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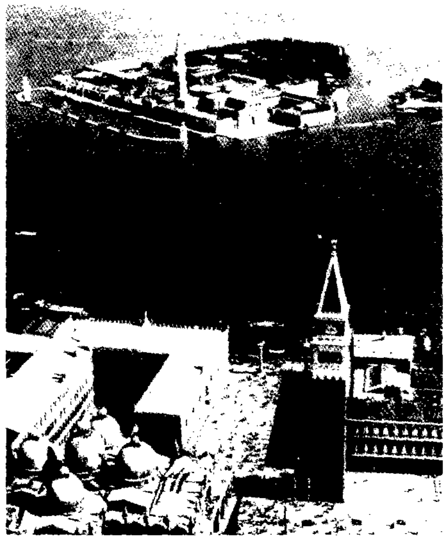
News about the 6th ESARDA Symposium

Venice, 14-18 May 1984

L. STANCHI



The Island of San Giorgio Maggiore

In Roman times (probably well before the founding of Venice at the Rialto) the Island of San Giorgio Maggiore may have been a place of call, or shelter for ships making from the open sea to the mainland along routes made perilous by turbulent and unpredictable floods. It was called the "island of cypresses", and planted with orchards. In ancient times, certainly, salt fields and mills were to be found there. The original church dedicated to St. George, from which the island takes its name, is generally believed to have been built in 790 A.D.

In 982, through the liberality of the Doge Tribuno Memmo, the first Benedictine monastery was founded there by the patrician Giovanni Morosini, a follower of San Romualdo. Both monastery and church in the course of time underwent frequent alterations occasioned by fire, earthquake, age, ...

Countless relics of saints, including those of St. George, were brought to the church at different times.

With the fall of the Republic of Venice began the devastation and the plundering on the island which had one last moment of splendour during the Conclave of 1800, which elected Pius VII, while the Holy See was in exile from Rome.

The Giorgio Cini Foundation

The island was then rescued in 1951, from the neglect and wilful damage to which it had been subjected, through the intervention of the Giorgio Cini Foundation, which was recognized as a corporate body by an Act of the President of the Republic on July 12, 1951. With the effective assistance of the Government, the Giorgio Cini Foundation was able to obtain the concession of the island for the purpose of restoring the historic buildings and founding social, cultural and artistic institutions there.

Since then, many international conferences, some at an inter-governmental level, and hundreds of congresses and symposia have been welcomed on San Giorgio, which have gathered together thousands of scientists, philosophers, historians, artists, doctors, biologists, economists, technicians and internationally famous people of the cultural world.

The sixth ESARDA Symposium will take place as previously announced at the Cini Foundation in the Island of S. Giorgio in Venice on May 14-18, 1984. A panoramic view of the Island is given on the next page with numerical indication of the various places. Oral sessions will take place in the Hall of the Tapestries (7) while the posters will be located in the Palladian Refectory (6). Coffee breaks will be adjacent to poster sessions. Buffet lunches will take place at the Gymnasium (17) on Tuesday and Thursday.

The ESARDA Symposium Organization

The registration desk will open at 13.00 h on Monday 14 May 1984. The first oral session will take place at 15.00 h. The second and fourth day will be entirely dedicated to the symposium hoping to terminate a little earlier than the preceding ESARDA symposia. The buffet lunches will allow a shorter interval at noon.

As is customary ESARDA will offer a dinner to the participants and their spouses. This will occur on the evening of Tuesday 15 in a place to be defined later. The third day, Wednesday 16, will have only a morning session while the afternoon will be free for private arrangements or for the organized trip (at moderate cost) to the very interesting islands of Murano, Torcello and Burano where there will be a sea-food dinner. The fifth day, Friday 18, will again have only a morning session and the final summing up of the symposium. Participants who need to return immediately back can travel in the afternoon, but Venice deserves some more attention, and not only visits to monuments and museums, but also strolls in the small streets and the small canals can be recommended. Venice is unique in the world and was constructed by man for men and not for cars or other machines.

It is better to stop here because I am, perhaps, too enthusiastic about Venice !

St. George and the Dragon, by Carpaccio

1. The Palladian Basilica - 2. The suite of the Presidency of the Foundation - 3. The Palladian cloister - 4. The cloister of the cypresses - 5. Longhena's Library - 6. The Palladian Refectory - 7. The Hall of the "Tapestries" - 8. Buoras Dormitory - 9. The Green Theatre - 10. The Centre of Culture and Civilization - 11., 12., 13. The Marine Centre - 14. The Arts and Crafts Centre - 15. The Little Theatre - 16. The indoor swimming pool - 17. The Gymnasium

Impressions of the Versailles Symposium 1983

J.L. Wieman,
ECN Petten, Netherlands

The fifth annual ESARDA Symposium on Safeguards and Nuclear Material Management was held on April 19-21 in Versailles, France, and I had the pleasure to participate in it.

Two aspects that stroke me as generally significant were, first that the location of the meeting was in France - underlining the value of the 1981 accession of the Commissariat à l'Energie Atomique (CEA) to the ESARDA contract - and, second, that representatives of nuclear facilities were so much involved in the discussions. Theme of the symposium was "Interaction between safeguards authorities and operators" and the operators' experience with inspections and their suggestions for improvement of safeguards applications were addressed directly or indirectly in several sessions.

The symposium opened with invited papers by Mr. D.H. Davies (Commission of the European Communities), Mr. H. Grümm (IAEA) and Mr. B. Ouvrieu (CEA). These papers informed or reminded the participants of some of the fundamental perspectives and concepts of the international safeguards system, that most of them are involved in at the R & D level.

Mr. Davies emphasized that the European Community's support of the safeguarding of the fuel cycle should be seen in the framework of its commitment to reliable and safe nuclear power programmes. In his opinion, ESARDA is serving quite well its purpose of coordinating R & D work in the Community's member states. He added further that it would be important for experts in the safeguards field to address not only colleagues on the specialized matter of their work, but also to communicate their achievements to the interested layman. The general public should be able to appreciate the goals and technical solutions of the safeguards system that ultimately serves its vital interests.

Mr. Grümm illustrated with some quantitative information how the IAEA proceeds to attain its inspection goals for safeguards implementation. It was also interesting to learn that the Agency has considered the possibility to increase safeguards cost-effectiveness by regarding the number and type of nuclear facilities in a State's fuel cycle, when allocating its limited resources over various safeguards tasks.

The INMM chairman, J. Jaech, presenting his paper at the ESARDA symposium

However, no objective method for such "fuel cycle orientation" has been developed yet that would prevent States from perceiving the practice as discriminatory.

Therefore, the present system of equal treatment of equal facilities still continues to be applied by the IAEA. The French position on this subject, presented in Mr. Ouvrieu's paper, was that the current safeguards approach of the IAEA seems to fulfil its purpose well, but may require revision in the light of future expansion of nuclear energy programmes. Unannounced inspections and fuel cycle oriented safeguards strategies are candidate approaches for such a revision.

It is not my intention to review the

The chairman of the symposium, W.L. Zijp, at the closing session. At his left, L. Stanchi, scientific secretary of ESARDA.

whole symposium for the ESARDA bulletin. For such a review, I would refer to the chairman's closing overview, contained in the proceedings. But I want to note that, as a consequence of the theme of the meeting, expressions like "cost effectiveness", "cooperation" and "efficiency" were becoming keywords in many discussions.

It is clear that for many facilities, inspections involved non-negligible expenses in terms of down-time for PIT, preparation of documents, and escorts for inspectors. In one presentation, the costs of safeguards in a MOX facility were quoted as a few per cent of the total production costs. It became also apparent, however, that a good communication between the operators and safeguards authorities could significantly reduce the burden for the facility. The efficiency of inspections can be enhanced by cotiming with normal plant shutdowns, by use of attributes/variables verification schemes and by the improved (often computerized) NDA measurement instruments that are now under field tests or already in routine use by the IAEA. The effect of good coordination between plant and inspectors was apparent in one paper, which estimated the additional cost for safeguards in a large fuel fabrication plant at only one-tenth of one per cent of the production costs.

Research workers should listen carefully to the other parties (safeguards authorities and operators) since all new developments will be subjected to cost-effectiveness constraints and have to provide solutions for real difficulties in practical situations. If, as I expect, the recent ESARDA symposium fulfilled that purpose, it certainly was a success.

I like to add that the host of the symposium, CEA, showed great hospitality in the organization of the meeting itself, the accommodations and the dinner. The visit to Versailles was a most pleasant experience, and not only from the professional point of view. With a group of about twenty-five participants I also enjoyed the technical tour to the Marcoule-Tricastin complexes. This excursion to the Rhône valley offered us a unique opportunity to visit the Phénix breeder reactor, the Marcoule vitrification plant and the EURODIF facility. It left us duly impressed with the progress of the French nuclear power programme. And the piece of simulated vitrified waste, that all of us received as a souvenir, may turn out to be a useful bit of argument in our domestic debates on nuclear power - so often ridden with myths on the dangers of radwaste. I would like to thank CEA for that, too.

