/35), more European involvement in the concept and organization of the programme was desirable.

This opinion was formally submitted to the SALE Programme Management by representatives.

THE ESARDA WORKING GROUP ON NON-DESTRUCTIVE METHODS

R.J.S. HARRY
PETTEN - Netherlands

AIMS:

The principal aim of the Working Group is to establish and recommend criteria to be used as a basis for agreement between plant operators and the Safeguards Authorities on the acceptability of non-destructive measurements of nuclear fuel. Almost as important, but less easily expressed, is the aim of the participants to discuss the techniques they use or would like to use, the problems they have overcome or still face, and the accuracies and precision which they achieve or are required by management or Safeguarding Authority. On the basis of this exchange of information it is possible to arrange bilateral or multilateral collaboration on topics of common interest.

MEETINGS:

The Working Group meets two times a year. Specialists of ESARDA-partners and an observer from IAEA participate in these regular sessions. In addition to the regular meetings, some informal meetings have been arranged on specific topics. These meetings have also been attended by experts from groups with appropriate experience, but which are not normally represented on the Working Group. In a meeting on Pu-containing waste with different plant operators a fruitful exchange of experience took place; however the large differences between the individual cases did not offer an opportunity for a common research effort of the group in the near future.

At that meeting also the CEC Joint Research Centre plans for a central laboratory for the measurement of actinides contaminated waste were presented. Another topical meeting dealt with the gamma-spectrometric determination of Pu-isotopic composition, which resulted in a project proposal.

RESULTS:

Compilation of reference material for NDA

A list of standard reference materials within six countries of the EEC, the Commission and the IAEA is now ready for publication. It is intended to update the list at an appropriate time interval. A short ESARDA-report has been issued, but also the complete list can be obtained through the ESARDA secretariat.

Compilation of methods

The preparation of a list of NDA-methods in use, or to be used in the near future, for accountancy and verification purposes is now nearly finished. It is foreseen that the report will be issued in 1978 as an ESARDA report.

PROJECTS IN PROGRESS:

Certified reference uranium-oxide for gamma-spectrometric determination of U-enrichment

On the basis of the information contained in the reports mentioned above, it became clear that gamma-spectrometry is one of the most widely applied non-destructive techniques for U-enrichment determination. Further the reference materials available were not suited for calibration of the technique, due to the small sizes or the status of the reference materials.

Therefore now a project has been started to prepare primary standard reference materials. Five enrichments have been selected between 0.3 % and 3.1 %. Of each enrichment, 100 samples of 200 g U_3O_8 will be prepared in specially designed aluminium containers. This is the first time that such a standard will have been prepared in the field of non-destructive analysis of nuclear material.

In order to make the certified reference material acceptable to the safeguarding authorities, observers from Euratom and IAEA have been invited to be present at all key steps of the project.

Collaboration with the United States of America, National Bureau of Standards, has been established for the preparation, characterization and certification of the material. The certification will be performed by both the Commission and NBS.

The project will be executed by members of the ESARDA Working Group of non-destructive methods together with staff members of NBS and the JRC-Geel (Central Bureau of Nuclear Measurements).

Intercomparison of Pu-isotopic ratio determinations by gamma-spectrometry

As a first step towards common actions in the field of NDA of Pu, the participants at the meeting on Pu-isotopic ratio measurements by gamma-spectrometry decided to start a small scale intercomparison exercise.

Results of gamma-spectrometric determinations of the Pu-isotopic ratios are influenced by the following two classes of factors:

- quality of the measurement and data evaluation;
- gamma abundances and half-lives.

In order to evaluate the accuracy of the gamma-spectrometric analysis one has to compare measurements on material with identical isotopic composition and to utilize the same set of nuclear data. It has been decided to utilize the NBS isotopic standards which are available in most laboratories, and to compare the results of gamma-spectrometry on the basis of one agreed set of nuclear data. About seven or eight laboratories intend to participate. It is expected that results can be received at the end of February 1978. These results will show what is the interlaboratory spread and if the gamma-spectrometry results are consistent, what is the systematic deviation from the certified isotopic composition of the standards. The comparable experimental results form a necessary basis for future evaluation discussions about this measurement method.

