ORNL/SUB/97-XSV750-1

OAK RIDGE
NATIONAL LABORATORY

MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ARIANE International Programme Final Report

Fissile Materials Disposition Program

UT-BATTELLE

ORNL-27 (4-00)

DOCUMENT AVAILABILITY

Reports produced after January 1, 1996, are generally available free via the U.S. Department of Energy (DOE) Information Bridge.

Web site http://www.osti.gov/bridge

Reports produced before January 1, 1996, may be purchased by members of the public from the following source.

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone 703-605-6000 (1-800-553-6847)
TDD 703-487-4639
Fax 703-605-6900
E-mail info@ntis.fedworld.gov
Web site http://www.ntis.gov/support/ordernowabout.htm

Reports are available to DOE employees, DOE contractors, Energy Technology Data Exchange (ETDE) representatives, and International Nuclear Information System (INIS) representatives from the following source.

Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831
Telephone 865-576-8401
Fax 865-576-5728
E-mail reports@adonis.osti.gov
Web site http://www.osti.gov/contact.html

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/SUB/97-XSV750-1

ARIANE INTERNATIONAL PROGRAMME
FINAL REPORT

Coordinated in the United States by R. T. Primm III

Date Published—April 9, 2002
Date Issued—May 1, 2003

Report prepared by
UT-BATTELLE, LLC
Oak Ridge, Tennessee 37831
under
Subcontract XSV750

Funded by
Office of Fissile Materials Disposition
United States Department of Energy

Prepared for
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

CONTENTS

FOREWORD

Section 1. ARIANE TECHNICAL PROPOSAL

Section 2. PROGRAMME STATUS

Section 3. IRRADIATION DATA REPORT—PART 1

Section 4. IRRADIATION DATA REPORT—PART 2

Section 5. IRRADIATION DATA REPORT—PART 3

Section 6. REASSESSMENT OF THE IDENTITY OF RODS IRRADIATED IN ASSEMBLY M109 AND USED IN THE FRAMEWORK OF THE PROGRAMMES M109, ARIANE AND FIGARO

Section 7. SIMS ANALYSIS OF THREE IRRADIATED FUEL SPECIMENS

Section 8. FINAL REPORT

FOREWORD

The participation of Oak Ridge National Laboratory staff in the ARIANE (Actinide Research in a Nuclear Element) Program was sponsored by the Fissile Materials Disposition Program, Office of Fissile Materials Disposition, National Nuclear Security Agency, United States Department of Energy. This report is a reproduction of the final ARIANE Program documentation as it was provided by the staff of Belgonucleaire. Not one word has been altered from the original documentation.

This report is a collection of eight documents, the sum of which constitute a complete set of documentation of the ARIANE destructive assay program. Computational modeling of the irradiation conditions and the comparison of calculated to measured inventories are reported elsewhere.*

The first section of this report, a technical proposal prepared by the staff of Belgonucleaire in 1996, is included to provide the reader with a brief overview of the entire program. ARIANE included a large number of measurements, and the quantity of data contained in the three irradiation report sections can easily become overwhelming to the reader.

The second section is a presentation provided by Belgonucleaire staff at the final meeting of the ARIANE Program participants. It is included for several reasons. Significant changes in the scope of the program occurred between inception and conclusion. The reasons for these changes were varied—some due to errors in procedure, others due to analysis costs being greater than expected. This section is not intended to be used for criticism against any of the program participants. Rather it provides a summary of the work accomplished (rather that work planned) and is intended also to serve an educational purpose because there are few opportunities for young engineers to participate in experimental programs.

The third, fourth, and fifth sections constitute what was originally intended by the program staff at Belgonucleaire to be a single report (the Irradiation Data Report). The reader is cautioned that some portions of the fourth report supercede the third and likewise some portions of the fifth supercede the preceding two sections.

The third section (Part 1 of Irradiation Data Report) contains inventories, power, and burnup histories for samples from the Dodewaard and Beznau reactors. Dodewaard boiling-water reactor (BWR) samples DU1, DM1, DM2, DM3, and DM4 are described. This section provides the final information on these Dodewaard samples. It contains descriptions of the assembly, the core, and the rods. Burnup and power data are reported as being for the sample (rather than for the assembly). This is noteworthy because the sample rods are quite different from the surrounding rods in the assembly. The power history includes information on void fraction and rod temperature.

In Sect. 3, for the Beznau pressurized-water reactor (PWR), samples from assembly M109 are described; the samples are BM1, BM2D, BM3, and BM4D. The original program management plan called for BM1 and BM2D to be extracted from rod E11 and BM3 and BM4D to be extracted from rod G5. Section 6 presents a study in which Belgonucleaire staff (and subsequently the ARIANE Program Committee) showed that the program plan had not been followed and that BM1 and BM2D came from rod D3 and BM3 and BM4D came from rod B6. Fuel characteristics for both sets of rods are given in this report. Power histories for both sets of rods are also given.

Section 5 is the final portion of the Irradiation Data Report. This report introduces new samples from Beznau and from Gosgen. These new samples were introduced because of the

*B. D. Murphy and R. T. Primm III, "Prediction of Spent MOX and LEU Fuel Composition and Comparison with Measurements," *Proceedings of ANS International Topical Meeting on Advances in Reactor Physics and Mathematics and Computation in the Next Millennium, PHYSOR 2000, Pittsburg, Pennsylvania., May 7–12, 2000.*

Beznau "cask rotation" problem (described in Sect. 6) and because of analytical chemistry problems in the analyses of Gosgen samples GU1 and GU2. Section 6 provides power history data for BM5 and BM6 mixed-oxide (MOX) samples and for GU3 and GU4 low-enriched uranium (LEU) samples. Fuel characteristics are also given as well as descriptions of the assemblies and the rods. For BM5 and BM6, core burnup, assembly burnup, and sample burnup are reported. BM5 and BM6 were from the M308 assembly. GU3 and GU4 are from fuel assembly 1601 and later were transferred to assembly 1701 in Gosgen. These samples were substituted following inadequate analysis results from samples GU1 and GU2.

Section 5 provides linear power and burnup histories at the actual axial levels of the PWR samples. This is for the Beznau and Gosgen samples only. The reported values are the burnup and fuel-rod linear power at the axial height of the samples and averaged over all rods in the assembly. For Beznau, and for assembly M109, data are reported for BM1 and BM2D from rod D3 and for samples BM3 and BM4D from rod B6. Data are also reported for samples BM5 and BM6 from rod K7 in assembly M308. For the Gosgen reactor, data are reported for sample GU1 from rod 14H13 in assembly 12-40 and for GU3 and GU4 from rod 16B05. Rod 16B05 was in assembly 1601 during cycles 16 and 17 and in assembly 1701 for cycle 18.

During the ARIANE Program, a series of fuel pellet, radial profile, nuclide inventory measurements were made using a technique called secondary ion mass spectrometry (SIMS). These measurements are described in Sect. 7.

Section 8 contains the results of all the analytical chemistry measurements for all of the fuel samples. In addition to reporting the results from the analytical chemistry laboratories, recommended values of inventories (in those cases where there was significant disagreement among laboratories) are provided.

The editors note that each analytical laboratory produced a technical report of its measurements. These laboratories regarded those reports as containing proprietary analytical chemistry procedure data and requested that these reports not be released outside of ARIANE Program Committee members. The editors note that the final results of all analyses are included in Sect. 8.

In summary, there are data for DU1, DM1, DM2, DM3, and DM4 BWR samples. With regard to PWR MOX samples, there are data for BM1, BM5, and BM6. BM1 was involved in the cask rotation occurrence (Sect. 6). BM5 and BM6 were not. However, the ARIANE Program Committee judged that BM1 is reliably described, and it is also a sample for which we have SIMS data. With regard to PWR LEU samples, data exist for samples GU3 and GU4, and some SCK/CEN data for GU1 are of good quality.

The ARIANE Program was funded through a consortium of private entities. To avoid any potential legal concerns about the use of the data, the following contractual notices concerning release of the data are reprinted here (brackets, [ ], denote comments added by editors).

> From the "Agreement between Belgonucleaire and Oak Ridge National Laboratory concerning 'Collaboration on a Joint International Experimental Programme on the Evaluation and Accuracy of the UO_2 and MOX Source Term," Article 6.7, signed by ORNL representative on June 6, 1996 and by Belgonucleaire representatives on August 8, 1996—"Twenty-four (24) months after the Programme Completion, the Participants and Represented Parties shall be free to use without restriction the technical data included in the Programme Information."

> From correspondence from D. Boulanger, Belgonucleaire, February, 2001, "On behalf of Marc Lippens … , I am pleased to answer your questions, as follows:

—the existing Irradiation Report issued in two parts (AR 96/05 Rev B of March 1999 and AR 99/13 of July 1999) have not been further reviewed and will not be reissued. The third part is being finalized at the moment [included in this document]. It contains the additional information on the assembly average power at the sample axial level, as requested by the ARIANE participants. This third part will be issued in the coming days, together with the Minutes of the last PCM and the CD containing the ARIANE Final Report (full WORD files as well as EXCEL Files for the key data) [EXCEL files included on CD included with this report].

—the laboratory reports (indeed with permanent confidentiality) will be sent as soon as we receive the final issue of SCK-CEN's report. This report should reach us in February and will be released directly [laboratory reports are proprietary and are retained by the editors]. We would thus suggest starting the 2-year period on March 31, 2001, i.e., once every Participant has the whole set of reports in his hands."

ARIANE

Technical proposal

**An experimental programme
to improve the evaluation and the prediction
of actinides and fission products
in MOX and in UO_2 spent fuel elements**

Revision March 1996

BELGONUCLEAIRE
4, Avenue Ariane
B.1200 Brussels
Belgium

Phone : 32-2-774 05 11 FAX : 32-2-774 05 47

ARIANE Programme

(Actinides Research In A Nuclear Element)

1. Introduction

1.1. The prediction of the source term of actinides, fission and activation products are of major importance in numerous nuclear fields, such as :

- the knowledge of the fuel isotopic composition at various steps of the irradiation cycles and at the end of life for the definition of basic licensing data for UO2 and for MOX fuel;
- the current increase of fuel enrichment for power reactors with a possible reevaluation of criticality licenses for transportation, storage and reprocessing of spent fuel based on burnup credit;
- the fundamental research programmes for actinides;
- the necessity to improve the calibration of recent source term codes for high burnup conditions and for MOX fuel recycling scenarios.

1.2 With respect to the remaining uncertainties in the prediction of some significant isotopes, BELGONUCLEAIRE is proposing to carryout an experimental programme on fuels irradiated in LWR's.
This programme called ARIANE (Actinides Research In A Nuclear Element) has the goal to reduce uncertainties and to improve the knowledge of the inventories of actinides and fission products of major interest.

2. Preliminary Structure of the ARIANE Programme

2.1. Accurate radiochemical post-irradiation examination of irradiated MOX and UO_2 fuel samples having reached significant peak pellet burnups in PWR's and BWR's operating conditions.

A sufficient number of samples will be prepared and analyzed in order to cover a large spectrum of burnup data and isotopic compositions and aliquots of some of the same samples will be submitted to investigations in three laboratories.

2.2. The various tasks of this PIE programme will include :

- The extraction of irradiated fuel rods from LWR assemblies.
- The conditioning and the transportation of the rods and samples to appropriate laboratories.
- The detailed PIE analysis of the selected samples, including :
  - burnup analysis (by Nd isotopes).
  - complete uranium vector determination.
  - complete plutonium vector determination.
  - minor actinides (Am and Cm isotopes and Np237) determination.
  - a selection of measurable fission products determination.
- The preparation of experimental reports including the results and the accuracy of the measurements
- The neutronic characterization of the selected irradiated fuel rods and samples, including.
  - The detailed power history of the fuel rods samples.
  - Description of the geometrical model of a macrocell representing the environment in which the rod of interest was irradiated. This model should allow to generate accurate cross sections for source term codes.

The publication of the final report in which the complete experimental data will be available as a reference for any source term code calibration.

3. Proposed scope

3.1. Extraction of 2 MOX rods from Beznau-1 and shipment to PSI
Extraction of 2 UO_2 rods irradiated in GÖSGEN and shipment to TUI
Cutting and preparation of 6 samples (4 MOX and 2 UO_2 samples).
Radio chemical analyses of the 6 samples.
Preparation of aliquots of 3 samples to be send and analysed in two other labs.

3.2. Selection of 2 MOX segments from Dodewaard.
Selection of 1 UO_2 segment from Dodewaard.
Cutting and preparation of 2 MOX samples.
Cutting and preparation of 1 UO_2 sample.
Radio chemical analyses of the 3 samples.
Preparation of aliquots of one MOX and one UO_2 sample and same analyses in two other labs.