Remarks on the Impressions of the Versailles Symposium, 1983

The article by J.L. Wieman is giving "impressions"; apart from that perhaps it might be useful to give the following information.

The fifth annual symposium on safeguards and nuclear material management was attended by 225 participants, also from outside the Community countries, of which we will mention e.g. the U.S.A., Canada and Japan.

The programme contained 44 oral presentations and 49 posters. These 93 presentations can be categorized according to their origin:

Research and development	***60%***
Plant operations	***20%***
Inspections	***10%***
Various combinations	***10%.***

The symposium has demonstrated the orientation of ESARDA towards an increasing participation of the plant operators.

In the closing overview and summary of the symposium, the symposium chairman W.L. Zijp draw the following conclusions:

1. With respect to hardware tools: many instruments developed or under development should be tried out under field conditions with the aid of the operators. There is a noteworthy increase in the use of modern electronics, computer systems and microprocessors.
   With respect to software tools, one can observe that computerized data management systems are being developed and implemented in fabrication plants. Near real time accountancy is becoming increasingly important, for the benefit of both operators and inspectors. There is good progress in the development of statistical techniques and procedures, but these are not always mature enough for immediate on-site application by the inspectors.
2. With respect to the pure technical point of view several contributions to this symposium indicate that the experience with several safeguards techniques under real plant conditions is increasing.
3. We have seen and heard in the contributions and in the discussions the importance of safeguards effectiveness for the inspectorates and the concern (expressed from the operators side) with respect to the cost-effectiveness.
4. The decrease of financial budgets worldwide urges us to be extremely efficient and effective in all safeguards efforts and resources (in planning R&D, in development of instruments and techniques, and in on-site applications). Therefore researchers should listen carefully to the needs of both operators and inspectors.
5. It was emphasized from various sides that close, intense and regular contacts between the three parties involved in safeguards (operators, inspectors and researchers) are important.
6. Apart from the exchange of more pure scientific and technical information normal for this type of symposia, the ESARDA symposia also promote the exchange of views and the interactive discussions between these three parties. This aspect of the role of the ESARDA symposia has increased in importance. Also the plant oriented working groups of ESARDA in which now also the plant operators are participating offer a good environment for a fruitful cooperation between researchers, inspectors and operators.
7. It was the first time that we had such an active participation from the plant operators to an ESARDA symposium. The participation did not only exist in paying attention to the topics dealt with, but also in showing results and giving suggestions for improvement of safeguards application. This point is very encouraging for the future work of ESARDA.
8. Many though not all contributions had some bearing on the importance of the interaction between operators and inspectors.
   Three sessions have been fully dedicated to the contribution from the plant operators or to the interface between operator and inspector. The main theme of the symposium has certainly been addressed.

The proceedings of the Versailles symposium are available from the symposium secretariat.

The success of this symposium has encouraged the ESARDA to continue its series of annual symposia with the following one in Venice, 14-18 May 1984.

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Hexapartite Safeguards Project Overview*

Introduction

Commercial exploitation of the gas centrifuge process for uranium enrichment began in earnest in the early 1970's. From the outset attention was given to the need to apply effective and efficient international safeguards to plants of this type. The general principles for achieving this were easily and relatively quickly established, since the physical characteristics of the gas centrifuge enrichment process readily lend themselves to the maintenance of accurate material accounts. The process involves no chemical transformations, demands the highest standards of physical integrity and hence containment of nuclear materials, and the necessary measurement technologies (weighing and isotopic analysis) are capable of the highest standards of precision.

However, the elaboration of a basic safeguards approach proved very difficult because of the sensitivity of this novel process. Throughout the 1970's there were many efforts at resolving these difficulties notably in the IAEA Advisory Group Meeting held in Tokyo in 1977. In each case agreement could not be reached on the point as to whether or not inspectors would need access to the cascade halls of gas centrifuge enrichment plants if an effective and efficient safeguards approach was to be implemented under NPT conditions. It was argued by several technology holders that access was unacceptable because information sensitive on both commercial and non-proliferation grounds would be at risk and that an effective and efficient safeguards approach could be implemented without access to the cascade halls. In the absence of a fully agreed safeguards approach existing plants were inspected provisionally under ad hoc conditions on the basis of which inspectors did not have access to the cascade halls, with the understanding that this would not prejudge the scope of inspections under a routine inspection regime as provided in INFCIRC/153-type safeguards agreements.

This situation was clearly unsatisfactory and in the late 1970's the need to come to an agreed safeguards approach was given added impetus by the expansion of existing gas centrifuge enrichment programmes and the initiation of new ones. Eventually in 1980 there was a series of informal discussions between the IAEA, EURATOM and technology holders of the gas centrifuge process and the outcome was a consensus to collaborate to re-examine the situation and to solve the outstanding problems.

Form and purpose of HSP

An initial ad hoc meeting was held at URENCO's offices in Marlow, England in November 1980. The participants were the IAEA, EURATOM, Australia, Japan, Troika (comprising the Federal Republic of Germany, the Netherlands and the U.K.) and the U.S.A.

The participants all shared a common commitment to achieving rapid and real progress and to study practical applications at real plants not paper studies on model plants. The aim was to establish a sound technical basis for the development of effective and efficient safeguards strategies by the inspectorate(s) (i.e. the IAEA and EURATOM)

- effective in the way that they met the objectives of the inspectorate(s)
- efficient in the way that they made good use of the resources applied.

With these aims in mind the proposal for a Hexapartite Safeguards Project (HSP) was accepted and it was agreed that:

a. The goal of the project would be to develop, within 2 years, an adequate basis of technical experience and information which could be used by the IAEA, EURATOM and the State involved in their evaluation of the various safeguards approaches and the possible development of arrangements for the direct implementation of an effective and efficient safeguards approach to specific plants.

b. The technical objective of the HSP was to facilitate the application of effective and efficient international safeguards at uranium enrichment plants of the gas centrifuge type. This was to be achieved through the exchange of relevant information, thereby co-ordinating individual development efforts, and by the technical consideration of possible safeguards approaches. The non-access case by inspectors to the cascade halls of the plants and other cases of varying degrees and frequency of access were to be treated in parallel.

The participants also agreed that they were not looking for a legal structure for the project but rather for practical and satisfactory co-operation towards a common objective.

Participants to the HPS Final Plenary Meeting

Discussion and results

To carry out the basic information exercise four working teams were set up, each to study a specific aspect of the problem. These were:

Team 1 - Facility characteristics
Team 2 - Containment and surveillance
Team 3 - Nuclear materials accountancy
Team 4 - Safeguards strategies including different degrees of access to cascade areas.

The groups met as required to accomplish their work and their progress was monitored by a series of HSP Plenary Meetings:

- Second Plenary Meeting, Boekelo (the Netherlands), March 1981
- Third Plenary Meeting, Germantown, Maryland (U.S.A.), July 1981
- Fourth Plenary Meeting, Tokyo (Japan), November 1981

The four teams completed their work and their reports provided the basis for the work of a further sub-group, which was set up to define, assess and evaluate the advantages of the "non-access" and "limited frequency unannounced access" models.

After detailed consideration the assessment sub-group concluded that a safeguards approach based upon limited frequency unannounced access (LFUA) to cascade areas was capable of meeting safeguards objectives, in particular those for material of high strategic value. However, it was agreed by the participants in the sub-group that for the application of this approach it would be necessary that the approach be accepted by all participants and equally applied to all technology holders participating in the HSP; that the nature and scope of Inspectorate(s) verification activities be clearly and unambiguously defined and described; and that security concerns with regard to the protection of sensitive information be satisfactorily met.

A number of participants considered that non-access approaches were also capable of meeting the safeguards objectives. However, the group agreed that the limited-frequency unannounced access model exhibited three main advantages as compared to the non-access alternative:

a. Less intrusiveness into plant operations and lower equipment and manpower costs, both for the operator and for the Inspectorate(s).
b. The implementation of the model, especially in already existing facilities or facilities already under construction, is simpler.
c. The availability, within the timescale of HSP, of instruments measurement techniques associated with the access approach may be more credibly demonstrated.

The principal disadvantage of the access model was that it implied a higher risk of revealing sensitive information.

The assessment group recommended that a safeguards approach based upon limited-frequency unannounced access to cascade areas should be studied in detail for each technology to see how the above conditions could be applied.

The fifth plenary session of the HSP held in Sydney, Australia, in March 1982 endorsed the conclusions and recommendations of the assessment sub-group.

In conjunction with HSP each technology holder prepared and conducted demonstration programmes to demonstrate to the Inspectorate(s) various techniques in practical situations at enrichment plants. These demonstrations were considered as useful, informative and well organised.

