

**Report of the Consultants' Meeting on  
Preparation of Guidelines on Implementation of Routine  
Automation in Advanced Neutron Activation Analysis  
Laboratories**

**2 - 4 December 2009**

**IAEA, Vienna, Austria**

Vienna, Austria, January 2010

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## 1. BACKGROUND AND OBJECTIVES

### Background

There is currently a substantial need to develop strategies for research reactor (RR) effective utilization on a national, regional and international basis for a significant number of these facilities that are old, underutilized and consequently under-funded. Enhancement of RR utilization is often pursued by increasing the neutron activation analysis (NAA) activities. This is an obvious choice for small and medium size RRs that might be involved in education and training activities but have little or no opportunities at all for neutron beam research or radioisotope production.

The IAEA has, over the years by its programs for technical cooperation as well as by coordinated research projects, stimulated the orientation of NAA groups worldwide on fields of application in which large amounts of samples may exist for analysis. Programs related with environmental contamination (air, soil, and water), cultural heritage and archaeology, natural resources and the processing may serve as examples. In addition, there are a number of good examples in literature of the NAA on hundreds or even thousands of samples that need to be examined (e.g., determination of selenium in nail clippings for epidemiological studies). In addition, quite some efforts have been and should be still undertaken with support of the IAEA (e.g. in Africa and Latin America) to create partnerships with industry by third party oriented NAA services to emphasize the social-economical role of RRs. NAA laboratories benefit from the IAEA's Analytical Quality Control services (AQCS) in continuous improvement of the intrinsic quality of their analysis results, whereas programs on quality management implementation, eventually followed by accreditation, have contributed to enhance the (inter)national trustworthiness of these facilities. Moreover, training courses have been given with emphasis on customer oriented services.

Whereas the markets for NAA laboratories may have been identified, and quality may have been established, an underestimated **problem remains the absence of automation, which limits tremendously the analytical capacity.** Most NAA laboratories have usually only 1 or 2 detectors, commercial sample changers are very expensive, and therefore unaffordable. As a consequence, the samples can be counted only during office hours. The capacity is also limited by the time consuming data handling due to the lack of associated automation. The analysts often have to transfer the output of the analyzer – a list of gamma-ray energies and peak areas, sometimes topped with element assignment - through various file transformation programs: firstly to the spectrum interpretation software for qualitative analysis, next to a program for quantitative mass fraction calculations, and finally to the reporting software. In this linear chain of processes a missing link is formed by the administration of samples and customers that may be present only in a spreadsheet.

Furthermore, NAA is a multi-element technique, in which often 2-3 measurements are done and intermediate results therefore have to be combined for the final output. Most of the commercially available software has been made for gamma-ray spectrometry and not for NAA. The newly developed IAEA k0-software addresses some of these problems. However, it remains rather limited due to the fact that it is based on unconventional spectrum analysis principles. For this reason its acceptance and applicability is far below the original expectations. Indeed, mastering this software requires very lengthy training under supervision of an expert. Furthermore, the level of automation and opportunities for implementation of the k0-software in advanced NAA laboratories for routine measurements remain unfulfilled,

compared to what modern industry provides for alternative techniques such as X-ray Fluorescence Spectroscopy (XRF), Automatic Absorption Spectroscopy (AAS) and Inductively Coupled Plasma (ICP) Spectroscopy.

Two examples may illustrate the seriousness of the situation. The NAA group in Peru has in principle an outlook for many customers and samples, with paid services, but operates only at about 25 % of its capacity since a lot of time is lost in simple data handling and file transfer activities. Another NAA laboratory in Kazakhstan may have customers for thousands of samples per year, but automation is missing and the spectrum processing takes an hour or more per sample! It is simply detrimental for any NAA service if the analysts have to reject requests for NAA not because of lack of irradiation and counting time, but because of **limited capacity in automation and data processing**.

This Consultants' Meeting fits well into the scope of enhancement of RR utilization. The experts were able to share their best practices on the current status of automation in NAA laboratories, examine needs and opportunities to increase the measurements capacity, as well as assess and propose concrete guidelines to achieve desired objectives.

### **Objectives**

The meeting has focused on the particular aspects of the RR-based NAA, namely the automation of measurements, data processing and analysis. The specific objectives of the meeting were:

- Critically examine the situation in advanced automation procedures in leading NAA laboratories
- Critically examine the needs and opportunities to increase the measurement capacity in less advanced NAA laboratories
- Prepare concrete guidelines, including potential solutions and investments needed, in order to establish fully automated advanced NAA laboratory

The meeting also provided a forum to exchange ideas and information through scientific presentations and brainstorming discussions, leading to the following overall objectives: 1) enhancement of RR utilization in Member States for practical applications, 2) increased cooperation between different RR centres and user communities, and 3) promotion and development of specific applications of RRs.

## **2. WORK DONE AND RESULTS ACHIEVED**

The consultancy meeting was attended by 6 participants, from Australia (1), Morocco (2), The Netherlands (2), Peru (1) and USA (1). The meeting started off with welcome, opening and introductory remarks by Mr Pablo Adelfang, head of Research Reactor Unit, NEFW. Later the welcome address was given by Mr D. Ridikas, the IAEA Scientific Secretary of the meeting, Physics Section, NAPC, followed by a self presentation of all meeting participants. Mr P. Bode (Delft University of Technology, Reactor Institute Delft - RID, The Netherlands) was nominated as a chair person and Mr J. Bennett (ANSTO, Australia) was appointed as a *rapporteur* of the meeting. Mr D. Ridikas, the IAEA Scientific Secretary outlined the specific objectives of the meeting within the ongoing IAEA project D2.01 on Enhancement of Utilization and Applications of Research Reactors.

All participants presented their views on the subject of this meeting. The presentations were followed by lively discussions amongst the participants. Further, intermediate summaries and compilations of findings and comments contributed to involving participants into the aims of the meeting and the strengthening of the exchange of knowledge and experience.

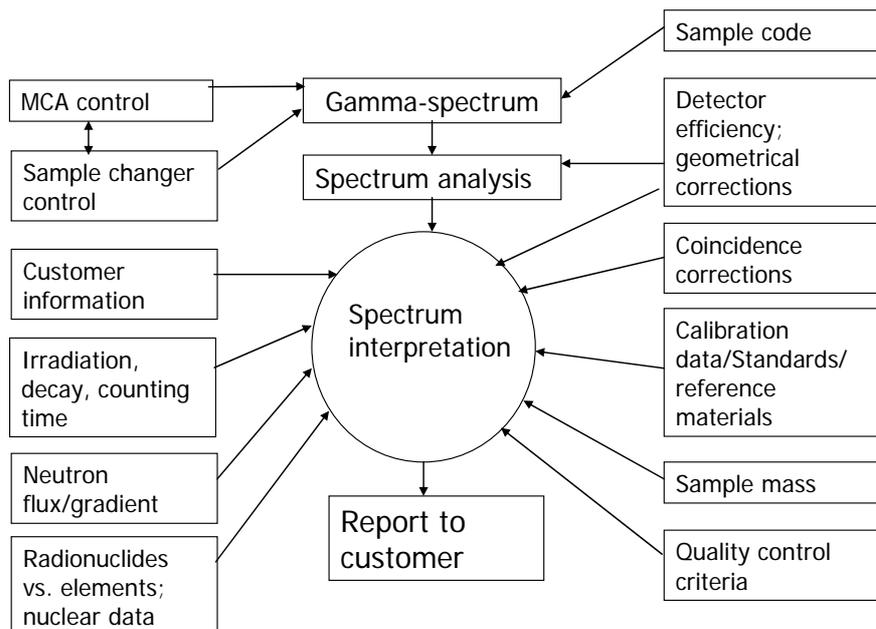
The Annexes of this report include: 1) future work plan, 2) book of individual abstracts, 3) meeting agenda, and 4) list of participants. Copies of the presentations, papers and administrative information were distributed at the end of the meeting to all participants and may be obtained from the Scientific Secretary on request. The full meeting report as a working document is also available on request from the Scientific Secretary.