3.3. Scope extension to be discussed between the participants

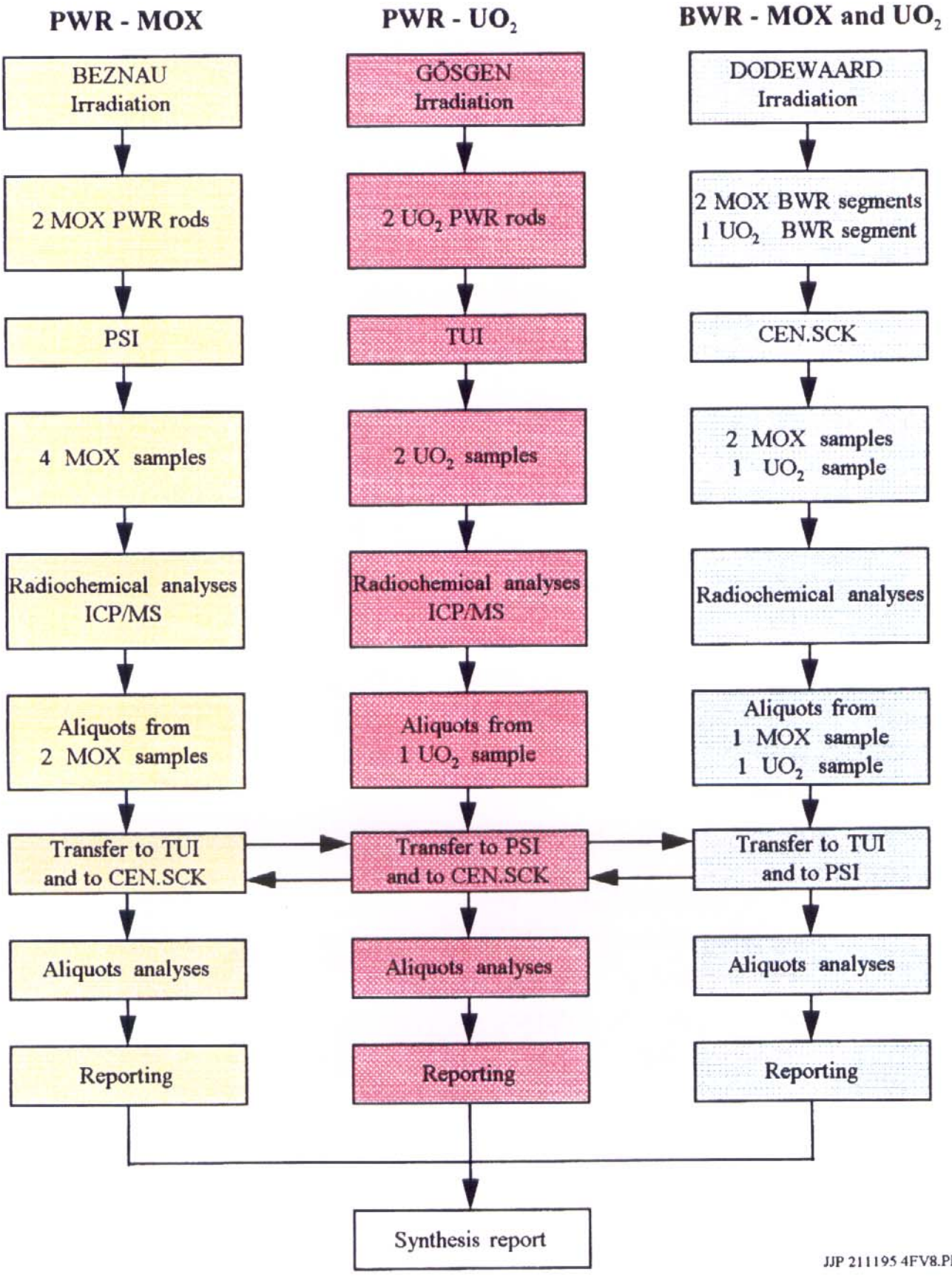
3.4. Support.

- Characterization of the selected fuels.
- Theoretical support.
- Transportation from lab to lab.
- Final waste disposal.
- Technical meetings.
- Administration and contractual matters.
- Project management.

ARIANE

Table 1

Experimental programme

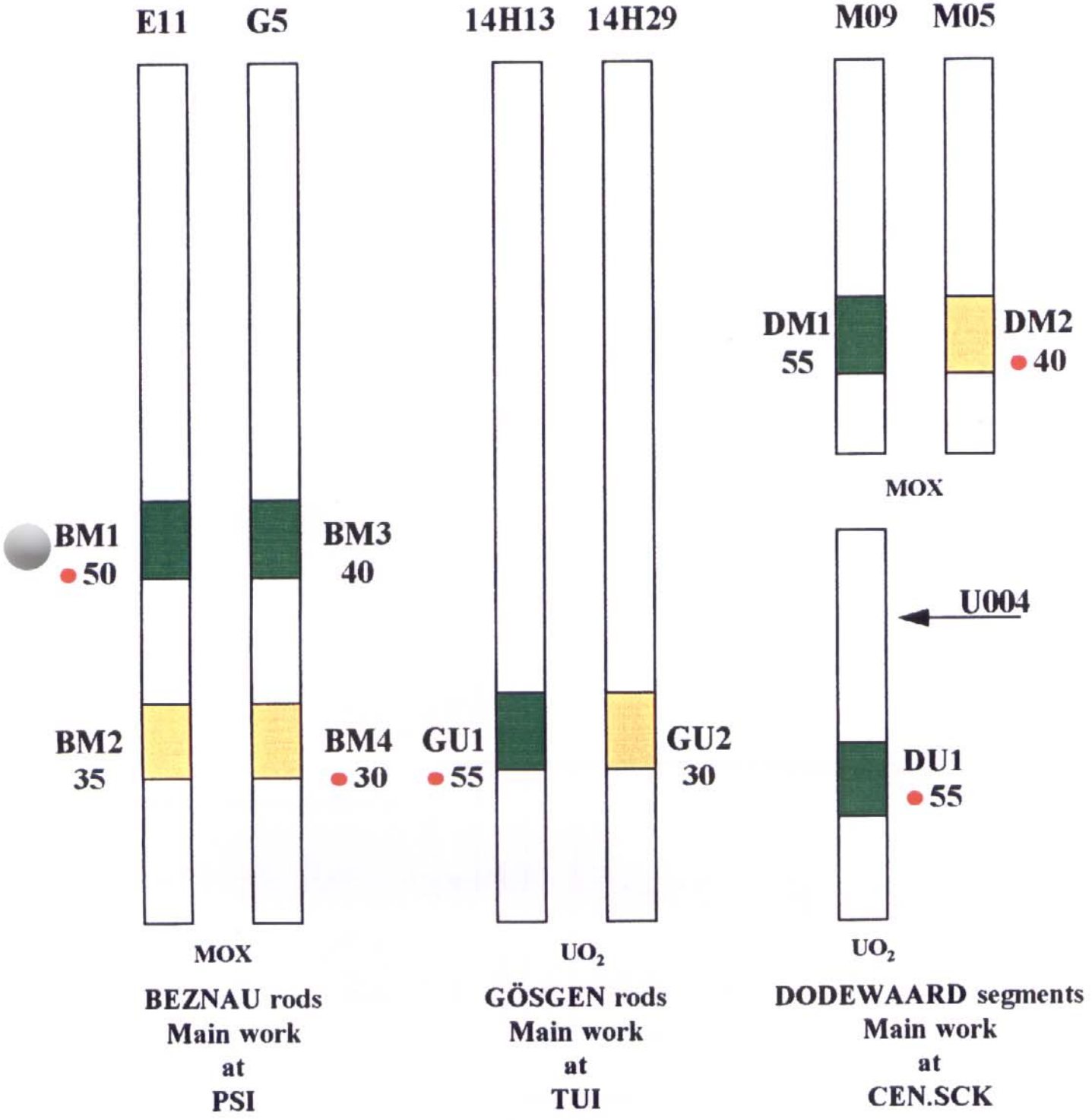


Major tasks or items to be covered by the programme

- Fuel procurement : irradiation, extraction, shipments, handling, reception...wastes.
- Programme implementation
  Pre-organization -Technical proposal
- Post irradiation analyses - improvement and validation of techniques
- Theoretical support
- Technical follow up and technical reporting
- Contractual arrangements
- Programme management
  - Coordination
  - Organization of PCM
  - Reporting
  - Budget and finance
  - Planning
  - Interfaces with participants and subcontractors.

ARIANE sampling

Table 3



submitted to experimental *cross-check*

presently proposed for TOP 15 FP isotopes determinatio

ARIANE
tentative test matrix

GROUP	BM				DM		DU	GU	
Irradiation	BEZNAU 1 - PWR				DODEWAARD - BWR			GÖSGEN - PWR	
Fuel type Fuel fabrication Fuel characteristics : (*) U 235 (W/O) Pu / U + Pu (W/O) Fuel density (%TD)	MOX - MIMAS BN 0.2 5.9 95				MOX - MIMAS BN 0.2 6.4 94		UO_2 JNF 4.9 - 95	UO_2 SIEMENS 3.4 - 10.4	
Assembly of rigin	M 109				Y 014	Y 012	Y 013		
Fuel rod identification	E 11		G 5		M 09	M 05	U 004	14H13	14H29
Sample identification Sample burnup (GWd/tM)	BM1 50	BM2 35	BM3 40	BM4 30	DM1 55	DM2 40	DU1 55	GU1 55	GU2 30
Sample preparation Transport to	PSI TUI CEN	PSI - -	PSI TUI CEN	PSI -	CEN TUI PSI	CEN -	CEN TUI PSI	TUI CEN PSI	TUI - -

Table 4

PIE Scope of Work

- The experimental programme is focused on the use of techniques from wich best accuracies can be expected.

- Radiochemical Analyses on 9 samples
  - Conventional burn up analyses (Nd isotopes)
  - U and Pu isotopic vectors
  - Am and Cm isotopic vectors
  - Np237
  - Cs133, Cs134, Cs135, Cs137
  - I129, Tc99
  - Eu 153, Eu 154, Eu 155
  - Sm147, Sm149, Sm150, Sm151, Sm152
  - Ce144

  development of new chemical separation processes

- New : Other significant fission products on some of the samples

- Recent investigation technique will be proposed by some of the laboratories (PSI, ITU)

  ICP/MS
  (Inductively Coupled Plasma Torch/Mass Spectrometry)
  for very low nuclides concentrations of minor actinides.

ARIANE
experimental work schedule

(Status November, 1995)

	Expected periods and status			
	SCK.CEN	P.S.I.	T.U.I	
Milestones / Fuel type	BWR MOX and UO_2	PWR MOX	PWR UO_2	Aliquots
1. Preparation	(1)	(2)	(3)	(4)
- Reception of the fuel rods	Completed	Completed	Completed	-
- Gamma scan	Completed	Completed	Completed	-
- Samples cutting	Completed	Nov. 95	Completed	-
- Samples preparation	Nov. 95	Dec. 95	Completed	-
- Aliquots ready for shipment (*)	Mar. 96	April 96	Completed	-
- Shipments of aliquots (*)	April 96	April 96	April 96	-
2. Fuel samples analysis				
- B.U. analysis, U + Pu vector	End April 96	April 96	Completed	-
- Minor actinides, fission products	End June 96	April 96	End of 95	-
- Draft report	Sept. 96	May 96	Early 96	-
3. Aliquots analysis (*)				
- Aliquots receptions	End April 96	End April 96		End April 96
- B.U. analysis, U + Pu vector	End May 96	June 96	-	May 96
- Minor actinides, fission products	End June 96	Aug. 96		June 96
- Draft report	Sept. 96	Sept. 96	-	Sept. 96
4. Experimental reports (*)	Sept. 96	Sept. 96	Sept. 96	Sept. 96
5. ARIANE final report	End of 96	End of 96	End of 96	End of 96

(*) Planning under re-evaluation for these items

ARIANE Status (Mar. 96)

Participations

Have confirmed their participation :

- TRACTEBEL (ELECTRABEL) : Belgium
- CEN.SCK : Belgium
- BELGONUCLEAIRE : Belgium
- NOK : Switzerland
- GKN : Netherlands
- TOSHIBA (BWR Jap. utilities) : Japan
- HITACHI (BWR Jap. utilities) : Japan
- JRI : Japan
- GNB : Germany
- SIEMENS : Germany
- PSI : Switzerland
- MITSUBISHI (NFI, PWR Jap utilities) : Japan
- NEL : Japan
- ORNL : USA
- BNFL : U.K.

ARIANE HIGHLIGHTS

This new proposal is the consequence of :

1. Pending questions regarding the source term accuracies

2. The feedback and comments from various organizations showing interest :

   - In the field of source term.
   - In the field of actinides.
   - In high burnup fuel characterization.
   - In MOX licensing.
   - In theoretical predictions.
   - In ORIGEN-2 code type improvements.
   - In improving their MOX data base.
   - In appropriate measurement techniques.

3. A tradition at BELGONUCLEAIRE to promote and to coordinate R & D activities in the fuel branch and specially in the MOX fuel branch at the international level.

4. The result of the meetings organized in Brussels on June 22, 1993 and on September 29, 1994.

Basic Issue

- Range of accuracies to be applied to the predictions of the "source term" for irradiated MOX fuel ?

(• For high burnup irradiated UO_2 fuel)

"Source term"

- Significant actinides
- Significant minor actinides
- Significant fission products

For :

- MOX fuel irradiated at various burnup levels and under various operating conditions.

(• high burnup irradiated UO_2 fuel)

Burn up :

- Peak pellet values ranges

from 30 to 50 GWd/t (PWR type)
and 40 to 55 GWd/t (BWR type)

General issues

To provide theoretical and experimental support to :

- MOX fuel source term for licensing.
- Source term for the review of criticality licences with respect to burn up credit.
- Source term in relation with extended burn up policy.
- Source term computer codes calibration and improvement.
- Actinides research programmes.
- Neutronic computer codes calibration and improvement.
- MOX fuel source term in relation with actinide recycling in fast or thermal reactors.
- Safeguards issues.

Experimental way

- Selection of different MOX and UO_2 irradiated samples under LWR's. operating conditions (BEZNAU-1, DODEWAARD, GÖSGEN)
- Experimental analyses of the selected samples for selected significants isotopes
- Reporting

Theoretical way

- Adaptation of neutronic and source term codes to fit in with experimental investigation.
- Production of characterization data, modelizations, irradiation and power histories, neutronic data required for supporting a theoretical follow up.
- Reporting

Programme Status

Programme Status

1. Programme scope
2. Work progress
3. Reporting
4. Budget
5. Programme completion

0005241/221 - "-" - A2.2

1. Programme Scope

1.1 Programme initial scope (1st PCM - Dec. 95)

- Samples
  - MOX PWR : BM1, BM2, BM3, BM4
  - MOX and UO_2 BWR : DM1, DM2,DU1
  - UO_2 PWR : GU1, GU2
- Isotopes
  - Base
  - TOP 15 (10)
- Laboratories
  - SCK.CEN, PSI, ITU
  - Mother laboratory, cross-check (liquid aliquots)
- Test matrix
  - All samples : Base in mother lab.
  - BM1, BM3, DM1, DU1, GU1 : Base in cross-check
  - BM1, BM4, DM2, DU1, GU1, (+GU2) : TOP 15 in mother lab.