Each technology holder prepared a paper describing its view of what inspection activities and design information would be useful and acceptable in adopting the LFUA safeguards model for its centrifuge enrichment plants and discussed its paper with the inspectorates.

The sixth plenary meeting of the HSP took place at Aachen in the Federal Republic of Germany in November 1982: The Inspectorate(s) tabled their general paper "Possible Inspection Activities Inside Cascade Areas for Limited-Frequency Unannounced Access Applied to Gas Centrifuge Enrichment Plants" based on the technology holders' papers mentioned above. After reviewing it, it was agreed that the paper should be redrafted as an HSP paper acceptable to all the participants, and should incorporate inspection activities outside the cascade areas.

After reviewing the paper in detail, and trying to reconcile the differences in opinions, it was realised that an integral test of the LFUA model was required to prove the appropriateness of assumptions made by the technology holders. This was conducted at Capenhurst, U.K.

A drafting sub-group of the HSP met in London in December 1982, in order to consider the results of the integral test and re-draft the above paper. The group finally agreed the text of a paper on those inspection activities related to the inside of the cascade area.

The Seventh Plenary Meeting of the HSP took place in Luxembourg in January 1983. The Inspectorate(s) submitted their paper "Possible Inspection Activities Outside Cascade Areas" which was incorporated into the previous paper, after reviewing by the participants, and finally the paper "Inspection Activities Associated with Limited-Frequency Unannounced Access Model Applied to Gas Centrifuge Type Enrichment Plants" was finalised. The Hexapartite Safeguards Project completed its tasks at the Luxembourg Meeting on the technical level, two years and three months after its establishment.

Conclusion

It has been agreed that the safeguards approach involving limited-frequency unannounced access by IAEA inspectors to cascade areas together with inspection activities outside the cascade areas offers an effective and efficient safeguards measure capable of meeting the objectives of IAEA safeguards and also of minimising the risk of revealing sensitive information in accordance with INFCIRC/153-type agreements. The experts participating in HSP thus arrived at a consensus that this safeguards approach would be appropriate for all commercial gas centrifuge uranium enrichment plants situated in states party to the NPT.

This safeguards approach clearly provides the clear and unambiguous definition and description of the nature and scope of the Inspectorate(s) verification activities as provided above.

As HSP was looking toward the common objective of an effective and efficient safeguards regime it was necessary to formalise the acceptance of these findings by all participants and the assurance of their equal application to all technology holders. In order to meet related security concerns about the protection of sensitive information it will be necessary for each of the technology holders and the Inspectorate(s) to make their own appropriate efforts as well as to co-operate to facilitate the implementation of the proposed safeguards approach.

*) HSP contact points are: Dr. F. Brown (Chairman, U.K.), Mr. F. Bett (Australia), Mr. W. Gmelin (Safeguards Directorate, Luxembourg), Dr. R. Gerstler (FRG), Dr. A. von Baeckmann (IAEA), Mr. S. Matsuzawa (Japan), Mr. P. Verbeek (Netherlands), Dr. R. Marsh (U.K.), Mr. J. Menzel (U.S.A.).

Annual Report 1982 on Safeguards Research and Development Activities in the Federal Republic of Germany

Chr. Brückner, R. Buttler, U. Knapp, H.R. Mache, D. Stünkel, R. Weh

Summary

In 1982, safeguards research and development work in the Federal Republic of Germany was carried out according to a total manpower expenditure of 44 man-years. Contributions to the programme were made by Kernforschungszentrum Karlsruhe GmbH (KfK), Kernforschungsanlage Jülich GmbH (KFA) and different firms of the nuclear industry.

A substantial part of the work was performed within the framework of the Joint Programme on the Technical Development and Further Improvement of IAEA Safeguards between the Government of the federal Republic of Germany and the IAEA[19].

The main results achieved in 1982 for the R&D projects with a significant manpower effort involved will be reported in the following, the individual contributions being arranged in accordance with the ESARDA R&D programme. For further information a reference list has been attached.

DP Systems for Nuclear Materials Safeguards in Nuclear Research Centres

Within the framework of its R&D activities KfK and KFA Jülich are operating various nuclear facilities such as research reactors, testing facilities, hot cells and laboratories. The amount, nature and utilization of the nuclear materials differ greatly and therefore, for the purpose of safeguards the nuclear research centres have been splitted into several material balance areas. To comply with the requirements of Euratom and IAEA two separate computer-aided nuclear materials information systems were developed in parallel.

The **KA**rlsruhe **N**uclear Material **I**nformation **S**ystem (KANIS) of KfK was implemented on a dedicated mini-computer system and is divided into several accounting sub-systems in the individual nuclear facilities[18]. The information system relies on a more general concept and the internal data structure is material-type oriented. Accounting of changes in materials is done via operation oriented processes with the help of dialogues run on display units. The system provides all reports prescribed by Euratom as well as updated and stratified listings of inventories for inspection support. Special emphasis was placed on the data integrity which is achieved by extensive data checks during the input process. KANIS has been operated at the SNEAK Fast Zero Power Assembly since March 1981 and proved to be reliable, useful for the operator and inspectors and convenient in handling. The accounting system for the Institute for Materials Research is shortly before installation and the sub-system for the Hot Cells is still in the phase of programme implementation.

The **N**uclear Material **A**ccountancy and **C**ontrol **S**ystem (NACS) of the Nuclear Research Centre Jülich serves like KANIS the nuclear material accountancy and compiles all the prescribed reports such as inventory change reports, material balance reports, physical inventory lists[23]. It has been implemented on the large central computer system of KFA Jülich and runs under the normal Time Sharing System TSS. Input and processing of data were performed on-line and by dialogue between user and computer using decentrally distributed terminals. Especially the conditions inside the different facilities have been taken into account. Besides NACS provides information for internal management. Since 1979 the system has been in operation for the Hot Cells. Now the accountancy system is installed for all the relevant areas of KFA Jülich and the implementation work has been finished.

Computer Support for Safeguards Inspection

In collaboration of KFA, KfK, VDEW and NUKEM with Euratom and IAEA harmonized requirement specifications of data evaluation software for supporting and improving the cost effectiveness of inspections in various nuclear facilities have been worked out also as part of the Joint Programme on the Technical Development and further Improvement of IAEA Safeguards between the Federal Republic of Germany and the IAEA. As a first step the question of a common data format and data assortment has been studied in order to facilitate the information transfer between the operator's nuclear materials accounting computer and the inspector's in-field DP equipment[21].

Safeguards Approach for Fast Breeder Reactor

The development of a safeguards concept for the fast breeder prototype reactor SNR 300, performed within the framework of the Joint Programme on the Technical Development and Further Improvement of IAEA Safeguards between the Federal Republic of Germany and the IAEA, could be finalized with a comprehensive study by INB and SBK showing that all reasonable diversion possibilities as specified in a preceding diversion analysis will be indicated by the safeguards instrumentation. The **I**naccessible **I**nventory **I**nstrumentation **S**ystem (IIIS) which - monitoring the handling operations of fuel- and blanket assemblies - forms the most important part of the instrumentation, was fabricated and tested and is now going to be installed in the reactor plant.

Safeguards Concept for an Industrial Reprocessing Plant

Making use of the actual results of the current design work on a specific reprocessing plant the basic structure of a safeguards system for an industrial-scale reference reprocessing plant has been developed by DWK (Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen) with some support from KfK. Main features of the present concept are given below:

- Storage areas not considered - two material balance areas (head-end and chemical reprocessing) and a number of key measurement points have been defined where the flow of fissionable material will be measured.
- Conventional material accountancy with one inventory taking with plant shut-down per year is the basic safeguards measure.

- The head-end design was analysed, i.e. by means of a diversion study, with special respect to the effective application of containment/surveillance measures, which may be of prime importance there considering the physical change of the fissionable material from itemized to bulk form within the head-end MBA.
- The feasibility of a periodical inventory taking at different points of the process area without interrupting plant operation by using the installed instrumentation, was investigated. The influence of measurement errors on the overall uncertainty of the inventory data has been estimated. Methods for dynamic material accountancy still being under development have been carefully considered.

The conceptual work is going on parallel to the advance in plant design.

Nuclear Materials Accountancy in a Gas Ultra Centrifuge Enrichment Plant

For an enrichment plant with a material throughput according to an enrichment capacity of 1000 t USW/a, operators' nuclear materials accountancy and its verification by inspectors as the basic measures of international safeguards have been a matter of detailed investigations[24]. Considering the measurement uncertainties of the operator's plant instrumentation, the total uncertainty of the operator's MUF-determination was evaluated. For the process MBA σ_{MUF} was found to be about 6 kg U-235 compared to IAEA's provisional detection goals for LEU of 75 kg U-235.

For verification purposes a two-step "attribute-variable" strategy has been proposed consisting of a rough NDA of any inventory batch (UF_6 cylinder) being transferred to or from the plant or to be accounted for during the physical inventory taking and a fairly reduced number of batches for which after sampling a more accurate analysis will be done.