THE ESARDA WORKING GROUP ON ISOTOPIC CORRELATIONS AND REPROCESSING INPUT ACCOUNTANCY

C. FOGGI
C.E.C. Joint Research Centre - ISPRA (Italy)

One of the themes of collaboration among ESARDA partners has long been the "isotopic correlations" and the "reprocessing plant input analysis".
A Working Group was therefore set up, with a view to promoting and coordinating research work, exchanging information and providing reciprocal assistance in these fields. At present the Working Group is composed of representatives of the various member-organizations of ESARDA and some nuclear industries of the relevant countries.
In 1977 the ESARDA Steering Committee decided to accept observers to the Working Group from the IAEA (Vienna) and BNWL (Richland-USA).

What are "Isotopic Correlations" and "Reprocessing Plant Input Analysis" ?

Nuclear fuels subjected to irradiation undergo a number of changes in their chemical and isotopic composition, such as burn-up of part of the fuel atoms initially present, build-up of artificial actinide nuclides, some of which are fissile, build-up of fission products. These changes, even if small in absolute, are extremely important since they result in an appreciable variation of the amount and type of fissile materials present in the fuel, and this is of relevance both to the economy of the industrial process and to the safeguarding of the fuel. The changes are very often correlated in a rather simple manner, the relationship being in some cases a simple straight line. These relationships are called "isotopic correlations".

The concept of isotopic correlation can also be extended to other situations where the nuclear materials undergo changes in their isotopic composition: a typical example of such situations is the uranium enrichment process.

Isotopic correlations in irradiated fuels find their most promising area of application as a supporting measure for nuclear material accountancy at the interface reactor-reprocessing of the fuel cycle. The correlations which are used for this purpose, are based on the amounts of various isotopes which are present in the irradiated fuel; these amounts are either correlated amongst one another or to the amounts which were present in the virgin fuel before irradiation in the reactor. The relationships thus obtained are used to check the results of the analytical measurements at the reprocessing plant input or the accuracy of the reactor operator estimates.

Studies which are performed on isotopic correlations are either based on theoretical reactor physics calculations or on experimental data. The experimental data are either obtained from post-irradiation experiments carried out on fuel assemblies or from analytical measurements performed on samples taken from the accountability tank of the reprocessing plant at the moment of dissolution of the fuel.

The isotopic correlation techniques are already being applied by some reprocessing plant and reactor operators; safeguard applications are under development.

The activity carried out by the Working Group can be illustrated by three typical examples of common projects.

- **The Isotope Correlation Experiment (ICE)**

The purpose of the ICE is to demonstrate the applicability of the isotope correlation technique to the safeguarding of fissile material at the imput of the reprocessing plant. The experiment is being carried out on the occasion of the reprocessing, at the WAK plant(1), of a batch of irradiated fuel elements discharged from the Obrigheim reactor(2). The reactor was bought from the KWU company(3).

The decision to carry out the experiment was taken by the ESARDA Working Group on Isotope Correlations in 1976.
In the framework of this experiment, 5 fuel elements have been dissolved during the month of January 1978; the isotopic composition of the samples taken at the tank are being measured by WAK, KfK - Karlsruhe, Euratom Safeguards and IAEA Safeguards. In addition, some special analyses will be performed, namely: hull monitoring by KfK laboratories, isotopic composition of fission gases, analysis of minor actinide isotopes and burn-up measurement by the JRC-Karlsruhe laboratories, calibration of accountancy tank by GfK and the JRC-Ispra.

The experimental data produced by WAK, JRC and KfK within the framework of the ICE will be made available to the participants. It is expected that the first results will be distributed to the participants in April-May of this year. The post-experimental phase will be planned in detail later. A comprehensive ICE-report will be issued after the completion of the experiment; the report will include the description of the experiment, the results obtained, the analysis of the results and the conclusions.

- **The Data Bank of Isotopic Compositions**

Although the fields of application for the correlation techniques have been singled-out and exploitation has already started, further experimental effort and theoretical interpretation are needed to improve confidence in the technique. In this respect, ESARDA has taken the initiative of collecting, on a European scale, data on fuel isotopic composition generated during a number of reprocessing campaigns or post-irradiation fuel analyses.