0005241/221 - "-" - A2.3

1. Programme Scope

1.2 Programme extension (2d PCM - May 96 / 3rd PCM - Dec. 96)

- Samples
  - MOX BWR : DM3, DM4
- Isotopes
  - TOP 15 (10) → TOP 25
- SIMS
  - Radial distribution of isotopes
- Test matrix
  - DM3 + DM4 : Base in mother lab.
  - BM1, (BM3/ITU), DM1, DU1, GU1 : TOP 25 in cross-check
  - BM1, BM4, DM2, DU1, GU1 : TOP 15 (10) → TOP 25 in mother lab.
    (+GU2) : TOP 25 in mother lab.
  - BM1, BM3, BM4-D : SIMS

0005241/221 - "L" - A2.4

1. Programme Scope

Base Programme

- **Base actinides**

  ^{234}U, ^{235}U, ^{236}U, ^{238}U

  ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu

- **Minor actinides**

  ^{237}Np

  ^{241}Am, ^{242m}Am, ^{243}Am

  ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm

- **Fision products**

Volatiles :	^{129}I, ^{133}Cs, ^{134}Cs, ^{135}Cs, ^{137}Cs
Metallics :	^{99}Tc
Lanthanides :	^{144}Ce
	^{142}Nd, ^{143}Nd, ^{144}Nd, ^{145}Nd, ^{146}Nd, ^{148}Nd, ^{150}Nd, ^{147}Sm, ^{149}Sm, ^{150}Sm, ^{151}Sm, ^{152}Sm, ^{153}Eu, ^{154}Eu, ^{155}Eu

0005241/221 - "-" - A2.5

1. Programme Scope

TOP25 Programme

- **Base actinides**
  ^{232}U

- **Fision products**
  Metallics : ^{90}Sr, ^{95}Mo, ^{101}Ru, ^{106}Ru, ^{103}Rh, ^{109}Ag, ^{125}Sb
  Lanthanides : ^{147}Pm, ^{155}Gd

0005241/221 - "-" - A2.6

1. Programme Scope

SIMS Programme	
✓ **BASE ACTINIDES**	^{235}U and $^{238}U/^{238}Pu$ Vector Pu (^{239}Pu-^{240}Pu-$^{241}Pu/^{241}Am$ and ^{242}Pu) Pu content
✓ **FISSION PRODUCTS**	• **Lanthanides** Vector Nd (^{143}Nd - $^{144}Nd/^{144}Ce/^{145}Nd$ - $^{146}Nd/^{146}Sm$ - $^{148}Nd/^{148}Sm$ - $^{150}Nd/^{150}Sm$) • **Volatiles** Vector Cs (^{133}Cs - ^{134}Cs - ^{135}Cs - ^{137}Cs) • **Others** ^{85}Rb - ^{87}Rb - ^{88}Sr - ^{97}Mo - ^{99}Tc - ^{138}Ba - ^{139}La- ^{140}Ce

0005241/221 - "." - A2.7

1. Programme Scope

Work matrix
(valid till May 1998)

Samples	BM1	BM2-D	BM3	BM4-D	GU1	GU2	DM1	DM2	DM3	DM4	DU1
PSI											
Prepare	x	x	x	x							
Base	x	x	x	x	x (ǂ)		x (ǂ)				x (ǂ)
TOP 25	x˙			x˙	x˙						x˙
SIMS	x˙		x˙	x˙							
ITU											
Prepare					x	x					
Base	x (ǂ)		x (ǂ)		x	x	x (ǂ)				x (ǂ)
TOP 25	x˙		x˙		x˙	x˙	x˙				x˙
SCK											
Prepare							x	x	x	x	x
Base	x (ǂ)		x (ǂ)		x (ǂ)		x	x	x˙	x˙	x
TOP 25	x˙				x˙			x˙			x˙

(ǂ) no iodine analysis
˙ extension

0005241/221 - "-" - A2.8

1. Programme Scope

1.3 First result providing (3rd PCM-Dec 96/4th PCM-Dec. 97)

- Anomalies in mass balance
- BMx results did not match expectations
- Inquiry to understand and improve situation

1.4 Assessment of result quality (5th PCM-May 98)

- SCK.CEN
  - measurements under control
  - work proceeding
  - ICP-MS needed for elements Mo, Tc, Rh, Ru, Ag
- PSI
  - sample handling
  - underestimation of U content
  - rod identification
- ITU
  - reliability of data processing

0005241/221 - "-" - A2.9

1. Programme Scope

→ need for programme scope reorientation

→ need for laboratory requalification

0005241/221 - "-" - A2.10

1. Programme Scope

1.5 Countermeasures and programme redefinition (5th PCM-May 98/6th PCM-June 99)

- Objectives
  - no significant scope modifications
  - no extra expenses for participants
  - minimise planning impact
  - guarantee of a quality work

0005241/221 - "-" - A2.11

1. Programme Scope

1.5 Countermeasures and programme redefinition (5th PCM-May 98/6th PCM-June 99)

- Actions
  - programme
    - saving what can be saved
      - all SCK.CEN results (GU1 renormalized, BM3 dropped)
      - PSI results BM3+BM4-D (U, Pu, Nd)
      - PSI samples DM1, DU1 (+BM1)
      - ITU isotopic compositions
    - new material (GU3, GU4; BM5, BM6)
    - reduced cross-check (solid aliquots) : SCK.CEN ←→ PSI/ITU
    - PSI new measurements on DM1, DU1 (+BM1 (+TOP25))

0005241/221 - "C" - A2.12

1. Programme Scope

1.5 Countermeasures and programme redefinition (5th PCM-May 98/6th PCM-June 99)

- Actions
  - laboratories
    - audit
    - requalification
    - new "mentality"
  - BN
    - audit/collaboration with labs
    - reassessment of rod identity
    - neutronic calculations
    - reporting
    - management issues

0005241/221 - "2" - A2.13

1. Programme Scope

Work matrix
(valid after May 1998)

Samples	BM1	BM3	BM4-D	BM5(')	BM6	GU1	GU3(')	GU4	DM1	DM2	DM3	DM4	DU1
PSI													
Prepare	x	x	x	x (5)	x								
Base	x*	x*	x*	x	x				x (ł)				x (ł)
TOP 25				x	x								x
SIMS	x	x	x										
ITU													
Prepare						x	x (3)	x					
Base							x	x					
TOP 25							x						
SCK.CEN													
Prepare				x (5')			x (3')		x	x	x	x	x
Base	x (ł)			x		x (ł)	x		x	x	x	x	x
TOP 25	x			x		x	x			x			x

(') analysis performed at PSI (BM5) or ITU (GU3), and SCK.CEN (BM5' and GU3')
(ł) no iodine analysis
(*) (U, Pu, Nd) only

0005241/221 - "-" - A2.14

2. Work Progress

- Laboratories
  - Qualification of ICP-MS at SCK.CEN
  - New procedures at PSI and ITU
  - Sample cutting/preparation/transportation
  - Measurement programme : completed

- BN
  - Follow up
  - Meeting in Japan
  - Experimental data reduction
  - Reporting
    - rod identity (note)
    - irradiation report (AR 99/13)
    - 5th PCM minutes (AR 99/14)
    - final report draft 1, 2 (AR 2000/15)
  - Management

0005241/221 - "-" - A2.15

3. Reporting

Issued	N° BN	Title
AR 93 / 01	-	Source term and Actinides Evaluation in Irradiated LWR MOX Fuel (Minutes of the seminar Jun. 22-23 1993)
AR 94 / 02	-	Technical Proposal (Feb. 95 + Rev. Mar 96 + Rev. Oct 97)
AR 94 / 03	9408883	Minutes of the Organizational Meeting (Brussels, Sep 29, 1994)
AR 95 / 03	9500951	Preliminary Irradiation data (Jan 95) ☝ AR 95 / 03 should be AR 95 / 04
AR 96 / 05	9606546	Irradiation Data Report (Basic programme) (Jul 96)
Rev. A	9702871	Irradiation Data Report (Basic programme) (Jul 97)
Rev. B	9809718	Irradiation Data Report - Part 1 (Basic programme) (Mar 99)
AR 96 / 06	9601735	Minutes of 1st PCM (Brussels, Dec 14-15, 1995)
AR 96 / 07	9606406	Minutes of 2 nd PCM (Brussels, May 2-3, 1996)
AR 97/ 08	9701004	Minutes of 3 rdt PCM (Brussels, Dec 12-13, 1996)
AR 98 / 09	9800142	Minutes of 4 th PCM (Brussels, Oct 30-31, 1997)
AR 98 / 10	9805434	Minutes of 5 th PCM (Brussels, May 11-12, 1998)
AR 99 / 11	9809717	Final Report up to December 1998 (Dec 98)
Rev. A	9902185	Final Report up to December 1998 (Mar 99)
AR 99 / 12	9902146	SIMS Analysis of three Irradiated Specimens (Mar 99)
AR 99 /13	9904537	Irradiation Data Report - Part 2
AR 99 / 14	9908087	Minutes of 6 th PCM (Brussels, June 22, 1999)
AR 2000/15	0000253	Final Report Draft 1,2
AR	-	Laboratory Report ITU - Draft
AR	-	Laboratory Report SCK.CEN
AR /	-	Laboratory Report PSI
AR /	-	Irradiation Data Report - Complement
AR /	-	Minutes of 7th PCM

issued after 6 th PCM

to be issued after 7 th PCM

0005241/221 - "-" - A2.16

4. Budget

Incomes and Participations (October 1997)	MBEF (March 94)	Voting Share
TOSHIBA (BWR Jap. utilities)	12.0	2
HITACHI (BWR Jap. utilities)	12.0	2
SIEMENS (services)	11.0	2
GNB (WTI, IKE)	10.7	2
CEN.SCK (services)	4.6	1
NOK (services)	5.0	1
GKN (services)	5.0	1
TBL (ELECTRABEL)	11.0	2
MITSUBISHI (NFI, PWR Jap. utilities)	26.5	4
NEL	5.5	1
JRI	11.0	2
PSI (services)	4.6	1
BNFL	11.0	2
BN (services)	4.8	1
ORNL	11.2	2
Total	**145.9**	

0005241/221 - "2" - A2.17

4. Budget

Situation (MBEF, March 1994)

- Initial situation (before 4th PCM)
  - Participations 145.9
  - Basic budget 105.0
  - Balance 40.9
- First extension (decision 4th PCM)
  - Participations 145.9
  - New budget 133.9
  - Balance 12.0
- Reorientation (situation 6th PCM)
  - Participations 145.9
  - New budget 152.4
  - Balance - 6.5

0005241/221 - "-" - A2.18

4. Budget

Situation (MBEF, March 1994)

- Today
  - Participations 145.9
  - New budget 154.1
  - Balance - 8.2

Reasons for increase of negative balance (Δ = -1.7)

- Complexity in data processing
- Additional reporting/meeting
- Complementary follow-up / management

0005241/221 - "." - A2.19

5. Programme completion

- Release of of recommended values to the participants → Augustus 2000

- Reporting
  - Minutes of 7th PCM → Augustus 2000
  - Irradiation data-complement → Augustus 2000
  - Laboratories → Augustus 2000
  - Final report-definitive version → October 2000

0005241/221 - "-" - A2.20

AR 96/05
Rev. B
BN Ref. 9809718/221

ARIANE
International Programme

Irradiation Data Report
Part 1

Issued March, 1999

BELGONUCLEAIRE
Avenue Ariane, 4 - 1200 Brussels.

	Type of document: REPORT	BN reference No / File - " Rev" - Page 9606546/221 - " B " - 1
		Other reference : AR 96 / 05 Rev. B
Client :		Author(s) Th. Maldague, Ph. Bachez, P. Brusselaers

Project : ARIANE

Subject :

ARIANE PROGRAMME

IRRADIATION DATA REPORT

(Basic Programme)

with the contribution of NOK, GKN and SIEMENS.

Rev..	Date	chrono. Filing No.	Status	Typist's initials	Author: Initials	Author: Visa 1	Verified by: Initials	Verified by: Visa 2	Project: Initials	Project: Visa 3	Q.A.: Initials	Q.A.: Visa 4	Issued by: Initials	Issued by: Visa 5	Number of pages
C															
B	15/03/99	9809718	FIN	/	PaB		ThM						HBe		64
A	15/04/97	9702871	FIN	/	PaB		ThM		/	/	/	/	BJ		48
-	17/07/96	9606546	FIN	/	PaB		ThM		/	/	/	/	BJ		47

Distribution :

ARIANE Programme Participants

BN : Mrs. Boulanger
MM. Vanderborck, Lippens, Mertens, Renard, Maldague, Basselier, Brusselaers

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use or exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, without prejudice to any other right.

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 - 1200 Brussels
TVA : BE 403.126.258
RCB : 271.300
TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

- LIST of MODIFICATIONS -

DATE	REVISION	OBJECT
96.07.17	-	Final issue
97.04.15	A	Final issue
99.03.15	B	Revision results from introduction of samples DM3 and DM4, and rods D3 and B6

NOTICE

LIABILITY

This document was prepared by BELGONUCLEAIRE (BN). Neither BN or any person acting on behalf of BN.

(a) gives any warranty, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this document, or that the use of any information, apparatus, method or process disclosed in this document may not infringe third party, or

(b) assumes any liabilities with respect to the use of, or for damage resulting from the use of any information, apparatus, method or process disclosed in this document.

PERSONNEL IN CONFIDENCE/NOT FOR PUBLICATION

All property rights and copyrights are reserved. Any communication or reproduction of this document and any communication or use of its content without explicit authorisation of the ARIANE programme committee is prohibited. Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting of a patent or registration in the field of intellectual property.