By suitable stratification of the nuclear material and applying the principles of game theory to that optimization problem, the number of (expensive) mass spectrometric measurements necessary to comply with IAEA's detection goals, could be estimated. To detect a diversion of 75 kg U-235 with an 80% probability a total of 40 accurate measurements distributed over the feed-, product- and tails flows was found to be adequate.

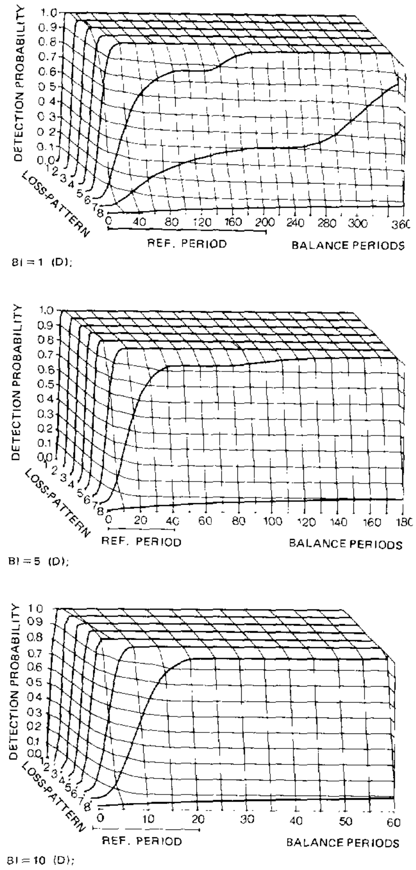


Fig. 1 - Detection probability for a total loss of M = 40 kg

Dynamic Material Accountancy (NRTA)

In some large nuclear facilities such as industrial-scale reprocessing plants presently under design, conventional material accountancy may not be sufficient to fully comply with IAEA safeguards objectives. Here, dynamic material accountancy can be an important complementary measure. Dynamic material accountancy in this context means a frequent determination of total Pu inventory in the plant without interrupting its operation, each time closing the material balance. The differences between the book and physical material inventories caused by measurement uncertainties and losses provide a sequential time series of MUF values which can be subjected to a statistical hypothesis test for detecting material losses, if any[2,5].

For evaluation a method was developed under which the values of te CUMUFR statistics (**CU**mulative values of standardized **MUF R**esiduals[1,2]) are subjected to a sequential hypothesis test (Power One). The MUF residuals can be considered as being the algebraic difference between the actual value of MUF and the estimated value, the latter based on preceding MUF values. The time series of the residuals is a linear transformation of the original MUF values, the residuals are independent of each other and have minimum variance. The Power One test in its turn is a two-sided sequential hypothesis test guaranteeing for an infinite duration the attainment of a maximum detection probability and a previously defined probability of false alarms.

The effectiveness of the method of evaluation was studied with the help of simulated data for the process material balance area of a 1000 tons U/a reference reprocessing plant. The results available have been obtained with a block model in which the process is divided into five process areas, namely head-end, first, second and third plutonium cycle, and concentration of plutonium. With realistic assumptions for the material transfers and inventory takings in the process parts and for their random and systematic measurement errors, the detection probabilities are determined for various loss strategies as a function of the total amount and the time structure of loss and the number of balance periods.

In Fig. 1 the results are presented for a loss of M = 40 kg plutonium and for different intervals in which the balance is closed (1, 5 and 10 days). Under the loss strategies 1 to 7 the same total loss is uniformly spread over 10, 20, 30, 40, 50, 100 and 200 days. Strategy 8 represents the "no-loss condition" and indicates the probability of false alarms.

It was demonstrated[2] that an "abrupt" loss (strategy 1) of 20 kg plutonium is detected in more than 95% of the cases directly after its occurrence whilst the probability of detection declines with the accountancy interval getting longer. By contrast, the probability of detection increases in case of extremely "protracted" losses (strategy 7) with an increasing balance.

More on plant specific information including operational details as well as details of the structure of measurement uncertainties is necessary to make definite conclusions on the capabilities of the method. Thefore,. a computerized plant model has been developed describing the time-dependent distribution of plutonium in the various buffer tanks and process components of a 1000 t/a reprocessing plant[3]. Fig. 2 shows the variation with time of the plutonium inventory in the first extraction cycle. On account of the high buffer capacity of the plant about 10 times more plutonium is contained in the tanks than in the extractors.

Parallel to the evaluation methods above

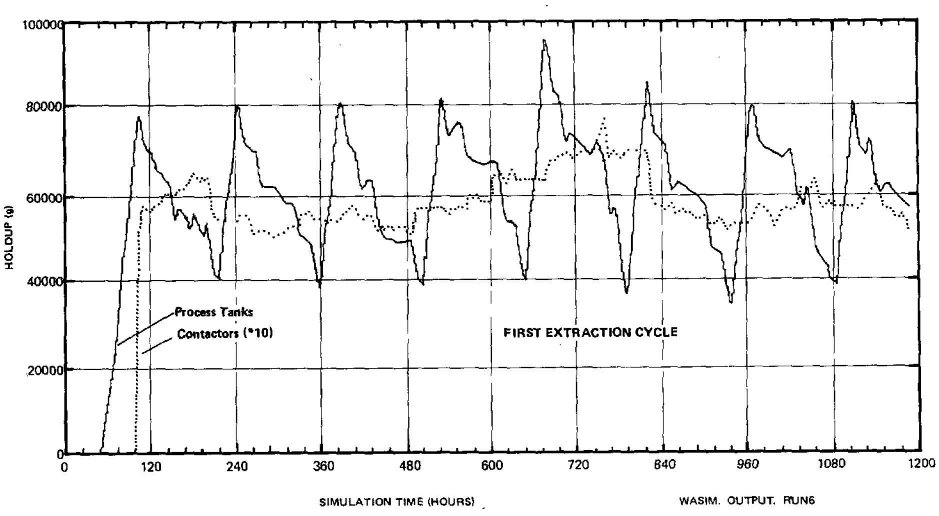


Fig. 2 - Variation with time of the plutonium inventory in the first extraction cycle

using the CUMUF residuals and the Power One test, a truncated test was performed which is directly applied to the cumulative MUF values[4]. This test statistic gives an estimate for a possible loss. In case of saddle point diversion (approximately constant diversion in each balance period), the test leads to acceptable detection probabilities. Moreover, it indicates a lower limit of the detection probability for loss, this limit being guaranteed also under the most adverse conditions.

Statistical Investigations on Data Verification

The verification of operators' data by the inspector is a major element of international nuclear safeguards. For an optimum combination of data verification and material accountancy the two alternative testing methods MUF-D and (D,MUF) are available. By theoretical studies and with the help of real-data from a HEU fuel fabrication plant (NUKEM) it was shown under a task performed on behalf of the Joint Research Centre of Ispra that a generally valid statement concerning the superiority of one of the two methods cannot be made[6] since the results are greatly dependent on the system parameters and diversion strategies.

The original (D,MUF) test was modified on the basis of the likelihood ratio test in such a way that a higher detection probability was attained[8].

A new test method was developed for the case that the inspector generating his own measurement data by use of operator owned instruments - thus achieving the same measurement accuracy as the operator - can close the material balance independently. In this way, compared with the normal (D,MUF) test a higher detection probability can be obtained[7].

U_3O_8 Reference Material

Within the framework of the activities conducted by the NDA working group of ESARDA with a view to preparing certified reference materials for measurements by gamma spectrometry of U-235 in fresh LWR fuel elements a user's manual has been written which contains instructions for the use of standards in calibrating instruments for enrichment measurements and an analysis of the systematic error sources associated with the use of the standards in the various applications.

Inspector's Instrument for Plutonium Isotope Measurements

For use in the micro-processor controlled MCA system developed by JRC-Ispra and intended for universal use as inspector's instrument in the evaluation of NDA measurements the specific evaluation software was developed allowing the determination by gamma spectrometry of the isotopic composition of plutonium samples. The performance of these evaluation programmes was demonstrated in a measuring campaign conducted with real samples from a MOX fuel element fabrication with plutonium from LWR fuel elements with high burnup rates (30-40 GWd/t U). The implementation of the evaluation software on the Ispra system is nearly completed.

K-Edge Absorptiometer and Hybrid Instrument

Until mid 1982 investigations into the measurement accuracy, stability and linearity were performed on the K-edge absorptiometer developed at KfK with samples from U, Pu and mixed solutions. A detailed report of the results obtained was published[12]. Meanwhile, a modified instrument has been set up at the Transuranium Institute (JRC-Karlsruhe); it allows analyzing under routine conditions plutonium product solutions from WAK which are compared with relevant measurements made by the inspection authorities. The instrument in its modified version also measures the isotopic composition of the sample solution.