### Discussion on Automation of NAA Laboratories

The individual presentations given by the experts provided a background for the detailed discussions that are summarized below. Focusing on the key objectives of the meeting, a number of key questions were addressed. These questions related to the role and nature of automation in an NAA laboratory, the benefits which automation may bring and the investment required.

- 1) What is meant by automation?
  - a. Automation is any process that reduces the need for operator intervention.
  - b. An ultimate concept would be to remove the need for any human intervention, with machine talking to machine and to software.
  - c. The following diagram illustrates most points of intervention (source: TUDelft):

#### Operations and Information



- d. As many independent modules should be created as possible, to give the analyst the greatest flexibility in its use in a given situation.

## 2) Need for automation and its benefits

- a. Automation will enhance the revenue-generating capabilities of a laboratory, and increase efficient research reactor utilization. All of these increase the visibility and impact of the facility and eventually may result in socio-economic benefits to the Member State.
- b. Automation is of most benefit where large numbers of similar samples need to be analyzed. Such fields include archaeology, environment, national geochemical mapping programs, epidemiology, and mineral resource exploration (e.g. uranium, oil, etc.).
- c. Automation may also be advantageous where there is a high demand to run small batches of samples. This is often the situation in research and development laboratories. For example, throughput is significantly increased if jobs can be run around the clock, rather than being limited to running during working hours.
- d. It is estimated (Source: IAEA) that there are about 150 NAA laboratories world-wide (institutes, universities and governmental laboratories). The majority may already have some level of automation (e.g. sample changers) but there are probably only a handful of laboratories that could be considered to have an advanced level of automation. Those that have only a sample changer are likely to suffer a bottle-neck in data processing.
- e. In order to justify the significant investment of resources required for automation, an existing need would have to be demonstrated and significant benefits would need to be identified. For example, a case may be made that new clients would be found once capacity is increased, turn-around times reduced and the reliability of a particular laboratory in providing services improved.
- f. The justification for automation may be different for laboratories having different primary activities. Teaching, research and commercial laboratories fulfill different roles and are likely to cite different reasons for needing automation.
- g. Care must be taken however to avoid creating a 'black-box' mentality. There must always be an option for the analyst to intervene and take manual control.

## 3) Barriers to automation

- a. There may be an apprehension that automation will lead to a reduction in staff. The counter-argument is that automation can free human resources to be deployed to higher-level tasks within an NAA laboratory.
- b. It may be perceived that there is insufficient demand to warrant the investment required to automate.

Working Material

- c. The benefits of automation may not be recognized and the knowledge of how to go about automating the laboratory may be lacking.
- d. The NAA scientist within an organization may be too junior to secure the support of decision-makers to invest resources in automation.
- e. Client demand may be perceived to be too low to justify automation. This may however be a consequence of a laboratory having not been sufficiently proactive in identifying and engaging with potential customers. Staff training is likely to be needed to improve this aspect within a laboratory, in order to reap the commercial rewards of automation. The staff trained under such an initiative may not be the analyst themselves but marketing personnel.

4) Investment required in automation

- a. The following table provides indicative prices for commercially available component items in a basic NAA laboratory containing 2 detectors. It can be seen that those items specific to automation make up 40-50 % of the total.

Item	Indicative Price USD (2010)	Comments
Sample preparation (micro-balance, grinding, oven, pelletizer)	42,000	
Reference materials and standards	3,000	
2 x detector, dewar, spectrometer, PC	100,000	
2 x lead castle	26,000	
Uninterruptible power supply	2,000	
Calibrated gamma-ray sources	8,000	
Calibrated weights	2,000	
Automated fast rabbit system	50,000	specific to automation but not currently available
Automatic sample changer	80,000	specific to automation
Integrated INAA software package	-	specific to automation but not currently available
Communication interfaces to connect several instruments (balances, timers, etc)	-	specific to automation
<b>TOTAL</b>	<b>~300,000</b>	

- b. One full-time equivalent staff member (university educated) with technical support could operate the complete system.

- c. It may be instructive to develop case studies based on the experience of the automated NAA laboratories (e.g. KAERI, MURR, TU Delft, Ecole Polytechnique Montreal, Becquerel Laboratories, etc.).

#### 5) Funding options

- a. For funds to be available through the IAEA, Member State laboratories need to apply for a relevant TC project, indicating the opportunities for enhanced research reactor utilization. There will be a minimum 2-year lead time before such a project could be activated and start its implementation.
- b. Other funding sources may include national resources, bilateral cooperation agreements and support from stakeholders including industrial partners.
- c. Use funds generated through commercial analyses to purchase equipment and software.

#### 6) Sustainability of support and training.

- a. It is recognized that sustainability of automated systems is a critical issue that needs to be addressed.
- b. Even if the Agency supplies documented hardware/instruments, sufficient training needs to be provided to ensure operation and maintenance can be carried out independently of the Agency.
- c. The problem is different for software where users would not usually be able to modify the code. However, if source codes were to be provided, training and 'help-desk' requirements would be higher. The alternative approach is to enable individual groups to develop their own software modules, using an agreed data transfer/share format that could then be available through the wider network.
- d. Training in management of analyses in large-scale projects.
- e. Training in how to market the services and engage with potential client networks (industry, government, mineral resources). In this aspect, the training may apply more broadly to promote the whole research reactor centre rather than just the NAA laboratory. This broader scope may be seen to be a spin-off benefit from the automation of NAA.
- f. Training in the use and development of modular software.

#### 7) Opportunities for standardization

- a. It does not seem possible to standardize the design of sample changers, irradiation systems or sample encapsulation systems to suit all facilities and users so there is no value in proceeding along this track.
- b. A modular approach to automation would enable a laboratory to select those components that best suit its needs and allow further individual/independent

development. At the highest level, these modules include a sample changer, automated fast rabbit system, software/hardware interfaces and an integrated INAA software package. Furthermore, the INAA software package itself can be divided into various separate modules.

- c. Given that there are only a limited number of software packages on the market, there is an opportunity to specify a standard text file format for output/input so that they can be integrated seamlessly, without user intervention. The most used software packages include ORTEC Maestro/GammaVision, Canberra Genie, HyperLab,  $k_0$ -IAEA, and Kayzero for Windows. There may be wider applications in spectroscopy.

Dedicated software should be produced for NAA data processing, data management and automation. Modules should be provided, rather than source code. The following capabilities should be added to the existing software: large data set entry, advance prediction and protocol optimisation, prior sample composition information regarding the presence of trace elements. The software should be divided into stand-alone modules such as: data entry, protocol, peak fit, detector characterisation, irradiation facility characterisation, NAA calibration, interpretation, reporting and QC/QA.

This approach would fit with the concept of providing a tool-box of modules that can be chosen from by the analyst, allowing alternative modules to be substituted/developed as required, with the connecting file formats having been clearly defined. This allows modules to be connected transparently. Such modules could be made available to the wider NAA community.