The task of gathering these data into a Data Bank was entrusted to the JRC-Ispra. The work for the preparation of the Bank was started in 1976, and was developed in three different steps. First, the Data Bank developed at the Karlsruhe Establishment of the JRC was transferred to Ispra; then the software was replaced by a new one operating under the supervision of the IBM Data Management System STAIRS, and the data format transformed and improved; the third step, now in course, transfers the control of the Bank from the STAIRS System to the ADABAS System, which is more suitable for the treatment of scientific data. At present, the Bank is operational, and the exchange of the control system will not interfere with its workability.

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(1) WAK : Gesellschaft zur Wiederaufarbeitung von Kernbrennstoffen, Leopoldshafen

(2) The Obrigheim Station is equipped with a pressurized water reactor, and is owned by Kernkraftwerk Obrigheim GmbH (KWO)

(3) KWU : Kraftwerk Union A.G., Frankfurt.

The unit of information stored in the Bank is the DOCUMENT. A document contains all the results of the measurements performed on:
- one single pellet, or
- one sample taken at the accountancy tank of the reprocessing plant.

The document also contains additional information for the complete identification of the fuel analysed, the reactor from which the fuel has been discharged, the laboratories involved in the analysis, etc.

At present, 260 documents are stored in the Bank; 130 of them refer to dissolver solution samples taken during the reprocessing of fuels discharged from the reactors at Garigliano (BWR), Trino Vercellese (PWR), Windscale (AGR), Sena (PWR), Dodewaard (BWR); the other 130 refer to pellet samples measured in post-irradiation experiments performed on fuels discharged from the reactors at Garigliano, Kahl (BWR), Trino Vercellese, Dodewaard, Tokai-Mura (BWR). Contacts with the Battelle Northwest Laboratories are in course, to obtain the data stored in their Bank.

The data which may be reported in a document are: the total amount of uranium, plutonium and thorium (whichever applicable) in the fresh and irradiated fuel, together with their isotopic composition; fuel burn-up; amount of curium and americium present in the irradiated fuel; selected ratios of krypton, xenon, neodymium, cesium and europium isotopes; measurement errors for all the data reported and calculated data.

The statistical evaluation of the data is performed by the CORRELATIO programme, developed by the ECN Petten, and is based on straight line fitting which takes into account errors in both X- and Y-directions.

The Symposium on the Isotopic Correlation

It has already been pointed out that the isotopic correlation techniques (ICT) are emerging as an important supporting measure for the accountancy and control of nuclear materials which pass through commercial fuel cycle facilities for the production of nuclear energy.

Research in the field of ICTs and their applications is being carried out at many laboratories and research centres in Europe, USA, Japan; there is indication that also laboratories in the Eastern Countries, Pakistan, India, Brazil, are interested in the ICTs.

An empirical use of ICT is already being made by reprocessing plant operators (mainly for consistency checks of input measurements) and by some reactor operators (for verification of the burn-up and the plutonium and uranium content of the irradiated fuel). Similar uses may probably be made by the safeguards authorities in the near future.

All these reasons led the ESARDA Steering Committee to take the decision to sponsor a Symposium on "The Isotopic Correlation and its Application to the Nuclear Fuel Cycle", to be held at Stresa (Italy) on May 9-11, 1978. The scope of the Symposium is to summarize the experience gained from past applications, to present new basic data, to inform potential users, and to highlight any areas where additional work may be required.

The symposium will be chaired by Dr. S. Finzi, Chairman of ESARDA and Director of the Applied Science and Technology Department at the Ispra Establishment (Joint Research Centre of the Commission of the European Communities). The Ispra Establishment is responsible for the organization of the Symposium.

30 Papers will be presented, dealing with the following subjects: theoretical interpretation of isotopic correlations in irradiated fuels, experimental results obtained on various fuel types, application of isotopic correlations to the safeguarding and management of nuclear materials. A panel discussion will close the Symposium.

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