TABLE OF CONTENT

Pages :

DISTRIBUTION LIST 5

PREAMBLE 6

PART I : BWR Samples

Dodewaard BWR Samples DU1, DM1, DM2, DM3 and DM4 8
1. Introduction 8
2. Fuel assembly description 9
3. Irradiation follow-up 9
Tables :
Table 1 to Table 9 ..... 11 - 19
Figures :
Figure 1 to Figure 9 ..... 20 - 28

PART II PWR-MOX Samples

Beznau PWR Samples BM1, BM2D, BM3 and BM4D 30
1. Introduction 30
2. Fuel assembly description and fabrication data 31
3. Irradiation follow-up 31
Tables :
Table 1 to Table 13 ..... 34 - 47
Figures :
Figure 1 to Figure 9 ..... 48 - 56

PART III PWR-UO2 Samples

Gösgen PWR Samples GU1 and GU2 58

Tables :
Table 1 to Table 2 ..... 60 - 61
Figures :
Figure 1 to Figure 3 ..... 62 - 64

Distribution List :

SIEMENS (D)	Dr. G. Schlosser	2 copies
SCK-CEN (BE)	Mr. P. D'hondt	5 copies
GNB (D)	Dr. R. Hüggenberg	2 copies
MHI (JP)	Mr. S. Abeta	2 copies
BNFL (UK)	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	Mr. Y. Nakajima	2 copies
HITACHI (JP)	Mr. T. Mochida	2 copies
ORNL (USA)	Mr. R. T. Primm III	2 copies
NEL (JP)	Mr. H. Naito	2 copies
JRI (JP)	Mr. T. Kaneko	2 copies
NOK (CH)	Mr. G. Devillaz	2 copies
GKN (NL)	Mr. W.R. Van Engen	2 copies
PSI (CH)	Mr. G. Lederberger	2 copies
TRACTEBEL (BE)	Mr. R. de Wouters	2 copies

Preamble

This report has been prepared by Belgonucleaire as a theoretical support to the ARIANE experimental programme.

It includes mainly the detailed power and burnup histories of the 11 samples selected for radiochemical analyses (DU1, DM1, DM2, DM3, DM4, BM1, BM2D, BM3, BM4D, GU1 and GU2). The samples constitute the so called "Part 1" of the programme. The powers pi given in this report are calculated "core normalized", i.e. Σ pi (each rod) = P (core), including all heating contributions.

The necessary core data and neutronic information have been provided respectively by :

- NOK for what concerns the 4 BEZNAU-1 MOX samples
- GKN for what concerns the 4 DODEWAARD MOX samples and the DODEWAARD UO_2 sample.
- SIEMENS for what concerns the 2 GÖSGEN UO_2 samples

Are also included in this report :

* The (as build) fuel characteristics,
* Fuel temperature evolution calculations, with COMETHE 4D code.

The irradiation history tables are provided on floppy disk media, in order to facilitate further data processing.

Part I :

BWR Samples.

DODEWAARD BWR

samples

DU1, DM1, DM2, DM3 and DM4

1. Introduction

The five ARIANE samples have been irradiated in five segmented rods loaded in the test fuel assemblies Y012,Y013 and Y014. These assemblies have been loaded in the DODEWAARD BWR core during five cycles for Y014 and Y013 assemblies (samples DM1, DM4 and DU1) and during 4 cycles for Y012 fuel assembly (DM2 and DM3 samples) (see report AR 96/06). These three assemblies have been irradiated in symetrical positions in the core, as shown on figure 1.

The concerned cycles are :

- cycle 19 from feb. 12, 1988 till jan. 6, 1989
- cycle 20 from march. 24, 1989 till jan. 2, 1990
- cycle 21 from feb. 21, 1990 till jan. 1, 1991
- cycle 22 from feb. 26, 1991 till jan. 10, 1992
- cycle 23 from feb. 18, 1992 till jan. 7, 1993

Main core data are gathered on table 1.

2. Fuel assembly description.

The fuel assembly consists of a 6x6 rod bundel with a grid support fuelless rod (water rod). These fuel assemblies as shown on figure 1 present a diagonal symmetry. The geometrical layout of the fuel assembly is shown on figure 2, and the radial and axial enrichments of the fuel assembly are given on figure 3. The assembly is surrounded by a wide water gap on two sides (control blade location) and by a small water gap on the two other sides.

The axial positions of the selected samples are shown on figure 3 as well. Figure 4 shows a drawing of a segmented fuel rod. The fuel rod data are given on tables 2 (as fabricated) and 3 (inital impurities).

3. Irradiation follow-up.

The reactor operation time has been divided into several time-steps where the power does not vary more than a few percent.

The tables 4 to 8 give, for each sample :

- the elapsed time (days)
- the core load factor (%)
- the sample linear power (W/cm) and the burn-up (MWd/tM) reached at the end of the time step
- the void fraction (v/o) at the sample level
- the fuel surface and center temperatures (°C) (*)

until the end of irradiation.

(*) Calculated from COMETHE code

- Table 4 is relative to DU1 sample
- Table 5 is relative to DM1 sample
- Table 6 is relative to DM2 sample
- Table 7 is relative to DM3 sample
- Table 8 is relative to DM4 sample

The irradiation history of each sample is illustrated on figures 5 and 6.

Table 9 gives the burn-up reached by the different host assemblies at the end of each cycle of interest.

Figure 7 shows the average (cycle averaged) void profile during each concerned cycle and for the fuel assemblies containing the ARIANE samples.

Figure 8 shows the radial relative temperature profile at the beginning, middle and end of irradiation for samples DU1, DM1 and DM2, and figure 9 for DM3 and DM4 samples.

Control rod insertion

Only sample DM2 (see table 6), located at the bottom of the fuel assembly has been slightly affected by control rod (CR) insertion.

It has not been deemed to include CR data, due to :

- the relatively short time of CR insertion (5 % of the total irradiation)
- the central position of DM2 inside the fuel assembly (see figure 3), far from the CR location

DODEWAARD MAIN CORE DATA

• Type of reactor :	BWR
• Nominal thermal power :	183 MW
• Electrical power :	59 MW
• Pressure primary system :	75.5 bars
• Cooling :	natural circulation (no recirculation pumps)
• Feedwater :	80 kg/sec (demineralised water)
• Coolant inlet temperature :	289 °C
• Channel average void factor :	32 v/o
• Fuel :	UO2
• Oxide density :	10.5 gr/cm³
• Number of assemblies :	164
• Number of rods per assembly :	36
• Lattice type :	6 x 6
• Assembly pitch :	12.7 cm
• Cladding :	Zr-2
• Number of control rods :	37
• Active fuel length :	1793 mm

- TABLE 1 -

Fuel rod characteristics

Characteristics	UO2 Standard Rod	UO2/Gd2O3 Standard Rod	MOX Segment	UO2 Segment
Pellet				
• Material			UO2 - PuO2	UO2
• Density (% TD)	95	95	94.3434	95.459
• Diameter (mm)	11.48	11.48	10.352	10.357
• U-235 / U (w/o)	3.2 / 2.6 / 1.8	3.2	0.239	4.941
• Pu / (U + Pu) (w/o)	-	-	6.431	-
• Gd / U (w/o)	-	2.7	-	-
• Isotopic compositions (w/o)				
U-234 / U	-	-	0.003	-
U-235 / U	3.2 / 2.6 / 1.8	3.2	0.239	4.941
U-236 / U	-	-	0.001	-
U-238 / U	-	-	99.76	95.059
Pu-238 / Pu	-	-	1.405	-
Pu-239 / Pu	-	-	61.844	-
Pu-240 / Pu	-	-	23.380	-
Pu-241 / Pu	-	-	8.826	-
Pu-242 / Pu	-	-	4.546	-
Am-241 / Pu	-	-	1.133	-
• Dishes	Yes	Yes	No	No
• Impurities (*)			1.16	1.0
• Measuring date			01/01/1988	
Cladding				
• Material	Zr-2	Zr-2	Zr-2	Zr-2
• Inner diameter (mm)	11.71	11.71	10.55	10.55
• Outer diameter (mm)	13.49	13.49	12.27	12.27
Rod (or segment)				
• Oxide linear weight (gr/cm)	10.58	10.40	8.80	8.78
• Active length (mm)	1793	1793	287.0	279.2

(*) : Equivalent ppm Boron / (U+Pu)

- TABLE 2 -

Results of Metallic Impurity Analysis

Element		Sample DU1 ppm (U + Pu + Am)	Sample DM1-DM2-DM3-DM4 ppm (U + Pu + Am)
Silver	Ag	0.6	0.08
Aluminium	Al	20	32.95
Boron	B	< 0.3	0.65
Barium	Ba	-	1.25
Beryllium	Be	-	< 0.001
Bismuth	Bi	-	< 0.01
Calcium	Ca	6	14.77
Cadmium	Cd	0.3	< 0.17
Cobalt	Co	< 20	0.07
Chromium	Cr	12	7.39
Copper	Cu	< 2	1.59
Iron	Fe	41	76.14
Indium	In	-	< 0.01
Lithium	Li	-	0.26
Magnesium	Mg	< 2	30.68
Manganese	Mn	< 2	1.0
Molybdenum	Mo	< 10	23.86
Sodium	Na	< 8	6.59
Nickel	Ni	< 10	5.0
Niobium	Nb	-	0.06
Phosphorus	P	-	5.91
Lead	Pb	4	0.75
Antimony	Sb	-	< 0.02
Silicon	Si	< 10	90.91
Tin	Sn	1	0.36
Tantalum	Ta	-	< 0.01
Titanium	Ti	-	18.18
Vanadium	V	< 10	0.41
Tungsten	W	< 2	0.68
Zinc	Zn	11	3.18
Samarium	Sm	< 0.2	< 0.03
Europium	Eu	< 0.2	< 0.01
Gadolinium	Gd	< 0.1	< 0.04
Dysprosium	Dy	< 0.1	< 0.04
Thorium	Th	< 1	< 0.10
Sulfur	S	-	27.27
Nitrogen	N	-	14.15
(Gd + Dy + Eu + Sm)		< 20	0.125
Chlorine	Cl	< 1	4.32
Carbon	C	< 1	131.17
Fluorine	F	< 1	0.357
Total impurities		197	465.3
Volatiles (l/g)		5	2.047
H2O		< 1	0.49
Eq. Boron		0.991	1.157

- TABLE 3 -

DU1 Follow Up

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 19 12.02.88 - 06.01.89						
6.30	99.3	53.1	215	175	865	481
12.03	99.6	52.4	227	527	914	497
21.54	99.2	52.1	228	1162	927	501
20.87	99.8	51.9	238	1803	970	512
7.30	99.9	52.7	230	2020	947	507
15.67	99.7	52.7	230	2486	954	509
11.48	99.8	52.3	247	2852	1012	520
7.29	100.1	52.6	249	3006	1021	522
13.55	100.0	52.8	249	3522	1026	522
14.09	99.8	53.3	251	3978	1035	524
9.90	100.0	53.8	252	4300	1041	524
17.89	99.0	52.9	269	4921	1101	531
17.71	100.0	53.6	274	5547	1119	532
20.90	99.7	53.8	281	6306	1150	534
23.47	99.9	53.5	293	7193	1195	536
22.07	99.1	53.4	296	8036	1209	535
20.03	98.9	53.5	300	8811	1227	535
20.74	98.0	53.5	297	9607	1220	531
10.60	98.3	54.1	289	10001	1191	526
16.89	95.6	53.5	272	10593	1141	521
6.75	92.6	52.7	256	10816	1100	519
11.04	91.1	52.1	246	11167	1075	518
0.00	87.3	50.9	240	11167	1060	518
Cycle 20 24.03.89 - 02.01.90						
4.20	74.3	44.2	227	11290	1026	518
13.14	95.1	51.9	280	11765	1170	518
13.92	97.3	53.4	262	12236	1121	515
28.73	96.2	53.0	257	13189	1111	512
21.13	98.3	53.2	255	13885	1108	510
26.09	98.8	53.1	253	14737	1105	507
21.86	100.1	53.3	255	15458	1112	504
26.74	99.9	52.8	262	16363	1131	498
16.74	97.0	51.7	273	16952	1160	494
11.67	99.0	52.1	280	17374	1181	491
0.99	99.9	52.3	283	17411	1189	491
6.62	99.9	52.2	283	17653	1190	490
6.94	99.1	51.3	288	17910	1205	489
6.32	99.7	51.3	290	18147	1212	487
13.65	99.9	51.3	290	18658	1212	484
21.36	99.5	51.2	286	19447	1200	480
5.97	96.0	50.1	274	19659	1166	480
14.03	95.4	49.9	270	20148	1155	478
5.88	94.8	50.9	249	20337	1102	483
14.90	95.4	51.3	240	20798	1081	484
3.25	93.1	50.5	224	20892	1043	489