- d. It needs to be possible to analyze spectra remotely from the irradiation facility, in another building/site or even a different country.
- e. Final reporting is customer-based so there is no opportunity for standardization.
- f. Data analysis and interpretation cannot be standardized. The modular approach however should allow for the three methods of NAA to be used, namely i) absolute, ii) relative (single and multi-element), and iii)  $k_0$ .

#### 8) The incorporation of analytical quality assurance in automation

- a. Analytical quality assurance should be incorporated in a modular form, including in data processing, leading to higher reliability.
- b. There needs to be a means to determine information related to the sample changer such as sample position related to the detector, identification of the sample. There needs to be a feedback mechanism.
- c. Automation offers the opportunity to process quality control data and perform trend analysis.

### 3. SUMMARY AND CONCLUSIONS

There was unanimous agreement that there are significant opportunities to increase the measurement capacity in less advanced NAA laboratories through automation. The following points summarize the current situation as it pertains to the majority of NAA laboratories. These points provide a guide to those areas that need to be addressed as a matter of priority to enable the widespread adoption of automated systems.

- Enhancement of RR utilization via NAA is seriously hampered by the lack of automation both in hardware and software.
- Most NAA laboratories worldwide are facing this problem.
- A lack of training currently constrains several aspects of the effective use of NAA, including in the areas of marketing, the quality management of projects with a large number of samples and the implementation of advanced technology.
- There are no commercially available solutions for data processing and management after gamma-ray spectrum analysis.
- Irradiation stage: there are no automated irradiation facilities with sample changers commercially available.
- Measurement stage: only one company currently offers a sample changer specifically for NAA.

### 4. RECOMMENDATIONS

The meeting adopted the following concrete recommendations to the IAEA, satisfying the stated objectives of enhancing RR utilization in Member States, promoting cooperation between different RR centres and end-users, and enhancing NAA capabilities in particular.

- a. Continue efforts to promote and realize automation in NAA laboratories so as to increase opportunities for enhanced RR utilization. Promote automation through the dissemination of good practice documents which should not be prescriptive.
- b. Encourage Member States that would benefit from NAA automation as a means to increase RR utilisation to apply for TC funding in the next cycle, possibly taking advantage of the outputs of the recommendations set out in Sections 2-3 of this report. Applicants would need to demonstrate confirmed support from stakeholders.
- c. Continue support of k<sub>0</sub>-IAEA and any improvements developed in response to Member State end-user requests (as determined through a Technical Meeting or workshop, possibly resulting in a Coordinated Research Project, preferably towards the end of 2010 and involving around 15 participants). A modular

approach, as described above, is recommended to be implemented through a Research Contract. The Agency would act as a facilitator (through a Consultancy Meeting) for relevant software developers to define the interfaces between the modules.

- d. Create a platform, e.g. through a Research Contract, to provide a means for the exchange of information on automated irradiation facilities and on sample changer construction.
- e. Provide sufficient training workshops and fellowships through the period of installation and commissioning of automated systems so that the NAA laboratory can assure the continued functioning of the systems beyond the term of the Agency support. It may be desirable to involve the staff of the Agency's Laboratory in Seibersdorf.
- f. Provide training courses for NAA staff to fill the increased capacity arising from automation. Courses would include: marketing; commercial outreach and finding applications and stakeholders for NAA services; and planning and organization of large scale NAA projects.
- g. Whilst not a recommendation within the scope of this CM, the meeting identified that there is a need to produce multi-element standards that are designed specifically for relative NAA. Such standards would need to be certified. The relative standardization method is a popular alternative to the  $k_0$ -method because it is accurate and easy to implement but suffers from the lack of multi-element standards.

## ANNEX I. WORK PLAN FOR THE FUTURE ACTIONS

The following table sets out a draft work plan of actions that should be taken in order to implement the recommendations in a timely fashion.

Activity	Coordination	Commencement date	Delivery date
Establish terms of reference for TM to be held in Q2-Q3 2010, Vienna.	RID & NETL	15 January 2010	15 February 2010
Begin planning for the training workshops in 2010	RID & ANSTO	March 2010	April 2010
Establish terms of reference for CM on modular structure of NAA software to be held in Q2-Q3 2010, Vienna	RID & IPEN	15 January 2010	15 February 2010
Initiate the CRP process if requested through the TM	IAEA	July 2010	September 2010
Formulate a questionnaire to determine the software, hardware, consumables and level of automation in NAA labs	NETL & CNESTEN	15 January 2010	15 February 2010
Design and implement the platform for information exchange	IAEA & ALL	March 2010	May 2010
Scope the terms of engagement for the modularisation of $k_0$ -IAEA	RID & IAEA	February 2010	June 2010
Determine the extent of involvement by the Seibersdorf Laboratory in hardware maintenance, etc.	IAEA	May 2010	June 2010

## ANNEX II. INDIVIDUAL CONTRIBUTIONS

### 1 Peter Bode, RID, The Netherlands

#### **AUTOMATION IN NEUTRON ACTIVATION ANALYSIS FOR ENHANCING RESEARCH REACTOR UTILIZATION**

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#### Abstract

Neutron activation analysis (NAA) has all the potentials of demonstrating the relevance of a nuclear research reactor via its application in programs of social-economical relevance and by providing services, at a competitive price, to third parties such as governmental bodies, NGOs and industry. Still, many NAA groups do not succeed in this due as they are operating at limited capacity, using only the office hours for performing measurements. Moreover, even if sample changers allow for running around the clock, the absence of commercially available software for transforming the peak areas into qualitative and quantitative information on the element content requires a lot of time-consuming actions by the analysts, and thus to an increased turnaround time. The main providers of software for gamma-ray spectroscopy have never extended their scope of products towards NAA, obviously because of lack of interest in a relatively small target group (it has been estimated that about 150 NAA groups may exist worldwide). This is in strong contrast to the situation in other techniques for element analysis, such as XRF, AAS and ICP, in which the manufacturers now provide complete packages by which all routines can be operated in a routine way, finally directly resulting in analysis' reports.

Only a few groups worldwide have demonstrated that automation in NAA is feasible, both with respect to hardware (like sample changers) and software (integrated modules for converting peak areas in element amounts). The NAA group in Delft started this already in the early 1970s. An overview will be presented of the developments and current status of automation of NAA in Delft. Based on this experience, it will be outline which gaps exist between commercially available hardware and software and the needs for automation in NAA; this may serve as a starting point for further actions.

## 2 Sheldon Landsberger, NETL, USA

### An Automated NAA Cyclic Irradiation Facility

Nuclear Engineering Teaching Lab  
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The Nuclear Engineering Teaching Lab (NETL) has implemented a fully automated short-lived NAA facility that includes irradiation and counting. The irradiation facilities include both thermal and epithermal neutron irradiations for routine and cyclic NAA.