The handicap of the simple K-edge absorptiometer that plutonium cannot be assayed precisely in the presence of high uranium concentrations, e.g. in the dissolver solution of an LWR fuel reprocessing plant, has led to conceiving a hybrid instrument. It combines the advantages of the K-edge absorptiometer and the X-ray fluorescence spectrometer. The resulting instrument is capable of determining the plutonium as well as the uranium concentrations of the feed solution of a reprocessing plant up to and including the product solutions without requiring expensive fission product separations or other steps of sample conditioning. The measurement concept was described and results of exploratory measurements performed on representative dissolver solutions were reported[13]. For feed solutions from LEU fuel reprocessing plants a relative measurement accuracy of about 0.5% for plutonium and about 0.3% for uranium can be presumed.

If instruments owned by operators are used for safeguarding, authentication of the results by the inspectors is a problem of major concern. Contributions for solving this problem have been elaborated being part of the ongoing discussions on that subject at the IAEA[14].

Laser Fluorimetry

Fluorimetry has been established as a very sensitive detection method for uranium, especially if used in melts. By use of monochromatic laser light as a selective excitation source the detection sensitivity has been increased considerably also for uranium solutions so that laser fluorimeters have been introduced as detection instruments in uranium prospecting.

At KfK the performance of a commercial laser fluorimeter was investigated to find out whether it can be used as a simple, fast and sensitive instrument for the uranium assay in liquid waste streams of nuclear facilities. For this purpose, the effects due to quenching of acids and various heavy metals on the detection sensitivity and accuracy of measurement have been investigated on high and medium active liquid wastes simulating materials. A detection sensitivity of 0.05 ppb for uranium has been obtained with an uncertainty of measurement of about 10%.

Consequently, MLW and HLW samples can be diluted by several orders of magnitude so that the disturbing quenching effects become negligible and a radiation hazard in sample handling is substantially reduced.

Performance and Evaluation of Interlab Tests

The IDA-80 interlab programme serves to determine the uncertainties of measurement with which uranium and plutonium as well as their isotopic abundances in feed solutions of reprocessing plants can be measured by qualified laboratories using the isotopic dilution analysis by mass spectrometry[9]. The programme is performed collaboratively by the Joint Research Centre of Geel (CBNM) and KfK, supported by ESARDA and IAEA. Thirty one laboratories from all over the world participated in the interlab tests and sent until mid-1982 their comprehensive data measured on the various samples. Evaluation of part 1 of the measurement programme (measurements on the samples collected from feed solutions of WAK) was terminated on a laboratory level and the results were communicated to the participants.

As a typical example in Fig. 3 the results reported by the individual labs are compared[11] with the reference value determined by CBNM. Only 40% of the results for the overall plutonium content were found to lie within the limits given by the standard deviation of the reference measurement.

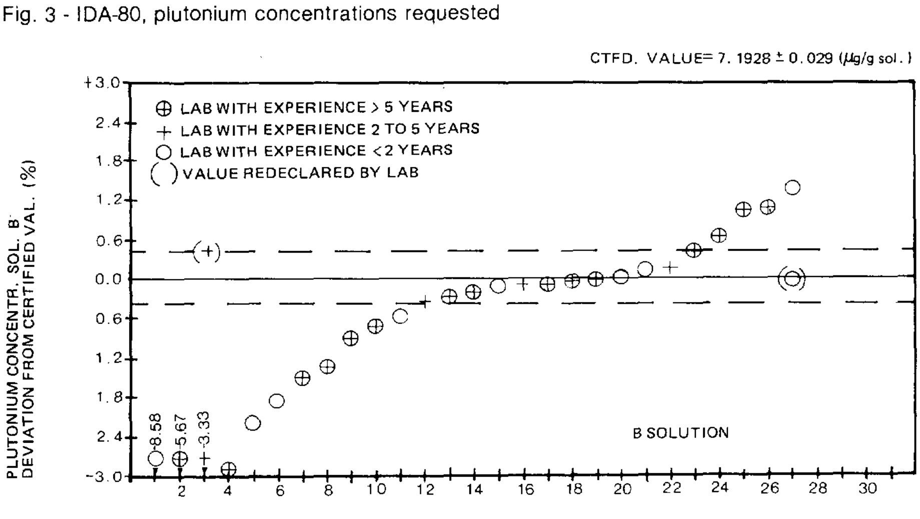
As a measure of permanent quality control another interlaboratory test for assay of uranium-235 in UF_6 was performed in 1982. The evaluation essentially confirmed the results already obtained in 1975 according to which the uncertainty of measurement originates primarily in the uncertainty regarding the isotopic composition of the reference material.

The empirical method of DoD (**D**istribution **o**f **D**ifferences) evaluation developed for estimates of the variances of inhomogeneous data groups was applied to the data from the AS-76 interlab test and the SALE programme used to determine uranium in uranyl nitrate and UO_2 [10]. In this way, better estimates were obtained reflecting more plausibly the expected findings of the measurements without excluding outliers. The theoretical basis of the DoD-method could be improved by a special investigation confirming also its capability as a robust statistical method[20].

Fuel Element Seal Demonstration Experiment at VAK

Two different seal designs developed by the Joint Research Centre Ispra and the Sandia National Laboratories, Albuquerque, U.S.A., respectively, have been considered in the demonstration test performed in the experimental BWR station at Kahl[17]. Identity marks (signatures) to be scanned by ultrasonics have been incorporated in both designs, the Ispra seal having internal marks formed by a brazing seam while the Sandia seals apply micro-groves machined in a pseudo-stochastic manner as external marks. In addition, for the latter design the seal integrity can be controlled by the ultrasonic read out.

Fig. 3 - IDA-80, plutonium concentrations requested



The previous tests performed over more than 1.5 years (on 8 Exxon fuel elements) and three years, respectively (on 3 KWU fuel elements), involving 28 Ispra seals in total, have shown that no constraints with respect to the routine application of the seals have to be envisaged neither from the operational nor from the nuclear safety standpoint. However, the temperature stability of the identification signal proved to be insufficient. This will necessitate further development work.

Eight Sandia seals clamped to 4 Exxon fuel elements have now been inserted into the reactor. The first reverification tests have yielded satisfactory results, also with respect to the temperature stability of the ultrasonic signals. However, additional investigations are needed to evidence the tamper resistance of the identification marks.

VACOSS Sealing System

After the development of the in-situ verifiable electronic seal VACOSS was successfully completed in 1981, ten VACOSS III seals, two adapter boxes I and three adapter boxes II have been delivered to the IAEA for field evaluation. Euratom got another three seals and two adapter boxes I for test purposes.

Independently from the test procedures performed by the control authorities one VACOSS III system has been sent to the Sandia Laboratories, Albuquerque, U.S.A., as has been agreed within the joint U.S./F.R. Germany electronic seal evaluation programme. At the same time the ELECTRONIC SEAL developed by the Sandia Laboratories has been tested by the Nuclear Research Centre Jülich in cooperation with ProCom GmbH, Aachen. The test programme comprised operational tests, environmental test and the examination of the coding as to security against manipulation. Both seals meet test requirements differing only to the extent to which they withstand various attempts of tampering with[22].

If the field evaluation of the VACOSS III seal by the IAEA is successful, the application on a routine basis should be possible in the near future.

Development of a Surveillance Camera System

A small series of ten units of a surveillance camera system developed at KfK has been manufactured on an industrial scale in the framework of the German support programme and delivered to the IAEA[15,16].

The camera system is based on a commercially available ELMO super-8 film camera. Mechanical modifications, a separate electronic control and an additional optical system offer the following advantages:

- single frame exposure at constant time intervals to be selected between 1 and 29 minutes,
- automated diaphragm and exposure time control up to 1 minute,
- recording of date and time on each frame by focussing the display reading to the film plane,
- independent power supply by batteries ensuring that about 20,000 exposures can be made without battery change.

After the first extensive test runs some improvements were made on the camera mechanical system. Then the cameras were used in field tests in a reactor plant. At present laboratory testing is going on at the IAEA. Additionally environmental tests of the cameras covering a broad range of temperatures and humidity are performed at KfK.

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Organizations Involved

DWK - Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH
INB - Internationale Natrium-Brutreaktor-Bau GmbH
KFA - Kernforschungsanlage Jülich GmbH
KfK - Kernforschungszentrum Karlsruhe GmbH
NUKEM GmbH
SBK - Schnellbrüter-Kernkraftwerksgesellschaft mbH
VAK - Versuchsatomkraftwerk Kahl GmbH
VDEW - Vereinigung Deutscher Elektrizitätswerke
WAK - Wiederausarbeitungsanlage Karlsruhe Betriebsgesellschaft mbH

The Intrinsic Calibration Method in Gamma-Ray Spectrometric Measurements Applied to Power Reactor Spent Fuel Assemblies

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Abstract

The influence of the source distribution on the overall relative efficiency is investigated for fuel assemblies of WWER type pressurized water reactors. Therefore, self-absorption factors are calculated on the basis of experimentally determined fission product distributions.