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 21 21.02.90 - 03.01.91						
4.15	71.5	33.2	165	20980	888	493
2.01	96.0	56.9	317	21062	1305	476
0.98	95.8	56.9	316	21102	1301	475
0.96	97.8	59.1	305	21140	1262	472
12.04	98.3	57.8	328	21650	1349	478
13.96	98.5	58.2	321	22229	1321	470
6.84	99.0	58.4	325	22515	1335	470
14.11	97.9	57.0	319	23097	1314	464
6.91	98.0	57.5	313	23376	1289	460
14.15	99.1	57.9	313	23946	1289	456
6.32	99.7	57.6	313	24201	1289	455
13.17	98.1	56.2	286	24687	1203	451
14.16	99.4	56.4	301	25238	1251	447
14.02	99.6	55.8	294	25770	1229	444
13.94	99.8	55.4	285	26283	1202	443
13.95	99.7	55.0	277	26781	1176	442
13.98	99.9	54.7	270	27268	1157	441
14.06	99.8	54.6	262	27743	1136	441
0.94	99.9	54.3	259	27774	1126	442
19.90	98.7	53.3	282	28498	1194	432
11.14	99.7	50.8	292	28918	1226	429
17.05	99.3	50.3	290	29556	1221	427
13.91	100.0	50.0	296	30086	1241	424
13.92	99.6	49.5	300	30625	1259	422
7.12	99.5	49.7	321	30921	1337	424
6.34	99.4	49.8	322	31184	1343	423
4.00	99.1	50.1	324	31352	1350	423
9.86	98.9	50.9	315	31752	1317	420
2.99	95.8	49.7	307	31871	1287	418
3.95	96.2	50.7	299	32023	1259	417
1.41	96.1	51.6	289	32076	1225	417
1.59	98.0	53.6	277	32133	1186	418
10.88	97.8	53.6	276	32520	1183	417
9.79	94.2	52.0	270	32861	1164	417
1.40	90.8	50.6	269	32911	1142	418
Cycle 22 26.02.91 - 10.01.92						
7.54	71.2	34.7	171	33078	877	434
7.09	97.8	51.1	356	33403	1499	434
5.80	99.7	55.2	332	33652	1395	420
7.98	99.9	56.1	321	33982	1352	416
11.66	99.7	54.6	329	34476	1387	418
14.44	99.6	52.9	334	35099	1417	419
10.94	100.1	51.2	338	35577	1438	421
20.33	99.5	49.1	340	36467	1453	422
19.65	100.0	47.1	336	37318	1446	421
20.49	99.9	44.8	326	38181	1411	418
14.27	100.1	42.8	312	38756	1357	413
6.89	99.9	41.2	294	39017	1281	408
20.96	99.9	41.0	289	39800	1271	407
7.29	100.1	39.2	272	40056	1203	403
7.82	100.0	38.1	276	40334	1221	404
4.71	99.7	37.5	355	40550	1586	447
7.89	99.1	45.5	324	40880	1437	426
14.10	99.0	46.5	314	41452	1398	423
13.74	99.4	46.6	312	42006	1398	424
17.70	99.8	46.5	311	42715	1400	427
10.65	99.8	46.7	304	43133	1375	425
9.24	98.7	46.8	297	43487	1343	421
10.01	98.4	46.9	286	43856	1297	416
1.33	98.1	47.3	278	43904	1262	411
1.01	98.4	47.5	270	43909	1229	406
1.22	98.3	47.5	263	43981	1195	403
11.06	98.9	47.7	264	44358	1203	404
7.65	98.1	48.0	255	44610	1162	399
1.60	97.7	48.5	246	44660	1124	394
4.63	96.9	48.4	236	44801	1082	390
6.97	96.4	48.3	234	45012	1075	389
9.98	96.6	49.2	225	45301	1039	384
0.99	95.0	49.2	213	45328	991	379
0.31	99.6	52.2	204	45336	957	376

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 23 18.02.92 - 07.01.93						
2.60	76.3	32.2	152	45387	775	363
1.48	84.4	36.5	218	45429	1011	381
3.35	95.0	45.2	254	45539	1165	400
2.85	98.9	49.6	246	45629	1129	395
4.60	99.7	50.8	241	45772	1109	392
6.53	99.8	50.8	238	45972	1098	391
9.98	99.8	50.6	237	46277	1095	390
2.67	99.7	49.6	239	46357	1104	391
9.08	99.9	49.6	239	46636	1106	392
4.92	99.7	49.0	239	46788	1107	392
4.02	99.9	48.4	240	46912	1112	393
2.87	100.0	47.5	243	47002	1126	395
7.04	100.0	47.5	242	47222	1123	394
5.06	100.0	47.0	242	47379	1124	394
1.88	99.8	46.2	241	47438	1124	394
5.44	99.7	46.2	241	47607	1125	395
1.57	99.8	46.0	240	47656	1121	394
5.12	99.9	46.0	240	47814	1118	394
1.93	100.1	45.2	242	47875	1132	396
8.36	99.9	45.2	241	48135	1129	396
5.53	99.9	44.1	241	48307	1130	396
7.94	99.9	44.0	240	48553	1127	396
4.07	97.4	39.4	236	48677	1107	392
1.28	89.6	35.6	215	48712	1013	377
3.26	91.1	36.1	219	48804	1031	379
3.60	98.6	39.5	237	48914	1114	393
1.57	100.0	41.3	240	48963	1128	396
7.04	100.0	41.3	239	49179	1125	396
6.95	99.8	41.0	237	49392	1122	395
8.11	99.7	40.7	235	49639	1114	394
1.78	99.5	39.7	232	49692	1099	391
3.98	99.7	39.2	231	49810	1093	390
3.03	99.9	39.7	231	49901	1096	390
3.87	99.8	39.1	229	50015	1086	389
7.21	99.0	39.0	229	50228	1088	389
7.70	99.6	38.1	224	50450	1064	385
6.09	99.4	37.3	219	50622	1045	381
6.95	99.9	37.3	218	50818	1042	381
6.91	99.6	36.6	211	51006	1010	375
4.44	100.0	36.6	210	51127	1006	374
2.57	99.6	36.3	208	51196	998	373
7.01	99.8	36.4	208	51384	999	373
6.59	99.8	36.3	207	51560	996	372
6.96	99.7	36.1	206	51745	992	372
6.95	99.8	36.0	204	51928	985	370
9.14	99.5	35.6	203	52063	981	370
1.57	99.6	35.7	202	52104	977	369
2.46	99.7	35.7	202	52168	978	369
4.49	99.9	36.3	209	52289	1008	374
7.49	99.6	36.1	208	52490	1006	374
9.00	99.8	36.6	209	52706	1013	376
5.59	99.8	37.1	211	52858	1025	378
3.72	99.7	37.5	211	52959	1027	378
3.14	99.7	37.6	210	53045	1023	378
5.49	99.8	38.2	212	53195	1031	379
1.57	99.9	38.9	211	53237	1027	379
3.09	99.7	38.8	210	53321	1023	378
4.02	100.0	39.5	210	53430	1025	378
3.98	99.7	40.1	207	53537	1012	376
4.02	99.9	40.8	206	53644	1009	375
3.34	100.0	41.5	204	53731	996	373
2.56	99.9	42.1	202	53786	986	371
1.10	99.8	42.7	199	53826	974	369
5.84	100.1	43.4	197	53974	967	367
4.44	99.9	44.7	191	54084	941	363
2.61	100.0	45.8	187	54147	924	361
4.11	99.1	45.5	185	54245	916	360
0.96	98.3	46.3	180	54267	895	357
2.97	98.4	47.1	177	54335	883	355
2.28	98.2	47.4	175	54386	875	355
0.80	97.7	47.5	173	54404	867	354

- TABLE 4 -

DM1 Follow Up

Elapsed Time (Day)	Core Ld. Fact (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 19 12.02.88 - 06.01.89						
6.30	99.3	53.1	231	188	850	470
12.03	99.6	52.4	244	567	928	501
21.54	99.2	52.1	244	1246	937	501
20.87	99.8	51.9	254	1931	991	517
7.30	99.9	52.7	244	2161	948	502
15.67	99.7	52.7	244	2654	950	501
11.48	99.8	52.3	261	3041	1032	525
7.29	100.1	52.6	264	3259	1045	526
13.55	100.0	52.8	264	3750	1047	526
14.09	99.8	53.3	264	4229	1052	525
9.90	100.0	53.8	265	4568	1060	525
17.89	99.0	52.9	283	5220	1130	537
17.71	100.0	53.6	288	5878	1152	538
20.90	99.7	53.8	296	6675	1184	538
23.47	99.9	53.5	307	7605	1224	537
22.07	99.1	53.4	310	8489	1235	532
20.03	98.9	53.5	315	9303	1251	526
20.74	98.0	53.5	313	10140	1244	520
10.60	98.3	54.1	304	10555	1222	518
16.89	95.6	53.5	286	11178	1173	513
6.75	92.6	52.7	271	11414	1127	508
11.04	91.1	52.1	261	11785	1095	503
0.00	87.3	50.9	254	11785	1074	500
Cycle 20 24.03.89 - 02.01.90						
4.20	74.3	44.2	238	11914	1018	491
13.14	95.1	51.9	227	12299	984	485
13.92	97.3	53.4	225	12704	981	484
28.73	96.2	53.0	236	13580	1026	488
21.13	98.3	53.2	228	14203	1005	485
26.09	98.8	53.1	229	14975	1014	485
21.86	100.1	53.3	245	15665	1066	487
26.74	99.9	52.8	248	16522	1083	486
16.74	97.0	51.7	252	17067	1098	485
11.87	99.0	52.4	254	17450	1106	484
0.99	99.9	52.3	257	17482	1116	484
6.62	99.9	52.2	270	17713	1156	484
6.94	99.1	51.3	277	17961	1177	483
6.32	99.7	51.3	282	18192	1193	481
13.65	99.9	51.3	289	18701	1214	477
21.36	99.5	51.2	292	19507	1225	473
5.97	96.0	50.1	299	19738	1243	469
14.03	95.4	49.9	298	20277	1242	467
5.88	94.8	50.9	292	20499	1228	468
14.90	95.4	51.3	274	21026	1181	470
3.25	93.1	50.0	299	21135	1137	471
Cycle 21 21.02.90 - 03.01.91						
4.15	71.5	33.2	237	21262	1075	474
2.01	96.0	56.9	330	21347	1312	438
0.98	95.8	56.9	330	21389	1312	438
0.96	97.8	59.1	318	21429	1292	449
12.04	98.3	57.8	342	21960	1332	421
13.96	98.5	58.2	334	22562	1327	429
6.84	99.0	58.4	338	22860	1334	424
14.11	97.9	57.0	332	23404	1329	429
6.91	98.0	57.5	325	23753	1318	434
14.15	99.1	57.9	324	24344	1320	433
6.32	99.7	57.6	323	24607	1320	433
13.17	98.1	56.2	296	25111	1257	446
14.16	99.4	56.4	311	25679	1299	437
14.02	99.6	55.8	304	26229	1284	439
13.94	99.8	55.4	294	26759	1260	441
13.95	99.7	55.0	286	27272	1237	442
13.98	99.9	54.7	278	27774	1217	443
14.05	99.8	54.6	268	28260	1192	444
0.94	99.9	54.3	265	28292	1181	445
19.90	98.7	53.3	289	29035	1255	435
11.14	99.7	50.8	299	29464	1287	430
17.05	99.3	50.3	297	30118	1284	429
13.91	100.0	50.0	303	30661	1305	426
13.92	99.6	49.5	307	31213	1323	423
7.12	99.5	49.7	328	31514	1393	417
6.34	99.4	49.8	330	31784	1399	417
4.00	99.1	50.1	331	31955	1406	416
9.86	98.9	50.9	322	32364	1380	418
2.99	95.8	49.7	314	32485	1354	419
3.95	96.2	50.7	305	32641	1325	421
1.41	96.1	51.6	295	32695	1293	423
1.59	98.0	53.6	283	32753	1255	426
10.88	97.8	53.6	282	33148	1254	426
9.79	94.2	52.0	276	33497	1236	427
1.40	90.8	50.6	268	33548	1212	425
Cycle 22 26.02.91 - 10.01.92						
7.54	71.2	34.7	174	33718	962	470
7.09	97.8	51.1	363	34050	1553	421
5.80	99.7	55.2	338	34302	1458	417
7.98	99.9	56.1	327	34639	1420	417
11.66	99.7	54.6	335	35143	1456	418
14.44	99.6	52.9	340	35777	1488	420
10.94	100.1	51.2	344	36263	1510	423
20.33	99.5	49.1	346	37169	1529	426
19.65	100.0	47.1	342	38036	1524	426
20.49	99.9	44.8	332	38914	1489	423
14.27	100.1	42.8	317	39498	1432	419
6.89	99.9	41.2	299	39764	1362	417
20.96	99.9	41.0	294	40561	1349	417
7.29	100.1	39.2	278	40923	1291	417
7.82	100.0	38.1	282	41107	1307	417
4.71	99.7	37.5	363	41328	1679	454
7.89	99.1	45.5	331	41665	1518	428
14.10	99.0	46.5	320	42248	1474	425
13.74	99.4	46.6	319	42814	1477	426
17.70	99.8	46.5	317	43538	1473	426
10.65	99.8	46.7	311	43965	1454	426
9.24	98.7	46.8	304	44328	1425	424
10.01	98.4	46.9	293	44706	1384	423
1.33	98.1	47.3	285	44755	1353	422
1.01	98.4	47.5	280	44791	1333	421
1.22	98.3	47.5	270	44834	1293	420
11.06	98.9	47.7	272	45222	1301	420
7.65	98.1	48.0	261	45479	1260	419
1.60	97.7	48.5	252	45531	1225	418
4.63	96.9	48.4	242	45676	1186	416
6.97	96.4	48.3	241	45892	1182	415
9.98	96.6	49.2	231	46190	1144	413
0.99	95.0	49.2	219	46218	1095	409
0.31	99.6	52.2	210	46226	1059	406
Cycle 23 18.02.92 - 07.01.93						
2.60	76.3	32.2	157	46279	828	374
1.48	84.4	36.5	224	46321	1114	410
3.35	95.0	45.2	261	46434	1268	420
2.85	98.9	49.6	253	46527	1235	418
4.60	99.7	50.8	248	46674	1215	417
6.53	99.8	50.8	245	46881	1204	416
9.98	99.8	50.6	244	47195	1202	415
2.37	99.7	49.0	240	47270	1211	416
9.08	99.9	49.6	246	47565	1213	416
4.92	99.7	49.0	246	47721	1213	416
4.02	99.9	48.4	247	47849	1218	416
2.87	100.0	47.5	250	47941	1231	417
7.04	100.0	47.5	250	48168	1233	418
5.06	100.0	47.0	250	48331	1234	418
1.88	99.8	46.2	250	48392	1234	418
5.44	99.7	46.2	250	48567	1235	418
1.57	99.8	46.0	248	48617	1227	417
5.12	99.9	46.0	248	48780	1228	417
1.93	100.1	45.2	250	48843	1241	418
8.36	99.9	45.2	249	49112	1239	418
5.53	99.9	44.1	249	49290	1239	418
7.94	99.9	44.0	248	49544	1236	418
4.07	97.4	39.4	245	49673	1220	416
1.28	89.6	35.6	223	49709	1120	403
3.26	91.1	36.1	226	49804	1134	404
3.60	98.6	39.5	245	49918	1223	416
1.57	100.0	41.3	249	49968	1241	418
7.04	100.0	41.3	248	50193	1238	418
6.95	99.8	41.0	246	50414	1230	417
8.11	99.7	40.7	244	50669	1222	416
1.78	99.5	39.7	241	50724	1211	414
3.98	99.7	39.2	240	50847	1206	413
3.03	99.9	39.7	240	50941	1207	413
3.87	99.8	39.1	238	51060	1197	412
7.21	99.9	39.0	236	51261	1190	412
7.70	99.6	38.1	233	51512	1174	407
6.09	99.4	37.3	227	51691	1148	403
6.95	99.9	37.3	227	51895	1149	403
6.91	99.6	36.6	219	52090	1109	396
4.44	100.0	36.6	219	52216	1110	395
2.57	99.6	36.3	217	52288	1100	394
7.01	99.8	36.4	217	52484	1101	393
6.59	99.8	36.3	216	52668	1097	392
6.96	99.7	36.1	215	52861	1092	391
6.95	99.8	36.0	213	53052	1084	389
5.14	99.4	35.8	212	53193	1079	388
1.57	99.6	35.7	211	53236	1074	387
2.46	99.7	35.7	211	53303	1074	387
4.49	99.9	36.3	218	53429	1106	392
7.49	99.6	36.1	217	53638	1102	391
9.00	99.8	36.6	219	53864	1114	393
5.59	99.8	37.1	220	54023	1122	394
3.72	99.7	37.5	221	54129	1124	394
3.14	99.7	37.6	221	54218	1124	394
5.49	99.8	38.2	222	54376	1132	395
1.57	99.9	38.9	221	54420	1128	394
3.09	99.7	38.8	220	54508	1123	393
4.02	100.0	39.5	220	54622	1124	393
3.98	99.7	40.1	218	54734	1110	390
4.02	99.9	40.8	217	54846	1106	389
3.34	100.0	41.5	214	54939	1092	387
2.56	99.9	42.1	212	55009	1082	385
1.10	99.8	42.7	209	55038	1068	382
5.84	100.1	43.4	206	55193	1054	380
4.44	99.9	44.7	201	55309	1032	377
2.61	100.0	45.8	196	55375	1010	374
4.11	99.1	45.5	194	55478	1003	374
0.96	98.3	46.3	189	55501	983	373
2.97	98.4	47.1	186	55572	972	373
2.28	98.2	47.4	183	55626	963	374
0.80	97.7	47.5	182	55646	960	374