#### Project Goals

- Automated loading, irradiation, counting and storage of samples
- Cyclic irradiation of shorter lived isotopes
- Automatic archiving of spectral data
- Sharing of resources with manual system

#### Description

- Combines sample changer, irradiation facility, and germanium spectrometer
- Samples may have single or cyclic irradiation in thermal or epithermal facility

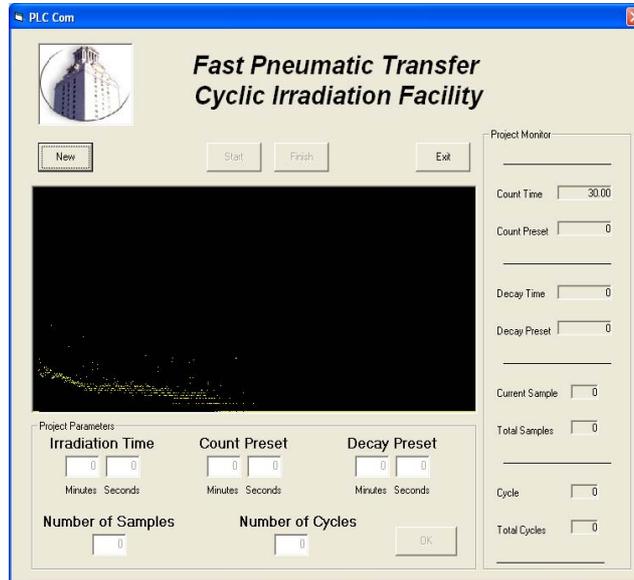
#### Sampler Changer

- Pneumatically actuated
- Combines loader and diverter
- Sensors monitor various states
- Three solenoid valves control cylinder up, cylinder down, and load sample
- A fourth ejects the sample

#### System Layout



## Interactive Mode



## Conclusions

The system has been beta tested and has been is now routinely used for NAA. This has greatly reduced time and expense of human resources.

### 3 John Bennett, ANSTO, Australia

## Design and Operation of NAA Facilities at ANSTO

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The NAA facilities at the 20MW OPAL research reactor in Australia have been commissioned. There are facilities for short irradiations (up to 15 minutes), long irradiations (up to 20 hours) and delayed neutron activation analysis (for uranium determinations). The very-well thermalised neutron flux (thermal to epithermal ratio  $>2,000$ ) and steady power provide near-ideal conditions for  $k_0$ -NAA.

The delayed neutron activation analysis facility is highly automated, allowing a magazine of sample cans to be irradiated and counted in sequence.

Due to the need to have the detector system in a separate laboratory from the terminal station of the short irradiation facility, the minimum time between activation and measurement is around 3 minutes.

An automatic sample changer was purchased from Changer Labs, USA (pictured below). It is the only sample changer currently on the market that is designed for NAA. A particularly convenient feature is its ability of the machine to choose the height at which a sample will be counted above the detector based on the dead-time.



There are two ORTEC HPGe detectors (27% and 32% relative efficiency). The software packages used for data accumulation and analysis are ORTEC Maestro, HyperLab and Kayzero for Windows.

The cost of the instrumentation and software for the NAA laboratory totalled around USD\$220,000.

### 4

**Moussa Bounakhla, CNESTEN, Morocco**

**Consultants' Meeting on Preparation of Guidelines on Implementation of Routine Automation in Advanced Neutron Activation Analysis Laboratories**

CNESTEN (Centre National de l'Energie, des Sciences et des Techniques Nucléaires)  
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The National Center of Energy, Sciences and Nuclear Techniques (CNESTEN) has successfully installed the first Moroccan reactor at its Nuclear Research Center of Maâmora (CENM). This reactor type TRIGA Mark II with a power of 2 MW will contribute in the development of several socio – economic sectors in the country such as environment, agriculture, industry, health, human sciences...

The reactor is characterized by: i) The rotary specimen rack assembly (Lazy Susan) located in the circular well in the reflector assembly, ii) Production of very short-lived radioisotopes accomplished by a pneumatic transfer system located in the G-ring of the core, iii) One central experimental tube (Central Thimble) in the middle of the core (A-ring) for in-core irradiation at the region of maximum neutron flux, iv) Three radial beam ports, one of which pierces the graphite reflector and terminates adjacent to the fuel, v) One tangential beam port, and other in-core irradiation facilities, such as hexagonal and triangular cut-outs etc.

The activities planned to be developed around this reactor are: Neutron Activation Analysis, Prompt Gamma Activation Analysis, Neutronography, Neutron diffraction, Radioisotope production and Fission traces dating.

Instrumental Neutron Activation Analysis (INAA) occupies an important place among the many uses of this reactor. CNESTEN got the authorizations to exploit its nuclear installations at CENM February 2009, INAA is already operational, and it will be completed by the installation and implementation of the PGAA system. Thus, a powerful analytical tool will be available in the country to contribute in protecting and preserving the environment and cultural heritage of Morocco, and also for training of young researchers and specialists in this field as well as for other contribution in development of socioeconomic sectors.

NAA Laboratory of CNESTEN is composed by:

- Physical preparation local for geological samples, sediments, rocks, ...
- Biological preparation local which need very clean area
- Radiochemistry local for sending/receiving samples to/from reactor
- Counting room

Pneumatic tube and gravitational systems are used for irradiation, respectively short and long one.

3 detectors, HPGe 30%, 40% and 70%, are installed and calibrated. The irradiations of monitors performed recently at 250 kW allowed to determine the values of the flux (thermal, epithermal and fast) at 2 positions dedicated to NAA technique: pneumatic tube and Lazy Suzan.

The same irradiations have been used in the implementation of Ko-method which requires the determination of two neutron flux parameters :  $f$  (thermal to epithermal ratio) and  $\alpha$  (deviation from  $1/E$  distribution) and the absolutely calibrated HPGe detector.

For data possessing, HypermetPC program, Genie 2000, Maestro and IAEA-K0 software are available.

Quantitative analysis is performed using IAEA-K0 and Kayzero for Windows.

Some reference standard materials have been also irradiated to assess accuracy of the method for major and trace elements.

The ASC2 Automatic Sample Changer with 20 positions including software and computer has been ordered from ORTEC. Thus, the capacity of CNESTEN's NAA laboratory will increase.

The sample changer characteristics are:



- ✓ It accommodates most HPGe detector sizes
- ✓ Automatic sample changer system for gamma spectroscopy
- ✓ Unattended acquisition and analysis of multiple high-resolution gamma-spectroscopy samples
- ✓ Low background design: no moving parts inside lead shield
- ✓ Completely safe: totally enclosed!
- ✓ Easy to use
- ✓ Twenty 1-liter samples standard; other configurations available

Operating the sample changer is very easy:

The samples are first registered into a loading jig, from which they are sequentially taken into the counting chamber by the pre-programmed action of the X-Y-Z robotic arm. The sample count starts as soon as the data for the first sample has been entered, thus maximizing count time. The sliding top of the lead shield is rolled back smoothly under computer control to allow for sample changing. When the sample is in place, the robotic arm releases it, and returns to its rest position as the shield lid closes and the count starts.

In terms of overall objectives of the meeting in the Terms of References, it is important to mention that:

- NAA is one of the priorities of CNESTEN
- NAA Laboratory of CNESTEN acquired equipments and trained staff of NAA laboratory under an IAEA TC project
- CNESTEN has ordered some consumables and equipments under bilateral cooperation between Morocco and USA
- CNESTEN submitted a proposal of PGAA project under bilateral cooperation between Morocco and Hungary
- CNESTEN is actively involved RAF/4/022 regional project
- CNESTEN has established his action plan for NAA of the year 2010 which focused on NAA applications in air pollution monitoring, cultural heritage, geochemistry and nutrition.

## 5 Eduardo Montoya, IPEN, Peru

### Status of Automated NAA Facility at IPEN

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One of the problems of the NAA group in Peru was that while it has in principle an outlook for many customers and samples, with paid services, the laboratory operated only at about 25 % of its capacity since a lot of time were lost in simple data handling and file transfer activities. Even more, several costumers (external and internal) expressed that while the accuracy of the laboratory is very good; the observation of the accorded turnaround times is deceptive.