The study indicates that the uncertainties caused by different nuclide distributions are not significant. They can be reduced by correction factors so far that the errors are negligible. Consequently, the intrinsic calibration method is doubtless applicable to measurements of power reactor spent fuel assemblies without an essential loss of accuracy.

Introduction

The burnup and Pu/U ratio of irradiated fuel assemblies can be derived from the concentration ratios of various fission products by applying the correlation method (see ref. 1, e.g.). The advantage of this method is doubtless based on the fact that only the overall rélative efficiency of the measuring equipment need be known for the evaluation of the gamma-ray spectra. This efficiency can be determined from the measured spectrum itself if it contains several photopeaks of a single nuclide[2]. Consequently, the relative efficiency which includes the intrinsic detector efficiency, the absorption between source and detector as well as the gamma-ray self-absorption within the source is dependent on the source distribution.

This method designated as intrinsic calibration is mainly applied in such cases in which suitable calibration standards with regard to activity, geometrical structure, and source distribution are not available. However, the procedure is only applicable to nuclides with the same spatial distribution within the source. This assumption is not generally fulfilled for irradiated assemblies of power reactors. The concentrations of various fission products depend on the neutron flux and neutron spectrum hardness in a different way which leads to various spatial distributions. Therefore, possible uncertainties in the intrinsic calibration method have to be taken into account. Following the estimations by Hsue and Crane[3,4], considerable systematic errors should be expected in the special case of $^{134}Cs/^{137}Cs$ if the peaks of ^{134}Cs are used for determining the overall relative efficiency.

The investigation of the influence of the nuclide distribution on the relative efficiency is recommended by the Internatonal Atomic Energy Agency, Vienna, as a contribution to improve the gamma-ray spectrometric method for safeguards measurements on spent fuel assemblies[5]. The present paper deals with this problem with regard to assemblies of WWER type reactors. The study is based on experimentally determined distributions of fission product concentrations.

Fission product distributions in WWER reactor type assemblies

Pressurized water reactors of the WWER type are operated with hexagonal assemblies. The cylindrical fuel rods are arranged in a triangular lattice. Some data of these assemblies are given in Table I.

Table 1 - Data on WWER type assemblies[6,7]

	WWER - 440	WWER - 70
Width across the flats /mm/	144	144
Number of fuel rods	126	90
Lattice pitch /mm/	12.2	14.3
Diameter of the fuel rods /mm/	9.1	10.2
Outer diameter of the pellets /mm/	7.55	8.6
Central hole diameter of the pellets /mm/	1.4	–

Detailed experimental data concerning distributions of different fission products within assemblies of the WWER-70 and WWER-440 reactors are presented in refs. 8-10. The distributions across the assembly cross-sections can be described in good approximation by the following terms:

- a rotational-symmetric component,
- an inclined plane according to the macro flux distribution in the core.

The second term may be eliminated by cumulative measurements on at least two opposite sides of the assembly. Therefore, only the first term need be considered for further evaluation.

The symmetrical components of the distributions are plotted in Fig. 1 for the nuclides ^{106}Ru, ^{134}Cs, and ^{137}Cs. The concentrations decrease from the outer to the inner side. The buckling in the centre of the assembly is caused by the central tube which is not filled with fuel. The nuclide ^{134}Cs has the strongest radial dependence from the shown distributions.

In the following the rotational-symmetric distribution is characterized by the quantity

$$k = n_{min} / n_{max} \qquad (1)$$

where n_{min} and n_{max} represent the minimum (fuel rods of the second inner row) and the maximum (fuel rods in the assembly corner). Table II contains the values k for different nuclides obtained from the measurements[8,9]. In connection

Table 2 - Coefficients k for characterising the fission product distributions across the WWER assembly sections[8,9]. Errors indicated in parentheses are given in units of the last digit.

Assembly type	^{106}Ru	^{134}Cs	^{137}Cs	^{144}Pr	^{154}Eu
WWER - 440 1)	0.77 (2)	0.73 (1)	0.82 (1)		
WWER - 70 2)	0.81 (4)	0.78 (3)	0.85 (2)	0.86 (2)	0.82 (3)

1) ^{235}U initial enrichment 3.6 %.

2) ^{235}U initial enrichment 2.0 %.

with further measurements[10] and theoretical predictions, they may be assumed as typical values for these assemblies. The quantity k determined from experimental burnup distributions of the PWR Yankee[11] and BWR Garigliano[12] results in values up to about 0.7.

It has been generally assumed that the relation between the concentrations of ^{134}Cs and ^{137}Cs is given by

$$n_{134} \sim (n_{137})^a$$

with a = 2. This assumption is based on the approximation that the ^{137}Cs concentration and the ^{134}Cs concentration are proportional to the neutron flux density and the square of the flux density, respectively.

By using the measured distributions across WWER assembly sections the calculation of the exponent leads to

$$a_{radial} = 1.58 \pm 0.07$$

This value can be explained as follows. In the case of fission products with relatively large resonance integrals I_o (for ^{133}Cs : $I_o / \sigma_o \sim 14$, σ_o is the thermal capture cross-section) the build-up rate of the following nucleus (^{134}Cs) depends not only on the thermal neutron flux but also on the neutron spectrum hardness. In fuel assemblies the thermal neutron flux decreases from the outside to the inside whereas the spectrum hardness increases[10,11]. Therefore, the quadratic diminution of the ^{134}Cs concentration with the neutron flux is partially compensated by an additional contribution from the increasing spectrum hardness. Consequently, the assumption of a quadratic relation between the concentrations of ^{134}Cs and ^{137}Cs across assembly sections is not justified and results in an overestimation of the influence of the ^{134}Cs concentration on the relative efficiency.

It should be mentioned that the quadratic dependence is mostly fulfilled for axial distributions. So, the results given in refs. 8 and 9 lead to the value

$$a_{axial} = 2.04 \pm 0.07$$

The validity of the approximation indicates that in pressurized water reactors the neutron spectrum hardness is nearly constant along the axis of the assemblies.

The influence of the fission product distribution on the γ-ray self-absorption factors

For calculating self-absorption factors of fuel assemblies the program SFAK[14] has been developed. This factor is defined as the ratio of the intensities of unscattered γ-rays with the energy E at the detector

Fig. 1 - Radial component of fission product distributions across WWER type assembly cross-sections

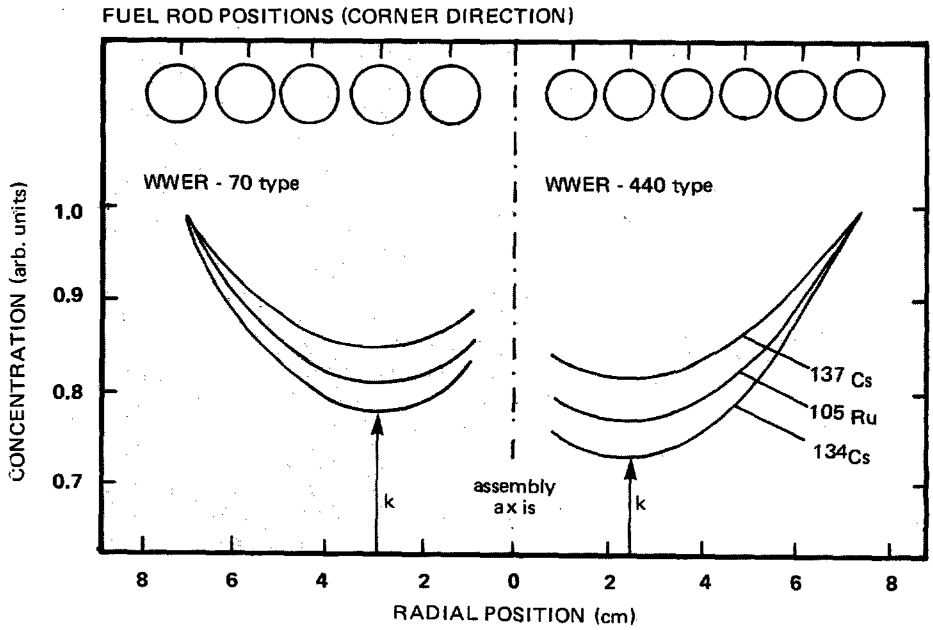
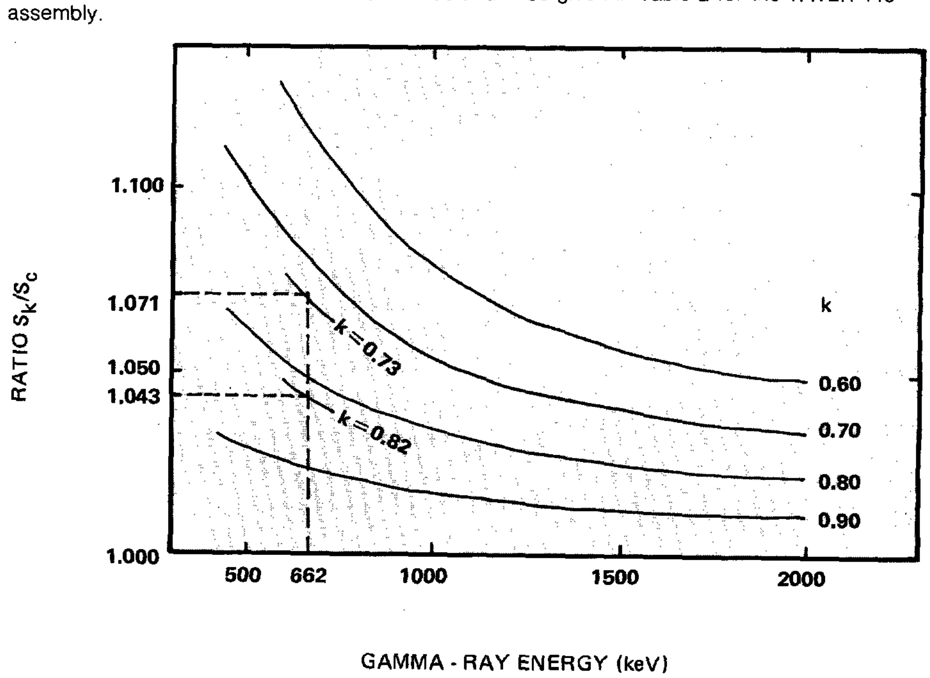