- TABLE 5 -

DM2 Follow Up

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 19 12.02.88 - 06.01.89						
6.30	99.3	6.1	349	284	1221	531
12.03	99.6	5.0	308	762	1106	521
21.54	99.2	4.7	299	1592	1099	523
20.87	99.8	4.1	284	2358	1053	507
7.30	99.9	4.6	319	2658	1246	577
15.67	99.7	4.5	319	3304	1274	589
11.48	99.8	3.7	285	3727	1110	533
7.29	100.1	3.6	286	3996	1124	539
13.55	100.0	3.6	288	4500	1152	549
14.09	99.8	3.6	292	5030	1187	562
9.90	100.0	3.6	295	5407	1216	573
17.89	99.0	3.0	260	6008	1049	515
17.71	100.0	3.0	264	6610	1083	528
20.90	99.7	2.9	257	7304	1069	524
23.47	99.9	2.7	245	8045	1029	513
22.07	99.1	2.5	235	8715	1004	507
20.03	98.9	2.2	226	9299	980	502
20.74	98.0	2.1	221	9890	971	502
10.60	98.3	2.3	229	10203	1010	513
16.89	95.6	2.4	231	10707	1030	520
6.75	92.6	2.6	232	10909	1036	522
11.04	91.1	2.7	236	11245	1060	528
0.00	87.3	2.4	219	11245	992	512
Cycle 20 24.03.89 - 02.01.90						
4.20	74.3	2.2	143	11323	732	450
13.14	95.1	2.5	173	11616	836	478
13.92	97.3	3.2	215	12002	991	514
28.73	96.2	3.1	215	12799	1003	518
21.13	98.3	3.0	226	13416	1053	528
26.09	98.8	3.0	230	14189	1074	531
21.86	100.1	2.9	233	14846	1090	533
26.74	99.9	2.4	211	15575	1022	523
16.74	97.0	1.8	185	15976	940	510
11.67	99.9	1.6	184	16253	937	510
0.99	99.9	1.5	180	16276	926	508
5.62	99.9	1.4	174	16424	905	505
6.94	99.1	1.0	162	16560	832	491
6.32	99.7	0.8	140	16675	793	482
13.65	99.9	0.8	141	16923	796	483
21.36	99.5	0.8	141	17313	800	484
5.97	96.0	0.9	142	17422	801	484
14.03	95.4	0.9	143	17681	808	485
5.88	94.8	1.8	192	17827	973	513
14.90	95.4	2.4	216	18242	1052	519
3.25	93.1	2.6	226	18337	1082	521
Cycle 21 21.02.90 - 03.01.91						
4.15	71.5	1.0	114	18398	706	459
2.01	96.0	4.1	273	18468	1234	528
0.98	95.8	4.1	272	18503	1230	528
0.96	97.8	7.2	350	18546	1514	549
12.04	98.3	4.2	278	18977	1248	524
13.96	98.5	4.9	303	19523	1326	519
5.84	99.0	4.5	296	19784	1301	515
14.11	97.9	4.3	288	20309	1273	508
6.91	98.0	4.8	303	20579	1313	503
14.15	99.1	5.3	317	21158	1348	491
6.32	99.7	5.0	311	21412	1327	488
13.17	98.1	4.9	310	21940	1316	479
14.16	99.4	4.6	302	22492	1287	473
14.02	99.6	4.3	297	23030	1267	467
13.94	99.8	4.2	294	23560	1253	461
13.95	99.7	4.0	290	24083	1237	455
13.98	99.9	3.8	288	24603	1226	449
14.05	99.8	3.8	288	25126	1220	441
0.94	99.9	3.6	286	25161	1215	442
19.90	98.7	2.7	234	25761	1086	464
11.14	99.7	0.8	172	26009	907	468
17.05	99.3	0.8	169	26350	895	465
13.91	100.0	0.7	164	26673	879	462
13.92	99.6	0.6	157	26955	866	458
7.12	99.5	0.5	142	27086	809	454
6.34	99.4	0.5	140	27200	803	452
4.00	99.1	0.3	130	27267	768	448
9.88	98.9	0.5	153	27452	844	455
2.99	98.8	0.5	144	27518	813	452
3.85	98.2	0.7	163	27601	872	456
1.41	96.1	1.1	187	27635	947	458
1.59	98.0	2.9	254	27687	1121	435
10.88	97.8	2.9	253	28041	1116	431
9.79	94.2	2.6	231	28333	1063	441
1.49	90.8	2.3	214	28374	1020	448
Cycle 22 26.02.91 - 10.01.92						
7.54	71.2	1.1	88	28460	629	419
7.09	97.8	1.3	120	28569	732	437
5.80	99.7	2.2	158	28687	855	449
7.98	99.9	2.7	179	28871	918	449
11.66	99.7	2.0	155	29104	844	446
14.44	99.6	1.4	137	29359	787	440
10.94	100.1	1.1	126	29536	750	435
20.33	99.5	0.9	117	29844	722	430
19.65	100.0	0.7	113	30129	707	427
20.49	99.9	0.6	111	30424	702	425
14.27	100.1	0.6	112	30629	703	425
5.89	99.9	0.6	113	30730	708	425
20.96	99.9	0.6	114	31038	709	424
7.29	100.1	0.4	103	31134	673	418
7.82	100.0	0.2	87	31222	620	409
4.71	99.7	0.0	46	31250	489	380
7.89	99.1	0.2	86	31337	618	408
14.10	99.0	0.7	121	31558	732	425
13.74	99.4	0.7	122	31773	734	424
17.70	99.8	0.7	120	32047	729	423
10.65	99.8	0.7	122	32215	733	423
9.24	98.7	0.6	120	32357	727	421
10.01	98.4	0.7	126	32520	748	423
1.33	98.1	0.8	130	32542	759	424
1.01	98.4	0.9	137	32560	782	426
1.22	98.3	1.1	148	32583	820	428
11.06	98.9	1.1	149	32797	823	428
7.65	98.1	1.2	154	32949	839	428
1.60	97.7	1.3	163	32983	865	428
4.63	96.9	1.6	173	33086	896	427
6.97	96.4	1.6	173	33242	895	426
9.98	96.6	2.0	191	33488	945	422
0.99	95.0	2.3	203	33513	977	417
0.31	99.6	3.8	277	33525	1115	348

C.R. insertion during 1.6 GWd/t

(~ 5 % of Irradiation time)

- TABLE 6 -

DM3 Follow Up

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 19 12.02.88 - 06.01.89						
6.30	99.3	54.4	223	184	886	491
12.03	99.6	53.9	235	543	933	501
21.54	99.2	53.6	236	1205	947	505
20.87	99.8	53.5	245	1859	990	514
7.30	99.9	54.2	235	2088	962	509
15.67	99.7	54.2	235	2568	969	511
11.48	99.8	53.9	252	2933	1028	520
7.29	100.1	54.2	254	3173	1035	521
13.55	100.0	54.4	254	3621	1041	522
14.09	99.8	54.8	253	4086	1043	521
9.90	100.0	55.3	253	4412	1048	521
17.89	99.0	54.6	272	5024	1118	530
17.71	100.0	55.2	276	5657	1140	530
20.90	99.7	55.5	284	6419	1171	531
23.47	99.9	55.2	297	7308	1223	533
22.07	99.1	55.1	300	8167	1241	531
20.03	98.9	56.3	304	8955	1259	529
20.74	98.0	55.3	300	9771	1253	525
10.60	98.3	55.8	290	10179	1226	522
16.89	95.6	55.2	273	10799	1171	515
6.75	92.6	54.4	259	11033	1125	510
11.04	91.1	53.8	249	11399	1096	507
0.00	87.3	52.6	244	11399	1076	507
Cycle 20 24.03.89 - 02.01.90						
4.20	74.3	46.2	244	11533	1071	499
13.14	95.1	53.7	288	11988	1232	514
13.92	97.3	55.1	268	12492	1169	510
28.73	96.2	54.7	264	13488	1163	507
21.13	98.3	54.9	262	14211	1162	505
26.09	98.8	54.8	259	15097	1164	505
21.86	100.1	55.0	261	15837	1177	504
26.74	99.9	54.5	269	16760	1210	503
16.74	97.0	53.5	279	17358	1271	516
11.67	99.9	54.2	287	17789	1309	523
0.99	99.9	54.2	289	17826	1318	525
6.62	99.9	54.1	289	18075	1316	521
6.94	99.1	53.3	293	18338	1329	518
6.32	99.7	53.3	295	18580	1328	512
13.65	99.9	53.3	295	19105	1315	499
21.36	99.5	53.2	290	19919	1279	481
5.97	96.0	52.1	278	20140	1241	479
14.03	95.4	51.9	274	20645	1223	473
5.88	94.8	52.7	252	20846	1157	471
14.90	95.4	53.0	242	21326	1127	471
3.25	93.1	52.2	226	21425	1092	470

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (Mwd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 21 21.02.90 - 03.01.91						
4.15	71.5	36.1	266	21569	1206	471
2.01	96.0	58.6	326	21646	1431	481
0.98	95.8	58.6	326	21688	1426	477
0.96	97.8	60.6	314	21728	1387	477
12.04	98.3	59.5	337	22239	1405	438
13.96	98.5	59.8	329	22845	1341	413
6.84	99.0	60.0	330	23139	1344	408
14.11	97.9	59.3	326	23742	1325	402
6.91	98.0	59.2	318	24032	1298	400
14.15	99.1	59.5	317	24618	1306	402
6.32	99.7	59.2	316	24879	1308	403
13.17	98.1	57.8	294	25403	1239	406
14.16	99.4	58.1	307	25957	1287	403
14.02	99.6	57.5	301	26512	1267	400
13.94	99.8	57.1	291	27050	1234	396
13.95	99.7	56.6	282	27570	1206	396
13.98	99.9	56.3	273	28076	1182	397
14.05	99.8	56.1	261	28564	1143	395
0.94	99.9	55.9	255	28596	1117	390
19.90	98.7	55.0	283	29294	1222	391
11.14	99.7	52.7	293	29713	1270	394
17.05	99.3	52.3	291	30362	1269	395
13.91	100.0	52.1	298	30896	1315	403
13.92	99.6	51.7	305	31441	1358	414
7.12	99.5	51.9	321	31731	1518	466
6.34	99.4	52.0	322	31997	1507	458
4.00	99.1	52.3	322	32165	1497	451
9.86	98.9	53.0	313	32572	1429	427
2.99	95.8	51.9	305	32693	1397	425
3.95	96.2	52.8	297	32848	1368	427
1.41	96.1	53.5	287	32901	1334	430
1.59	98.0	55.3	275	32959	1297	436
10.88	97.8	55.3	274	33349	1312	444
9.79	94.2	53.8	268	33695	1303	450
1.49	90.8	52.4	261	33746	1272	448
Cycle 22 26.02.91 - 10.01.92						
7.54	71.2	36.9	186	33929	1038	475
7.09	97.8	53.6	358	34181	1583	420
5.80	99.7	57.1	330	34441	1543	438
7.98	99.9	57.9	319	34779	1479	428
11.66	99.7	56.5	328	35271	1522	434
14.44	99.6	55.1	334	35895	1553	434
10.94	100.1	53.5	339	36375	1569	430
20.33	99.5	51.7	341	37277	1575	425
19.65	100.0	49.8	340	38149	1578	426
20.49	99.9	47.7	333	39048	1576	434
14.27	100.1	45.8	322	39657	1548	441
6.89	99.9	44.3	308	39939	1489	439
20.96	99.9	44.0	303	40774	1479	438
7.29	100.1	42.2	289	41066	1421	435
7.82	100.0	41.3	294	41352	1445	436
4.71	99.7	41.5	368	41556	1591	362
7.89	99.1	48.3	333	41917	1590	425
14.10	99.0	49.2	322	42519	1570	437
13.74	99.4	49.2	321	43095	1573	439
17.70	99.8	49.1	316	43830	1569	443
10.65	99.8	49.3	309	44264	1542	443
9.24	98.7	49.3	300	44630	1507	442
10.01	98.4	49.4	288	45014	1456	440
1.33	98.1	49.6	280	45064	1418	438
1.01	98.4	49.8	275	45100	1391	436
1.22	98.3	49.7	265	45143	1339	429
11.06	98.9	49.9	266	45526	1348	429
7.65	98.1	50.2	255	45786	1294	424
1.60	97.7	50.5	246	45839	1259	426
4.63	96.9	50.3	236	45984	1246	445
6.97	96.4	50.2	235	46198	1254	451
9.98	96.6	51.0	225	46497	1212	445
0.99	95.0	50.9	213	46526	1165	441
0.31	99.6	53.7	204	46534	1129	437