In order to solve as quickly as possible the urgent issue of data handling and processing, in 2008 we developed an application in Microsoft Excel, for the complete processing of data and automated presentation of results, of  $k_0$ -based instrumental neutron activation analysis. The application makes extensive use of the data generated by the Canberra's Genie-2000 spectroscopy system, minimizing the manual input of data by the user. A special feature of the application is the automatic determination of significant figures for each result, as well as the automatic rounding and presentation of the results and their expanded uncertainties ( $k=2$ ), in the right format. The application has been validated by the analysis of reference materials and it is actually on production and maintenance steps. The use of the application has allowed the improvement of the efficiency, of the analytical work, in the Laboratory of Nuclear Analytical Techniques of IPEN.

Also by the middles of 2008 we started the elaboration and (due our severe budgetary scarcity) slow implementation of a comprehensive automation project. The following guidelines were stated:

- 1) Automate as far as possible.
- 2) Use in house developed hardware and software, as far as possible.
- 3) Integrate all available equipment, even from heterogeneous sources.

The point three was found to be particularly important, due that the laboratory has a variety of equipments and instruments, made by different manufacturers (including some home made components like a pneumatic irradiation facility and an automatic sample changer). These equipments have different communication standards and protocols, which imposes some degree of difficult on their integration. On this basis, the technical considerations for the implementation of a network, for the interconnection of the analytical instrumentation and other scientific equipment, available at the laboratories of the RP-10 Nuclear Research Reactor, were elaborated. It is expected that the proposed network will allow the control ad communication of the instruments, reducing the human intervention, and consequently improving the operational quality standards. Several alternatives area were analyzed and it was proposed the use of the CAN (Controller Area Network) standard, with PIC microcontrollers, for the digital interfacing between the instruments and the CAN network.

## 6 Menno Blaauw, RID, The Netherlands

### **The k<sub>0</sub>-IAEA software - history, status, prospects.**

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The k<sub>0</sub>-IAEA software was developed over the years, starting from 2003. Originally, the software was to address the issue of poor results observed by the Agency in NAA intercomparisons. The specifications of the first version were decided on in a consultant's meeting: Orthodox k<sub>0</sub>, combined with the holistic interpretation method. Later on, peak fitting capabilities, a tutorial, PGNAA and QA/QC features were added.

Several training events have taken place, mostly initiated by the Agency. With the tutorial, the software does not require lengthy training by experts – some users have managed to get the software up and running all by themselves, one of them within 24 hours. k<sub>0</sub>-NAA as such is a complex technique however, and prior understanding of NAA helps enormously.

Currently, the software is in use only in some 15 institutes. Even though the help desk in Delft has been up and running since the first release, it is observed that some users have failed to contact Delft with requests for improvements and additional features.

Such features might be: a) Sample data import from other file formats, b) rounding off to the right number of significant digits when reporting, c) use of knowledge about upper limits in the sample, presence of interfering elements and the elements of interest, d) dealing with bulletted detector shapes, e) relative standardization options, f) features to predict detection limits in advance, g) features to assist in determining the analysis protocol.

Trainers with in-depth knowledge of the software currently do not exist – except for the author. A training event to teach future trainers for future regional training events is recommended. Also, a feedback loop and mechanisms to keep the knowledge levels up-to-date is needed.

## ANNEX III. AUTOMATION AND QUALITY ASSURANCE IN THE NAA FACILITIES IN DELFT\*

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*\* Paper, presented at the 10<sup>th</sup> Int. Conf. "Modern Trends in Activation Analysis", Bethesda, MD, USA, April 1999; Publ. in J. Radioanal. Nucl. Chem. 245 (2000) 127-132.*

### **Abstract**

The facilities for instrumental neutron activation analysis in Delft are described. Technical details of the fast rabbit systems, the normal pneumatic rabbit system, the large sample facility and the various coaxial and well-type Ge-detector spectrometers and sample changers are given. The capacity of the facilities is in the order of 15,000 samples per annum for full multi-element analysis. The capacity of the fast rabbit systems for INAA for use with short half-life radionuclides is even larger. The facilities are accessible for use by scientists from other establishments and countries as well.

### **Introduction**

The laboratory for Instrumental Neutron Activation Analysis is part of the Interfaculty Reactor Institute of the Delft University of Technology. Neutron activation analysis activities started at the 2MW swimming pool reactor in 1963. The reactor is operated at a 100 h week cycle. Operational availability (2 MW) of the reactor is typically in the order of 65-70 % of the scheduled annual duty time (ca. 5500 hours). Two pneumatic fast rabbit systems have been installed, each with a transfer time of approximately 1 s, inside the reactor pool and inside a radial beam tube. Three pool-side 'slow' rabbit systems are used for irradiations –still in plastic rabbits- up to 5 hours. Manually operated pool-side facilities are also available for longer irradiations in quartz ampoules. Large sample INAA is carried out using the facility in the reactor thermal column.

The variety of students and scientists, often untrained radiochemists, requires a user-friendly approach and thoroughly applied automation of spectrometers, facilities and procedures<sup>1-6</sup>. In the 1980's the excess capacity of the facilities was made available to provide scientific and technical services on a commercial basis<sup>7</sup>. Governmental authorities and institutions, and industry indicated the importance of laboratory accreditation that initiated in 1989 the development of the quality system and the achievement of laboratory accreditation in 1992/1993<sup>8-11</sup>. A new horizon for INAA was given in 1990 with the development of facilities and methods for the analysis of samples of kilogram size<sup>12</sup>.

### **Facilities for INAA using short half-life radionuclides.**

#### ***Fast rabbit irradiation system***

Two fast rabbit systems have been installed with the reactor. The 'old' fast rabbit system (1970) consists of an aluminium transfer tube and a simple blow-in/blow-out system<sup>13</sup>. The pool-side irradiation end of the system is located at 3 cm from the fuel elements,

providing a thermal neutron fluence rate of  $1.2 \cdot 10^{17} \text{ m}^{-2} \text{ s}^{-1}$  and  $(N_{\text{th}}/N_{\text{epi}}) \sim 40$ . In this system small polyethylene rabbits (useful volume approximately  $1 \text{ cm}^3$ ) are used<sup>1</sup>. The rabbits are transferred through the system using high purity nitrogen gas at 3 bar pressure. The transfer time from irradiation position to receiving end is approximately 1 s. The rabbits are contaminated during transfer with radioactive Al-dust, which implies that the sample container has to be manually unloaded from the rabbit. As such, measurements can not be started until 15 s after irradiation. Such a decay time appears to be still acceptable for many applications including those involving e.g.  $^{20}\text{F}$  or  $^{77\text{m}}\text{Se}$ . However, this system cannot easily be automated.

A conventional gamma-ray spectrometer is installed near the receiving end of this facility, inside the reactor hall at the reactor's top platform. The 12 % Ge detector has a 1.63 keV resolution for the 1332 keV line of  $^{60}\text{Co}$  and a p/C ratio of 50. The detector is equipped with a transistor-reset preamplifier and a fast main amplifier, coupled to a 5  $\mu\text{s}$  fixed dead-time ADC with Loss Free Counting Module. This can be considered the second generation of hardware dead-time correction after the Institute's own design for such a device<sup>14</sup>. The ADC is coupled to the local area computer network (see below).