Fig. 2 - Ratio S_k/S_c for WWER-440 assemblies submerged in water in dependence on the quantum energy E.
S_k, S_c - self-absorption factors for a nuclide distribution determined by the quantity k and a constant distribution, respectively. As an example the values S_k/S_c at a gamma-ray energy of 662 keV are indicated for the k values of ^{134}Cs and ^{137}Cs given in Table 2 for the WWER-440 assembly.



position with and without absorbing material respectively within the source.

For WWER assemblies the self-absorption factors $S_k(E)$ were calculated on the following conditions:

- Within the assemblies exist rotational-symmetric distributions of the nuclide concentrations characterized by the quantity k (eq. (1)).
- During the measurements one side of the assembly is directed to the detector. In this case the self-absorption is a minimum[15].
- The detector sees the whole section of the assembly.
- The distance between assembly and detector is large in comparison with the cross-section of the assembly.

The influence of the source distribution on the self-absorption is described by the ratio $S_k(E)/S_c(E)$, where $S_k(E)$ and $S_c(E)$ stand for the self-absorption factor of a distribution determined by the quantity k and a constant distribution, respectively. In Fig. 2 the calculated ratios are presented for WWER-440 assemblies submerged in water in dependence on the γ-ray energy.

If the efficiency ϵ_{k_1} determined from a nuclide with a distribution parameter k_1 is applied to a fission product characterized by k_2 then the relative efficiency ϵ_{k_2} has to be corrected as follows:

$$\epsilon_{k_2}(E) = C\, \epsilon_{k_1}(E)$$

$$\text{with } C = (S_{k_2}/S_c) \,/\, (S_{k_1}/S_c)$$

Using the values k for the distributions of ^{134}Cs and ^{137}Cs in WWER-440 assemblies given in Table II, the correction factor is $C = 0.974 \pm 0.006$ at a quantum energy of 662 keV. If a quadratic dependence between the concentrations of ^{134}Cs and ^{137}Cs ($k_1 = 0.67$) is assumed the correction would be changed to 0.956.

Calculations carried out for different experimental conditions (WWER-70 assemblies[16], narrow collimator, collimators with an inclined axis with regard to the assembly axis) result in correction coefficients between 0.965 and 0.981.

Considering the nuclides ^{106}Ru, ^{144}Pr, and ^{154}Eu with the corresponding values k and quantum energies the corrections are smaller in comparison to ^{137}Cs.

As a general rule, one can state that the differences in the self-absorption factors calculated for WWER assemblies on the basis of experimentally determined distributions of ^{134}Cs and ^{137}Cs amount to about 3%. This quantity is essentially smaller than the difference of 16% estimated by Hsue and Crane[3,4] for a boiling water reactor assembly.

We also estimated the self-absorption factor for an 8x8 BWR assembly with the same conditions including a quadratic relation between the concentrations of ^{134}Cs and ^{137}Cs as assumed in refs. 3 and 4. The estimation was carried out with the rod shielding factors given by Paoletti Gualandi and Peroni[17]. Even in this case, the estimation only results in a small difference of a 5.2% at a quantum energy of 662 keV.

Conclusions

The present study shows that the overall relative efficiency determined from the peak areas of several γ-ray transitions of a single fission product depends on the distribution of this nuclide within the fuel assembly. By applying this efficiency for determining the nuclide cncentration having an other distribution, a correction could be necessary. In the special case of the 662 keV γ-ray of ^{137}Cs the correction factor amounts about to 0.97 for WWER-440 assemblies, if the efficiency is determined from the photopeaks of ^{134}Cs.

This study indicates that the intrinsic calibration method can doubtless be used for measurements of power reactor spent fuel assemblies. The uncertainties caused by fission products with different distributions may be reduced by correction factors so far that the errors are negligible.

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Activities of the ESARDA Working Groups

Containment and Surveillance

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Within its terms of reference the working group includes important items such as:
- Inventory of C/S techniques,
- Design specifications for C/S devices,
- Field testing / Reliability / Vulnerability.

After several meetings (1981-82) dedicated to general aspects of quantification of the reliability of C/S devices the group is now systematically addressing its discussions and actions to C/S techniques and devices.

Meetings are organized on one specific topic or technique at a time and the subject is fully treated within the terms of reference given above.

The first of these technical meetings was dedicated to Portal Monitors (24 June 1982, JRC-Ispra). Reports were given by members of the Committee on progress with the development of portal monitors:
- the U.K. programme at Harwell,
- the FRG programme at KfK,
- the U.S.A. programme at Los Alamos and Sandia,
- the test programme in Japan, followed by the IAEA (Tokai-Mura plant).

The main points of the discussion on portal monitors were as follows:
- Portal monitors will only be considered by the IAEA if they comprise part of a complete safeguards system. Monitors operating in isolation are of less value.
- Portal monitors must be capable of operating reliably without supervision.
- The evaluation in progress at Tokai-Mura should give guidance as to whether the performance of portal monitors is acceptable for longterm safeguards purposes and will assist the Agency in refining safeguards policy.
- Further application of portal monitors to the solution of safeguards problems should await completion of the Tokai-Mura experiment.

During discussion of associated matters, the need was stressed for a high-sensitivity means of checking the source of alarms in portal monitors, if they occur. NDA devices were not thought to possess adequate sensitivity. The implications of alarms from portal monitors was also considered. There was particular concern that portal monitors might be intended to safeguard a complete plant and therefore any alarm might demand a major re-verification activity. No such problem is associated with seals which safeguard more limited quantities of material.

At its meeting on 18 April 1983 in Paris, CEA, the working group discussed the subject of "Electronic Seals". Three projects or realizations were described in detail by members of the committee or invited experts:

- the proposal within the Belgian programme at CEN/SCK, Mol including the general principle of the "electronic signature" by cryptography,
- the existing VACOSS seal and its major features related to several possible uses. The general schemes of the VACOSS seal applications for safeguarding transport between reactor plants and reprocessing plants. The experience gained with field testing of the VACOSS seal by Euratom.
- the Sandia electronic seal as developed in recent years.

A large part of the discussion time was dedicated to gaining a good understanding of the electronic signature and its validity in the International Safeguards framework. Clear indications appeared of the need to record dates of closures and other data which make the use of this seal possible in a scheme where the inspector is present only once and thus relies on the plant operator for the application of the seal on a container.

The identification of important applications of electronic seals was also a result of the meeting. The Euratom Safeguards Directorate and the IAEA indicated the important field tests to be performed:
- use of VACOSS seal during inventory taking in a plant,
- sealing of a power reactor (VACOSS on the shielding),
- transport containers for fuel (mainly when partially filled),
- sealing of hold up material in glove boxes (seal outside, fibre loops inside),
- remote interrogation through the operator,
- remote verification by LOVER or RECOVER systems,
- use of the VACOSS electronics and principle for several types of detectors.

Legal and technical problems were discussed.

As a general recommendation field testing is required as well as development for diversification of uses.

Future meetings will be dedicated to examining in depth the status and possibilities of passive seals; the two major techniques are fibre optic seals (COBRA) as developed by Sandia Nat. Labs. and the ultrasonic seals now being developed by several laboratories (JRC-Ispra, Sandia Nat. Labs., AECL, AERE).