- TABLE 7 -

DM4 Follow Up

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 19	**12.02.88 - 06.01.89**					
6.30	99.3	61.2	192	157	808	479
12.03	99.6	61.0	197	462	831	483
21.54	99.2	60.6	197	1015	839	486
20.87	99.8	61.0	201	1557	858	487
7.30	99.9	61.2	190	1743	829	487
15.67	99.7	61.2	188	2129	828	487
11.48	99.8	61.5	200	2419	866	493
7.29	100.1	61.7	197	2606	861	493
13.55	100.0	61.8	195	2954	859	493
14.09	99.8	61.9	188	3305	841	489
9.90	100.0	62.2	183	3544	827	486
17.89	99.0	62.2	200	3991	886	498
17.71	100.0	62.7	197	4449	880	497
20.90	99.7	63.0	199	4988	892	498
23.47	99.9	63.2	209	5612	930	503
22.07	99.1	63.2	204	6207	921	501
20.03	98.9	63.4	199	6734	907	497
20.74	98.0	63.3	191	7260	884	492
10.60	98.3	63.4	179	7515	846	483
16.89	95.6	62.6	166	7895	808	474
6.75	92.6	61.7	157	8038	780	467
11.04	91.1	61.1	152	8260	765	462
0.00	87.3	60.2	149	8260	755	459
Cycle 20	**24.03.89 - 02.01.90**					
4.20	74.3	56.3	201	8370	929	500
13.14	95.1	62.1	190	8705	892	490
13.92	97.3	62.6	175	9036	842	494
28.73	96.2	62.2	170	9682	828	478
21.13	98.3	62.3	166	10145	818	471
26.09	98.8	62.2	162	10703	810	468
21.86	100.1	62.4	162	11166	814	469
26.74	99.9	62.2	166	11737	830	471
16.74	97.0	61.8	172	12106	854	475
11.67	99.9	62.5	175	12370	863	476
0.99	99.9	62.5	176	12393	867	477
5.62	99.9	62.4	175	12544	867	477
6.94	99.1	62.1	178	12704	876	479
6.32	99.7	62.1	177	12850	874	478
13.65	99.9	62.1	177	13165	876	479
21.36	99.5	61.9	173	13651	861	471
5.97	96.0	61.0	167	13784	836	464
14.03	95.4	60.8	163	14085	821	456
5.88	94.8	60.8	151	14206	782	450
14.90	95.4	60.8	145	14493	761	445
3.25	93.1	59.9	136	14552	742	444

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surf. Temp. (°C)
Cycle 21	**21.02.90 - 03.01.91**					
4.15	71.5	52.3	257	14692	1189	516
2.01	96.0	66.5	224	14755	1057	504
0.98	95.8	66.5	224	14783	1058	504
0.96	97.8	67.6	216	14811	1026	499
12.04	98.3	67.2	229	15160	1082	507
13.96	98.5	67.3	222	15571	1059	502
6.84	99.0	67.4	218	15767	1041	499
14.11	97.9	66.8	217	16166	1041	498
6.91	98.0	66.7	210	16359	1017	493
14.15	99.1	66.9	209	16746	1016	492
6.32	99.7	66.7	208	16918	1013	491
13.17	98.1	65.4	205	17273	1002	489
14.16	99.4	65.8	206	17653	1009	489
14.02	99.6	65.3	204	18028	1003	487
13.94	99.8	64.8	199	18394	986	483
13.95	99.7	64.3	194	18752	969	480
13.98	99.9	63.8	187	19099	947	475
14.05	99.8	63.2	175	19430	904	468
0.94	99.9	62.8	162	19451	858	459
19.90	98.7	63.0	192	19910	968	477
11.14	99.7	61.8	197	20192	989	479
17.05	99.3	61.5	194	20627	980	477
13.91	100.0	61.5	196	20982	991	478
13.02	99.6	61.3	197	21330	994	477
7.12	99.5	61.8	201	21523	1013	479
6.34	99.4	61.9	200	21689	1009	478
4.00	99.1	62.1	197	21793	998	476
9.86	98.9	62.4	192	22043	980	473
2.99	95.8	61.5	188	22117	965	471
3.95	96.2	62.0	183	22213	949	468
1.41	96.1	62.2	176	22246	921	464
1.59	98.0	63.2	169	22282	892	459
10.88	97.8	63.1	169	22521	894	458
9.79	94.2	62.0	167	22735	889	456
1.49	90.8	60.9	164	22767	876	454
Cycle 22	**26.02.91 - 10.01.92**					
7.54	71.2	49.9	199	22963	1011	489
7.09	97.8	64.2	240	23166	1127	491
5.80	99.7	65.9	217	23339	1089	486
7.98	99.9	66.1	209	23561	1058	477
11.66	99.7	65.4	215	23883	1087	485
14.44	99.6	64.6	220	24292	1112	489
10.94	100.1	63.8	224	24609	1133	491
20.33	99.5	62.8	227	25207	1156	493
19.65	100.0	61.8	229	25791	1171	496
20.49	99.9	60.5	228	26402	1169	498
14.27	100.1	59.3	226	26825	1160	498
6.89	99.9	58.2	223	27027	1145	496
20.96	99.9	58.0	222	27635	1141	497
7.29	100.1	56.7	219	27845	1120	490
7.82	100.0	56.4	223	28070	1145	500
4.71	99.7	58.5	253	28216	1246	481
7.89	99.1	61.0	232	28465	1178	508
14.10	99.0	61.3	225	28885	1151	510
13.74	99.4	61.2	220	29285	1129	512
17.70	99.8	61.0	213	29785	1102	514
10.65	99.8	60.8	205	30075	1071	506
9.24	98.7	60.6	198	30317	1046	498
10.01	98.4	60.3	188	30569	1014	485
1.33	98.1	60.2	182	30601	994	480
1.01	98.4	60.1	178	30625	984	478
1.22	98.3	59.8	171	30653	963	476
11.06	98.9	60.0	172	30901	966	478
7.65	98.1	59.8	165	31069	944	472
1.60	97.7	59.8	158	31103	925	467
4.63	96.9	59.4	151	31196	909	462
6.97	96.4	59.3	151	31334	908	458
9.98	96.6	59.6	144	31526	894	447
0.99	95.0	59.2	136	31544	887	444
0.31	99.6	60.8	129	31549	889	443

Elapsed Time (Day)	Core Ld. Fact. (%)	Void Fraction (V/O)	Sample Power (W/cm)	Sample Burn-up (MWd/t)	Center Temp (°C)	Surf. Temp. (°C)
Cycle 23	**18.02.92 - 07.01.93**					
2.60	76.3	48.4	177	31609	969	474
1.48	84.4	53.2	190	31645	849	456
3.35	95.0	58.4	183	31726	945	464
2.85	98.9	60.6	170	31792	970	479
4.60	99.7	61.2	165	31893	963	471
6.53	99.8	61.1	164	32033	948	469
9.98	99.8	61.0	163	32246	945	468
2.57	99.7	60.3	164	32301	949	468
9.08	99.9	60.4	164	32495	950	468
4.92	99.7	60.0	164	32600	949	468
4.02	99.9	69.6	165	32686	951	468
2.87	100.0	59.3	168	32749	963	469
7.04	100.0	59.3	167	32902	960	468
5.06	100.0	59.0	167	33012	961	468
1.88	99.8	58.6	168	33053	964	468
5.44	99.7	58.6	167	33171	961	467
1.57	99.8	58.4	166	33206	956	466
5.12	99.9	58.4	166	33316	956	466
1.93	100.1	58.0	168	33358	965	467
8.36	99.9	58.0	168	33541	965	467
5.53	99.9	57.4	169	33662	970	467
7.94	99.9	57.3	168	33836	965	466
4.07	97.4	55.0	176	33927	1000	468
1.20	90.6	52.5	160	33956	971	466
3.26	91.1	52.7	171	34028	980	467
3.60	98.6	55.1	175	34110	997	467
1.57	100.0	56.0	171	34145	979	466
7.04	100.0	56.0	170	34301	976	465
6.95	99.8	55.7	169	34455	971	464
8.11	99.7	55.4	168	34633	968	463
1.78	99.5	54.8	168	34672	967	463
3.98	99.7	54.6	169	34759	973	463
3.03	99.9	54.8	167	34826	964	462
3.87	99.8	54.4	167	34910	965	462
7.21	99.9	54.3	166	35066	961	461
7.70	99.6	53.8	166	35233	960	460
6.09	99.4	53.2	165	35364	957	460
6.95	99.9	53.2	165	35514	956	459
6.91	99.6	52.6	164	35662	953	458
4.44	100.0	52.6	162	35756	945	457
2.57	99.6	52.4	161	35810	941	457
7.01	99.8	52.4	161	35957	940	456
6.59	99.8	52.3	160	36095	937	455
6.96	99.7	52.1	158	36239	930	454
6.95	99.8	52.0	157	36381	925	453
5.14	99.4	51.8	156	36486	921	453
1.57	99.6	51.8	155	36517	921	452
2.46	99.7	51.8	155	36567	918	452
4.49	99.9	52.2	155	36658	918	452
7.49	99.6	52.1	154	36808	915	451
8.00	99.8	52.3	152	36967	907	450
5.59	99.8	52.6	150	37077	902	449
3.72	99.7	52.8	149	37150	896	447
3.14	99.7	52.8	148	37211	896	447
5.49	99.8	53.1	146	37316	887	446
1.57	99.9	53.4	144	37346	877	443
3.09	99.7	53.4	144	37404	877	442
4.02	100.0	53.7	142	37479	870	440
3.98	99.7	53.9	140	37552	860	437
4.02	99.9	54.2	138	37625	850	434
3.34	100.0	54.5	137	37685	845	433
2.56	99.9	54.7	134	37730	832	429
1.10	99.8	54.9	132	37749	821	427
5.84	100.1	55.3	130	37849	814	424
4.44	99.9	55.8	126	37923	798	421
2.61	100.0	56.4	123	37965	783	418
4.11	99.1	56.1	122	38031	780	416
0.96	98.3	56.4	119	38046	763	415
2.97	98.4	56.8	117	38091	753	413
2.28	98.2	56.9	116	38126	747	412
0.80	97.7	56.9	115	38138	741	412

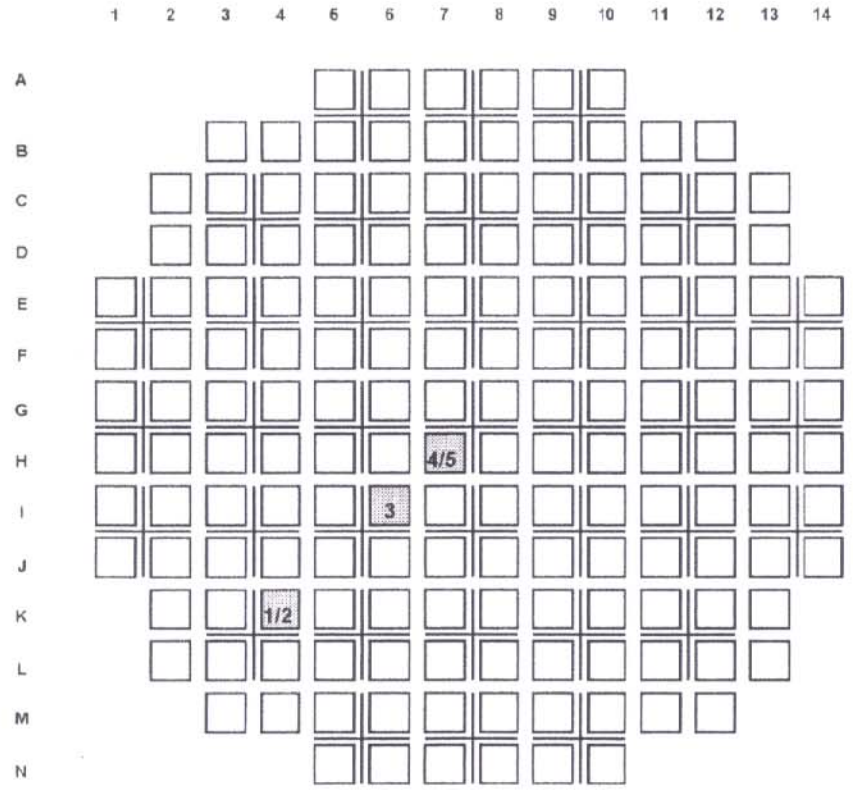
- TABLE 8 -

Assembly Average Burn-up
(GWd/tM)

	YO 12	YO 13	YO 14	Cycle BU
EOC 19	7.27	7.29	7.26	6.223
EOC 20	13.54	13.49	13.50	5.238
EOC 21	21.74	21.68	21.84	5.970
EOC 22	29.12	29.07	29.08	6.017
EOC 23		35.24	35.25	6.039