### ***Automated fast rabbit system and sample changer***

In 1984 a new automated fast rabbit system was installed<sup>15-17</sup>. Inert construction materials were used for the transfer tubes, viz. plastic polyethylene tubing in the inactive zone, and carbon-carbon composite material as an irradiation end. The irradiation end was installed in a radial beam tube. The neutron flux is in the order of  $4 \cdot 10^{16} \text{ m}^{-2} \text{ s}^{-1}$  and  $(N_{\text{th}}/N_{\text{epi}}) \sim 108-116$ . Transfer time in this system is in the order of 2 s. The same polyethylene rabbits are used as in the 'old' fast rabbit system. However, since the rabbits are not measurably contaminated (Figure 1), unpacking is unnecessary.

This facility (CAFIA, acronym for Carbonfiber Autonomous Facility for Irradiation and Analysis) can be operated without supervision. The facility includes a 64-position sample changer in between reactor irradiation end and receiving end with the spectrometer<sup>17</sup>. Exchangers in the system make possible that samples can also directly be transferred between reactor and detector for e.g. cyclic activation. The sample changer and gamma-ray spectrometer are located inside the reactor hall, in the direct vicinity of a radial beam tube. The system allows for several measurements to one sample at different decay times, whilst other actions can be performed in between counting periods. These might be actions resulting in a single measurement after activation, cycling activation or analyses in which one sample is measured more than once. Flexibility and versatility in the operation is attained by a combination of software and hardware control. The system controller also executes the communication between the gamma-ray spectrometer and the local area computer networks (see below).

The gamma-ray spectrometer of this system is a 33 % Ge detector (1.84 keV resolution for 1332 keV of  $^{60}\text{Co}$ , p/C ratio = 64), with conventional resistor reset preamplifier and other electronics. Also this spectrometer is equipped with a Loss Free Counting module, and the ADC is linked to the local area network as well.

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<sup>1</sup> Manufacturer of these rabbits (and also of the polyethylene inserts, the sample capsules) : Free University of Amsterdam, Faculty of Biology, De Boelelaan 1087, 1081HV Amsterdam, <http://www.bio.vu.nl/plastics>.

## **Facilities for INAA with intermediate and long half-life radionuclides.**

### ***Irradiation facilities***

Only polyethylene capsules of standardized dimensions are being used for all routine INAA. All irradiations are carried out in one of the three slow pneumatic pool-side rabbit systems. In this facility, polyethylene vials of approximately 30 cm<sup>3</sup> can be irradiated for a maximum of 5 h at a thermal neutron fluence rate of approximately  $5 \cdot 10^{16} \text{ m}^{-2}\text{s}^{-1}$  and  $(N_{\text{th}}/N_{\text{epi}}) \sim 55$ . Capsules with samples, standards and blanks are each sandwiched in between smaller capsules containing neutron flux monitors. The capsules are packed in columns, and sealed using polyethylene-sealing foil. As such, a rabbit can be loaded with a maximum of 14 samples, a sample of an internal quality control material and a blank, all stacked in 4 columns. The high load with neutron flux monitors is required to account for the longitudinal and radial neutron flux gradients<sup>18</sup>. The sending/receiving end of the pneumatic system is in a radiochemical laboratory physically separated from the reactor hall. Underpressure is applied to transfer the rabbits using normal air, resulting in a transfer time of approximately 8 s. After activation, the rabbits can be received in a heavily shielded lead castle with a 5 positions carousel. The entire unloading procedure requires approximately 5 m.

The thermal column irradiation facility is used for large sample INAA<sup>12,19</sup>. The polyethylene irradiation container, which can hold samples with a maximum size of 1 m length and 15 cm diameter, is lowered into the thermal column in a tube in which water is used as penetrable shielding. Inside the container, the sample is rotated during irradiation around its length axis; the flux monitors surrounding the sample do not rotate. The neutron spectrum in the graphite-stacked thermal column is highly thermalized, with a fluence rate at the irradiation position of approximately  $10^{13} \text{ m}^{-2}\text{s}^{-1}$  and  $(N_{\text{th}}/N_{\text{epi}}) \sim 10,000$ .

### ***Gamma-ray spectrometry facilities***

Several gamma-ray spectrometers are available, both with coaxial and well-type semiconductor detectors (Table 1) and most of them are equipped with automated sample changers. All spectrometers are composed of conventional NIM electronics. Pulses from an in-house developed pulse generator<sup>20</sup> are fed into the detector's preamplifier's test input to correct for dead time and pile-up losses. The NIM ADC's are linked to the local area computer network (see below) via an in-house developed 8k-buffered interface NIM module. This module communicates with the computer network via the RS 232C connection. This communication line is used for control of the spectrometer as well as for control of the sample changers.

Several of the sample changers have entirely been developed in-house; others are modified Nuclear Chicago sample changers, which were commercially available in the 1970's. All sample changers are equipped with position decoders. Each sample changer contains at a given position a capsule containing a radioactive source with calibrated activities of <sup>152</sup>Eu and <sup>22</sup>Na, and a not irradiated blank capsule for semi-automated spectrometer performance control (see below).

### ***Local Area Computer networks***

All spectrometers and sample changers are linked via the buffered interface module to a local area computer network (LAN) consisting of (1999) 26 PC's, operating under LINUX.

The in-house developed software package has a modular structure, enabling easy servicing, modification and upgrading. The software comprises servers for

- Management of the information on samples, irradiation and counting conditions.
- Control of the spectrometers' ADC and sample changer
- Control of the large sample scanning spectrometer.
- Communications with the automated fast rabbit system controller.
- Holistic spectrum analysis, interpretation and reporting<sup>21</sup>. The software contains a catalogue with self-measured gamma-ray intensities<sup>22</sup> and calibration constants for 50-60 elements.
- Automated internal quality control, control chart generation and quality assurance<sup>23</sup>.
- Management of the analysis' results of internal quality control samples.
- Archiving.
- Spectrometer performance control<sup>24</sup>.
- Element calibration<sup>25</sup>.
- Efficiency calibration<sup>26</sup>.
- Neutron and gamma ray self-attenuation correction with large samples<sup>27</sup>.

Several of these servers have restricted access for the computer manager or the quality assurance manager only. Once recorded or entered data cannot be deleted without archiving first. All raw spectral data are archived on tape or CD-ROM. Modifications in the software or in the databases do not overwrite the originally information. Modifications in the software are tested via the analysis and interpretation of a set of 'standard' raw data of gamma-ray spectra.

The most important features of the INAA software have been documented in a tutorial manual. Spectrum analysis is done in an interactive way. The analyst inspects the quality of the peak fitting –and adjustments may be needed-, and the quality of the element assignment. The time required for spectrum analysis, interpretation and reporting depends on the shape and complexity of the gamma spectrum, and the number of spectra that have to be measured for a given sample. On the average, a batch of 14 samples, 2 internal quality control samples and 20 neutron flux monitors, which may involve 36-108 spectra, can be analyzed in 0.5 – 2h.

### **Management of the INAA facilities**

The laboratory has developed in the early 1990's a quality system to improve on one hand the efficiency and effectiveness of its operations, and on the other hand to assess and to assure the analytical quality<sup>10,11</sup>. This quality system has been accredited for compliance with the criteria of the Dutch Council for Accreditation, which are derived from the Euronorm EN45001, closely following the ISO/IEC Guide 25. The management of the facilities now includes more than 'just' energy and efficiency calibrations of spectrometers. Employees have defined managerial tasks, responsibilities and powers for the gamma-ray spectrometers, sample changers, spectrometer performance control, element calibration and for the LAN.