Discussions, conclusions and recommendations will always be given in the spirit of the conclusions of the IAEA Advisory Group Meeting of June 1982 at Vienna which formulated recommendations on development/specification schemes where a good integration of the developers' ideas and Safeguards Authorities' requirements is possible. This Advisory Group also insisted on the need for technical groups to sponsor and follow field tests: the ESARDA Working Group on C/S has identified itself as being such a group. The TITUS seal, of the Ultrasonic Seal family with integrated sensor, developed at Ispra in collaboration with the French CEA, is a device which te group will consider in the spirit of the recommendations of the IAEA.

As a conclusion, for a year and probably until 1985, the ESARDA W.G. on C/S will dedicate its activity to the technicalities of C/S devices, field testing and better specification following an iterative process, and possible applications. This group is representative of all European development work on C/S for International Safeguards including the Euratom Safeguards Directorate; it also includes experts from U.S.A., Canada and IAEA and appears to be an effective forum for discussions leading to precise recommendations and actions in the spirit of the IAEA Advisory Committee.

Report on the Advanced Course on Safeguards at Ispra

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CEC, JRC-Ispra, Italy
G. Cullington, Member of the Steering Committee of the Course
CEC, Safeguards Directorate, Luxembourg

A training course entitled "Nuclear Material Safeguards : Techniques, Procedures and Prospects" was held at Ispra from 24 May to 2 June 1983, under the aegis of Ispra Courses. The course was organized in cooperation with the International Atomic Energy Agency, Vienna, and the Euratom Safeguards Directorate, Luxembourg.

The aim of the course was to illustrate the present status of safeguards implementation (including techniques and procedures), the very important interface relationships between the operator and the safeguards authorities, and areas where further development is foreseen.

The programme of lectures covered 6 main chapters, which are listed in Table 1. Three of these dealt with the purely technical aspects of safeguards, presenting both the present state of the art in the various fields and prospects for future developments. These areas were: Accountancy and related measurements, Informatics and telecommunications, Containment and surveillance.

It was this part of the course that covered the treatment of some advanced problems. These included the use of computers at the instrumentation level, concepts of data treatment and evaluation of all safeguards data, how to use data coming from an operator's near-real-time accountancy and, finally, verification strategies which take into account data produced in different parts of the fuel cycle.

The lecture on data evaluation covered not only the ideas and use of MUF-D but also included an analysis of how discrepancies should be tackled and taken into account in the evaluation. It was pointed out that one of the biggest problems is not the analysis of data but obtaining enough data to analyse.

The two following chapters were of more political relevance and included: i) the tasks of the safeguards authorities and ii) the political bases of safeguards. The lectures were given by persons with political and managerial responsibilities in the two safeguards organizations, and covered issues such as safeguards effectiveness, how decisions are made, and the qualification of inspectors. In view of the fact that the majority of the participants were themselves inspectors, the last two areas were among the most appreciated subjects treated during the course.

Table 1 - Course Programme

Accountancy and related measurements
- Operator/inspector interface and data available to safeguards
- The role of measurements
- Data evaluation
- Real-time accountancy
- Across the fuel cycle verification

Informatics and telecommunications
- The role of computers and informatics
- The role of telecommunications

Containment and Surveillance (C&S)
- Techniques, experience, reliability, effectiveness and problems
- Prospects for C&S

The task of the safeguards authority
- Safeguards effectiveness assessment
- Decision making

The political bases of safeguards
- The Treaty of Non-Proliferation
- The Euratom Treaty and the special cooperation agreements

In-field inspection
- Strategies of inspection, results and technical problems for enrichment plants, reactors, fuel fabrication plants, reprocessing plants
- Operator's point of view on the technical problems arising from implementation (enrichment, reactors, LEU fabrication, MOX fabrication, oxide reprocessing, fast fuel reprocessing)
- Experience of safeguards implementation in a country of the European Community

The legal aspects of how and why safeguards have to be applied, were covered from the points of view of the Non Proliferation Treaty (for IAEA safeguards) and the Euratom Treaty (for the safeguards within the European Community). The requirements that stem from the non-proliferation policies of the countries which supply nuclear materials to the Community were also illustrated.

The last topic to be covered was in-field experience in the implementation of safeguards. The types of plants considered were: centrifuge enrichment plants, light water reactors, fabrication plants both for low enriched uranium fuel and for mixed oxide fuel and reprocessing plants, both for light water reactor fuels and for fast reactor fuels. For each of the plant types considered a representative of the inspection organizations described the aims and the objectives of safeguards activities, the strategy which was applied and the kinds of information which were to be obtained from verification activities.

Each of these talks was followed by presentations from speakers representing those under inspection. These operators presented a wide spectrum of view points ranging from complaints about intrusiveness and costs, to the more positive approach of encouraging inspectors to use the data which are available to them.

It was during this part of the course that the almost complete lack of European operators among the participants was most noticeable. The only operators present were two from the South African fuel manufacturing industry and one from Italy. These lectures were followed by an interesting survey, when a representative from Belgium gave his view of the application of safeguards to the nuclear activities in his country. The course closed with a talk on the interface between R&D and the implementation by inspectors in the field.

Most courses contain a day out and this one was no exception. The reprocessing plant EUREX (in Saluggia, near Turin), owned by the Italian organization ENEA was 'inspected' and the lectures on reprocessing plants were delivered during the visit.

Twenty eight lecturers from inspection bodies, R&D organizations and nuclear industries, contributed to the success of this course by giving lectures of an extremely high technical standard. The lecturers, together with their affiliations, are listed in Table 2.

The distribution of the course participants was as follows: 9 active inspectors from the European Safeguards Directorate and 7 from the IAEA; a total of 14 people involved in R&D work in safeguards; and a relatively small number of operators (only 3).

The objectives attained by the course can be summarized as follows. The inspectors were given an update on how inspections are made. But, perhaps more importantly, they were given the reactions of the operators, who presented their views on how safeguards are applied and how they might be less intrusively and more effectively applied according to their point of view. There was normally a good discussion after a lecture, or group of lectures. The fact, that the meeting was unofficial allowed these to be more open and frank than is sometimes the case, and the dialogue was more effective than usual as a result. This effectiveness was increased because among the lecturers were some of the important personalities of safeguards. The fact that a large number of inspectors from Euratom and IAEA was present allowed a very wide-ranging exchange of experience between the two organizations.

People involved in R&D were able to keep in touch with the inspector's viewpoint, which is obviously more affected by practical situations that some researchers are willing to believe.

There were also 11 Ispra staff members present, most of whom will be moving into safeguards as a result of changing priorities and projects in Ispra. These people received a formal introduction to safeguards, even if the level was rather higher than is normal for beginners.

One aspect the organizers had not expected and were extremely grateful for, was that many of the lecturers remained for a large part of the course. Four of them were present for 100% of the course and another 6 for 50% to 70%. This added a considerable amount of experience to the discussion, and questions which were posed by the participants could be answered not only by the speaker in question but also by other experts who were still present.

The organizers conclude that the course would be better classified as a seminar due to the advanced nature of the lectures and discussion. They would like to thank all those who participated in any way and look forward to renewing the contacts made on future occasions. The organizers would also be very pleased to hear from any operators reading this article as to why almost no operators were present.

Table 2 - Lectures of the Course

Inspection Authorities & Government	P.T. Good	**DOE**, London
	W. Gmelin (guest speaker)	**EURATOM Safeguards**, Luxembourg
	B.W. Sharpe	**EURATOM Safeguards**, Luxembourg
	B. Love	**EURATOM Safeguards**, Luxembourg
	E. Van der Stijl	**EURATOM Safeguards**, Luxembourg
	G. Cullington	**EURATOM Safeguards**, Luxembourg
	R. Haas	**EURATOM Safeguards**, Luxembourg
	H. Kschwendt	**EURATOM Safeguards**, Luxembourg
	A. Von Baeckmann (guest speaker)	**IAEA**, Vienna
	C. Buechler	**IAEA**, Vienna
	C. G. Hough	**IAEA**, Vienna
	D.E. Rundquist	**IAEA**, Vienna
	R. Abedin-Zadeh	**IAEA**, Vienna
R & D	C. Beets	**CEN/SCK**, Mol
	R.J.S. Harry	**ECN**, Petten
	G.R. Bishop (guest speaker)	**JRC**, Ispra
	M. Cuypers	**JRC**, Ispra
	G. De Grandi	**JRC**, Ispra
	S. Crutzen	**JRC**, Ispra
	S. Guardini	**JRC**, Ispra
	B. Richter	**KFA**, Jülich
	F.T. Markin	**LASL**, Los Alamos
Plant Operators	H. De Canck	**BELGONUCLEAIRE**, Dessel
	R. Stewart	**BNFL**, Springfields
	J. Regnier	**COGEMA**, Cap de la Hague
	F. Pozzi	**ENEA-EUREX**, Saluggia
	H. Heger	**RWE**, Mülheim-Kärlich
	T.L. Jones	**UKAEA**, Dounreay

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