#### ***Equipment management***

The Reactor Operations group manages the irradiation facilities. The INAA staff inspects the neutron spectrum in the facilities after reactor core modifications via analysis of the Zr-Au triple nuclide monitor, and calculation of the  $f$  and  $\alpha$  values. If the new values

differ more than 10 % of the values at the time of element calibration, the element calibration parameters are adjusted.

The gamma-ray spectrometers are subject to a spectrometer performance control<sup>24</sup> at least once a week. To this end, an automatic routine is prompted during the early Monday morning hours. The routine consists of measurement of the calibration sources and non-irradiated blank capsules in the sample changers. The measurements are completed at the start of office hours. The performance control of all spectrometers can be completed within a few hours, unless the quantified criteria for the peak shape, peak tailings, and energy vs. channel number or for electronic shifts are not met.

### ***Calibrations***

The <sup>152</sup>Eu/<sup>22</sup>Na sources are used for the energy calibration of the spectrometers. The photopeak efficiency curves are determined by fitting the experimentally determined gamma ray intensity ratios of a <sup>82</sup>Br-source to the intensity ratios derived from the decay scheme of this radionuclide<sup>26</sup>.

The single comparator method requires the experimental determination of element calibration parameters. Moreover, well-type Ge spectrometry requires experimental determination of intensity ratios of all peaks since tabulated ratios cannot be used due to coincidence effects. The element calibrations are done with working standards derived from primary or secondary standards. In a calibration procedure, a working standard is measured on each of the detectors, and the calibration parameters and intensity ratios are so matched that the standard deviation of all measurements is less than 2.5 %. The quality of the calibration parameters is verified via the analysis of reference materials and through intercomparisons.

### ***Automated quality control***

The results from the analysis of reference materials and other internal quality control samples are saved in a database. Upon analysis, the software automatically determines the

weighted 'z' score of the experimental data, according to 
$$z = \frac{C_x - C_r}{\sqrt{S_x^2 + S_r^2}}$$

with  $C_{x,r}$  and  $S_{x,r}$  the concentrations and uncertainties of internal control sample as measured and as available from certificates, respectively. The software automatically identifies in the report the results for which  $|z| > 2$  or if  $|z| > 3$ . In the latter case, the results are not accepted and a corrective action might be needed. This automated quality control applies also to the results of the analysis of the flux monitors. Here, a polynomial fit is applied through the neutron fluxes determined in each stacked column of capsules. The z score is then derived from comparison of calculated neutron flux with the values on basis of the fitting.

The database contains analysis results on more than 60 reference materials, compiled since 1992. Control charts can be generated from this database by selecting the entity to be displayed, the X-axis variable and its order of sorting and the Y-axis variable (Table 2)<sup>23</sup>. These control charts are only used for visually inspection and not for statistical evaluation.

### ***Quality Assurance***

Some of the characteristic quality assurance aspects in the quality system of the laboratory for INAA are<sup>8-11</sup>

- Full documentation of all parts of the INAA procedures via standard operating procedures

- Database of previously analyzed materials, results, detection limits and experimental conditions
- Quantified criteria for decisions
- Requirement of training and qualifications for the various parts of the INAA procedure
- Full trackability of all operations via extensive registration of pre-defined operational variables, environmental conditions and non-conformances
- Independent, quadruple control of the analysis results : automated inspection by the software, first line control by the analyst, double check by assigned employees not involved in the analysis, and final check by head of the laboratory
- Internal audits and non-conformance evaluation
- Customer satisfaction evaluation.

### Access to the INAA facilities

The capacity of the INAA facilities has been estimated in the order of 15,000 samples per year for full multi-element determinations. A qualified user is capable to process approximately 1,000 – 1,200 samples per year. In the fast rabbit systems even more samples can be handled, particularly when only one element has to be determined, e.g. Se via  $^{77m}\text{Se}$ .

The facilities are used for scientific research programs of the Department of Radiochemistry and to support governmental bodies, technological institutions, industry, etc. Also guest scientists from other countries have been using the facilities for their own or for collaborative research projects. 15-20 qualified persons (technicians, students and academic staff) currently use the INAA facilities, processing approximately 4,000 samples per year, and analyzing approximately 50,000 gamma-ray spectra.

The facilities are accessible to scientists of other institutions and countries who wish to perform the analyses at IRI on their own or in collaboration with the Nuclear Analytical Methods group.

### Final Remarks

A design has been made for a poolside irradiation end for CAFIA. This carbon-carbon composite irradiation end will be installed in one of the Be-reflector elements. The thermal neutron flux will be in the order of  $2 \cdot 10^{17} \text{ m}^{-2}\text{s}^{-1}$ , which is a factor of almost 10 higher than in the current situation. The design in principle will allow for placement of this facility in a future 'neutron flux trap' in the center of the reactor core.

By 2000, an external neutron beam-line will be available for analytical studies. Prompt-gamma INAA will be one of the applications. A feasibility study on large sample prompt gamma INAA is currently on its way.

The old Ge(Li) detectors will, at the end of their lifetime, be replaced by large volume (e.g. 100 %) Ge detectors. It is expected that new amplifiers based on digital signal processing will contribute to a higher stability of the spectrometers and less effort for maintenance and trouble shooting.

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*Table 1. Counting facilities for intermediate and long-lived radionuclides in INAA*

<b>Detector</b>	<b>Size</b>	<b>Resolution (1332 keV <sup>60</sup>Co), p/C ratio respectively</b>		<b>Sample changer capacity</b>
Coaxial Ge(Li)	17 %	1.84	50:1	64
Coaxial Ge	18 %	1.77	50:1	100
Coaxial Ge(Li)	25 %		57:1	64
Coaxial Ge(Li)	17 %	1.77	47:1	Stand alone
Coaxial Ge(Li)	35 %		65:1	Stand alone
Coaxial Ge	97 %	1.82	97:1	Large sample scanning spectrometer
Well-type Ge(Li)	125 cm <sup>3</sup> , 12 mm well	2.30	27:1	64
Well-type Ge	125 cm <sup>3</sup> , 18 mm well	2.10	35:1	100
Well-type Ge	125 cm <sup>3</sup> , 18 mm well	2.08	35:1	200

Table 2. Overview of control charts for evaluation of quality control sample data.

Y-axis	X-axis	Selectable parameter	Sorting function for selectable parameter
Concentration	Measurement sequence number	Reference material and element	a. Concentration b. Date c. Sample code
Concentration	Type of reference material	1. Element 2. Spectral interference	a. Concentration b. Concentration ratio with interfering element c. Standardised difference
Normalised concentration	All elements	1. Reference material 2. Measurement	a. Atomic number b. Relative uncertainty c. Standardised difference

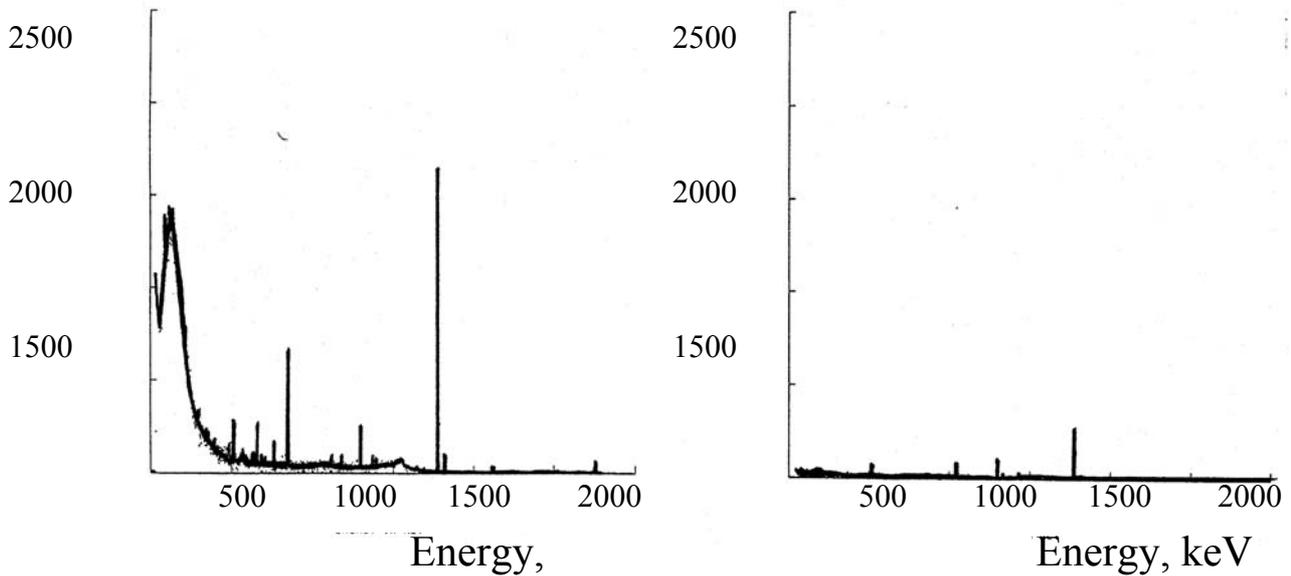


Figure 1. Gamma-ray spectra of the induced radioactivity of a polyethylene rabbit after irradiation and contamination during transfer in (left) the old fast rabbit system and in (right) CAFIA.

**ANNEX IV. DRAFT QUESTIONNAIRE FOR SHORT-LIVED NAA AT RR**

<b>Name, address, phone, e-mail, and www link of the responsible/contact person/facility</b>		
<b>No</b>	<b>Question</b>	<b>Reply/Comments</b>
1	Does your RR have a pneumatic facility for short-lived NAA? (If “No” please skip the rest of the questions.)	
2	Does the pneumatic facility have a) an epithermal irradiation-end, b) a thermal irradiation-end?	a) ... b) ...
3	What is the transfer time from irradiation-end to receiving-end? (in seconds)	
4	Do you count the samples still in the rabbit? If no, why? Do you unpack the rabbit?	
5	What is the shortest time you can start counting after irradiation? (in seconds)	
6	How do you measure irradiation start and stop times?	
7	In what respects is your system automated and how?	
8	Is your system fit for cyclic activation analysis? If yes, can you give an example of such an approach (e.g. no. of cycles, irradiation-decay-count time, etc.)?	
9	What data acquisition software(s) is being used?	
10	How do you correct for dead time?	
11	What kind of detector geometry do you apply: horizontal or vertical dipstick	
12	What are your typical sample-detector distances?	
13	Describe and provide a picture of your irradiation container and pneumatic facility.	
14	How many samples a year are analyzed using your pneumatic facility?	
15	Which measures have been taken to reduce the <sup>41</sup> Ar background?	
16	What type of health physics monitoring is done at your pneumatic facility? a) Dosimeters on the user b) Finger/wrist badges on the user c) Dedicated monitor at the retrieval end of the irradiation site	a) ... b) ... c) ...
17	Do you generate any revenues through the services provided by your NAA facility?	

**ANNEX V. AGENDA**

**Wednesday, 2 December 2009**

08:30-09:00	<b>Registration, Gate 1</b>
09:00-09:30	<p><b>Welcome &amp; Opening Remarks</b></p> <p><i>Mr P. Adelfang (Head Research Reactor Group, NEFW)</i></p> <p><i>Mr D. Ridikas (IAEA Scientific Secretary, Physics Section, NAPC)</i></p> <p>Self introduction of the participants, Election of Chairperson and <i>Rapporteur</i></p> <p>Discussion and Approval of the Agenda, Administrative Arrangements</p>
09:30-10:00	<p><b>Mr Danas Ridikas, IAEA</b></p> <p>Objectives of the Meeting (within the IAEA project Enhancement of Utilization and Applications of Research Reactors)</p>
10:00-10:50	<p><b>Mr Peter Bode, Delft University of Technology, The Netherlands</b></p> <p><i>Tentative title: The level of automation in comparable analysis techniques; case of automated NAA facility at Delft</i></p>
10:50-11:20	Coffee break
11:20-12:10	<p><b>Mr Sheldon Landsberger, University of Texas, USA</b></p> <p><i>Tentative title: Automatic pneumatic system of NAA for short-lived isotopes</i></p>
12:10-13:00	<p><b>Mr John Bennett, ANSTO, Australia</b></p> <p><i>Tentative title: Design and installation of the automated NAA facility at ANSTO</i></p>
13:00-14:00	Lunch break
14:00-14:50	<p><b>Mr Moussa BOUNAKHLA, CNESTEN, Morocco</b></p> <p><i>Tentative title: Status of automated NAA facility at CNESTEN</i></p>
14:50-15:40	<p><b>Mr Eduardo Haroldo Montoya Rossi, IPEN, Peru</b></p> <p><i>Tentative title: Status of automated NAA facility at IPEN</i></p>
15:40-16:10	Coffee break
16:10-17:00	<p><b>Mr Menno Blaauw, Delft University of Technology, The Netherlands</b></p> <p><i>Tentative title: Current version of the k0-IAEA software and its tutorial</i></p>

**Thursday, 3 December 2009**

09:00-12:30	<b>All; discussion on</b> <ul style="list-style-type: none"><li>• Advanced automation procedures in leading NAA laboratories</li></ul>
12:30-14:00	Lunch break
14:00-15:30	<b>All; discussion on</b> <ul style="list-style-type: none"><li>• Needs and opportunities to increase the measurement capacity in less advanced NAA laboratories</li></ul>
15:30-16:00	Coffee break
16:00-17:30	<b>All</b> <ul style="list-style-type: none"><li>• Drafting of the guidelines, including potential solutions and investments needed, in order to establish fully automated advanced NAA laboratory</li></ul>
18:30	Hospitality event

**Friday, 4 December 2009**

09:00-12:30	<b>All (continued)</b> <ul style="list-style-type: none"><li>• Drafting of the guidelines, including potential solutions and investments needed, in order to establish fully automated advanced NAA laboratory</li></ul>
12:30-14:00	Lunch break
14:00-15:30	<b>All</b> <ul style="list-style-type: none"><li>• Formulation of conclusions and recommendations</li><li>• Drafting of the meeting report</li></ul>
15:30-16:00	Coffee break
16:00-17:00	<b>All</b> <ul style="list-style-type: none"><li>• Finalizing meeting report</li><li>• Closing of the meeting</li></ul>
17:00	End of the meeting

## ANNEX VI. LIST OF PARTICIPANTS

**Consultancy Meeting on Preparation of Guidelines on Implementation of Routine  
Automation in Advanced Neutron Activation Analysis Laboratories**

**2-4 December 2009, IAEA, Vienna, Austria**

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