- TABLE 9 -

CROSS SECTION OF THE DODEWAARD REACTOR

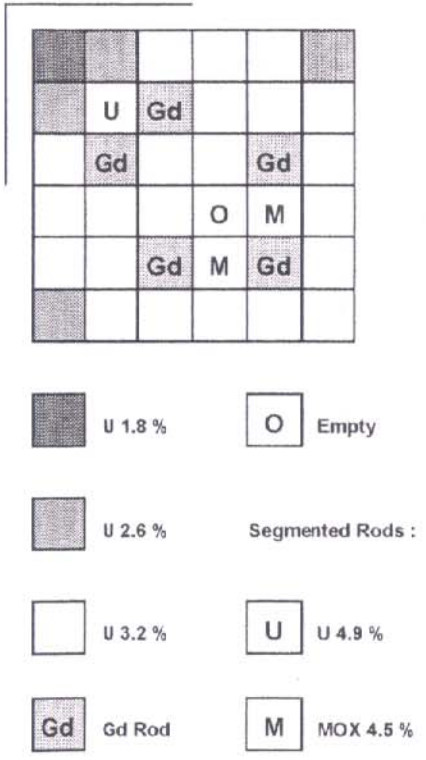


Irradiation period : 1 Cycle 19
2 Cycle 20
3 Cycle 21
4 Cycle 22
5 Cycle 23

- FIGURE 1 -

DODEWAARD

MOX FUEL ASSEMBLY

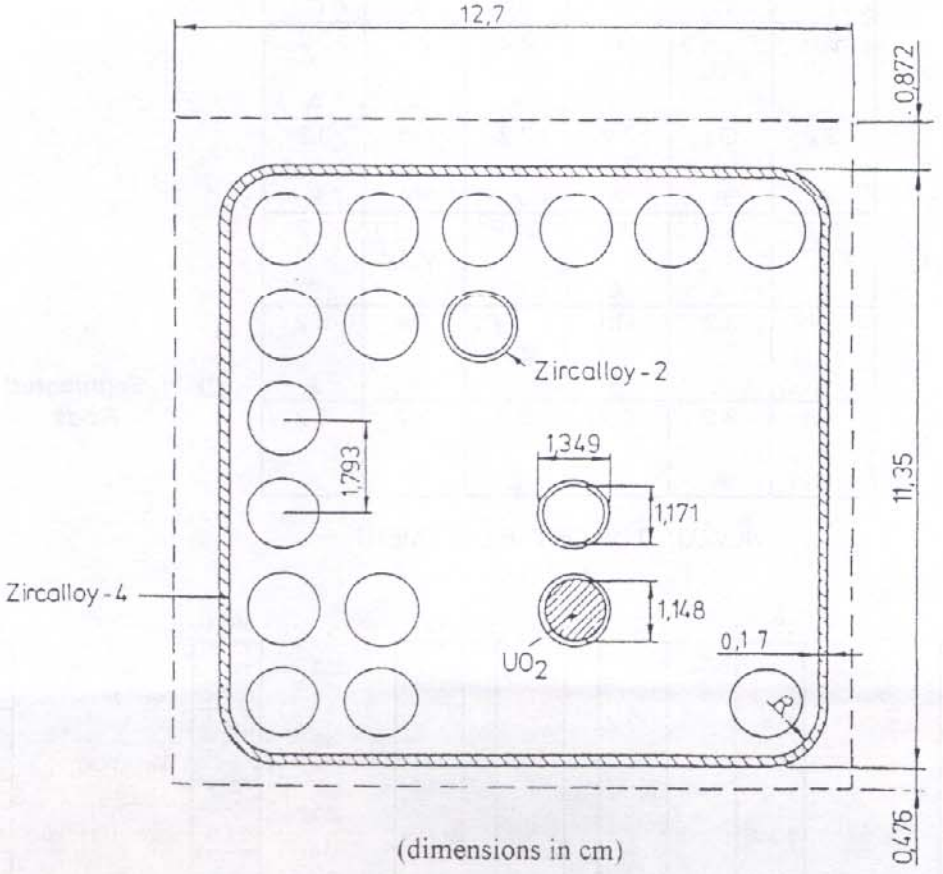


Report

BN reference No / File - "Rev" - Page
9606546/221 - " B " - 20

Other reference:
AR 96 / 05
Rev. B

Fuel assembly geometric data (standard)



(dimensions in cm)

- FIGURE 2 -

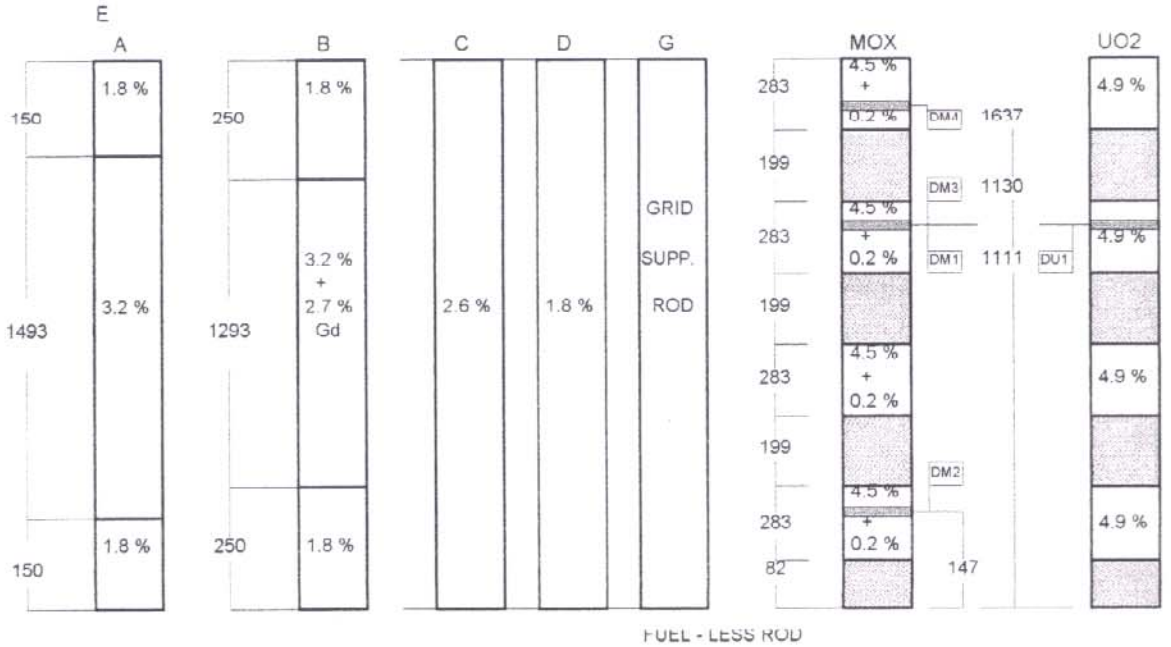
Fuel assembly enrichment distribution

Control blade location

	a	b	c	d	e	f
1	1.8 D	2.6 C	3.2 E	3.2 E	3.2 A	2.6 C
2	2.6 C	(*) UO2	Gd B	3.2 A	3.2 A	3.2 A
3	3.2 E	Gd B	3.2 A	3.2 A	Gd B	3.2 E
4	3.2 E	3.2 A	3.2 A	GSP G	(*) MOX	3.2 E
5	3.2 A	3.2 A	Gd B	(*) MOX	Gd B	3.2 A
6	2.6 C	3.2 A	3.2 E	3.2 E	3.2 A	3.2 A

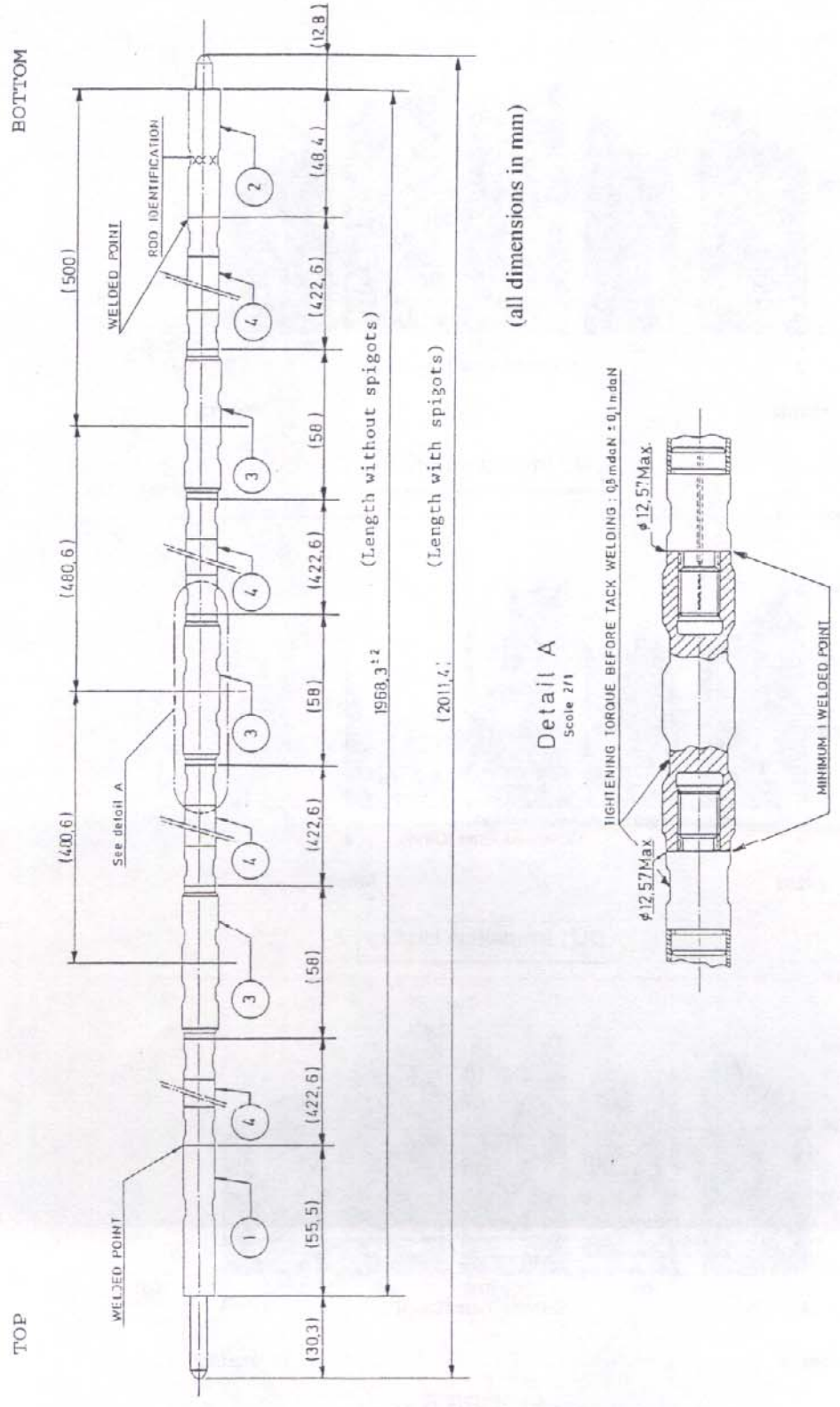
(*) : Segmented Rods

VIEW ON TOP OF FUEL ELEMENT

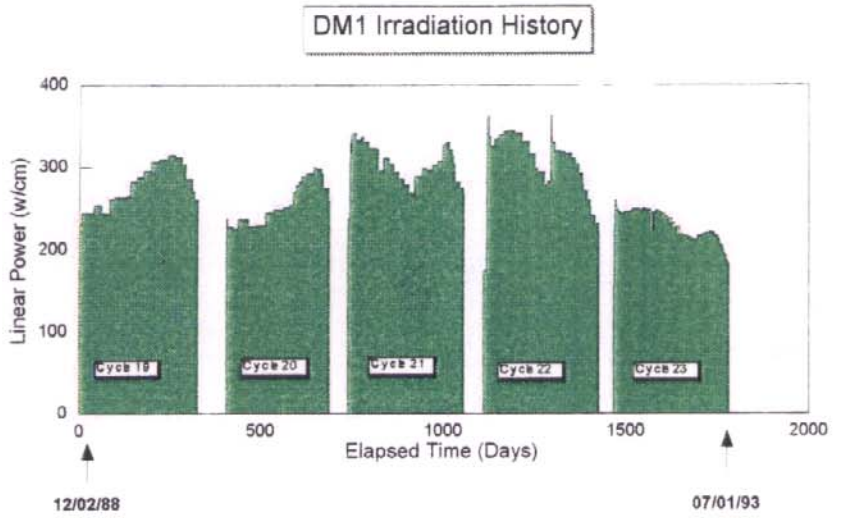


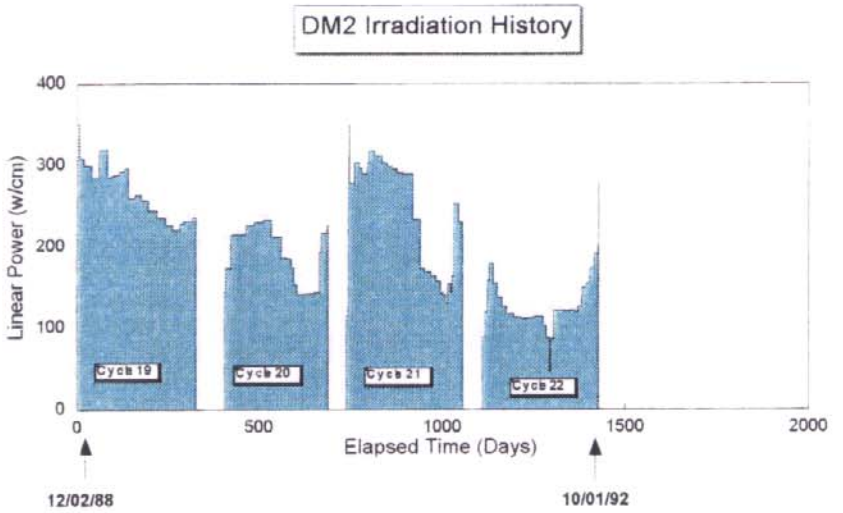
AXIAL ENRICHMENT DISTRIBUTION

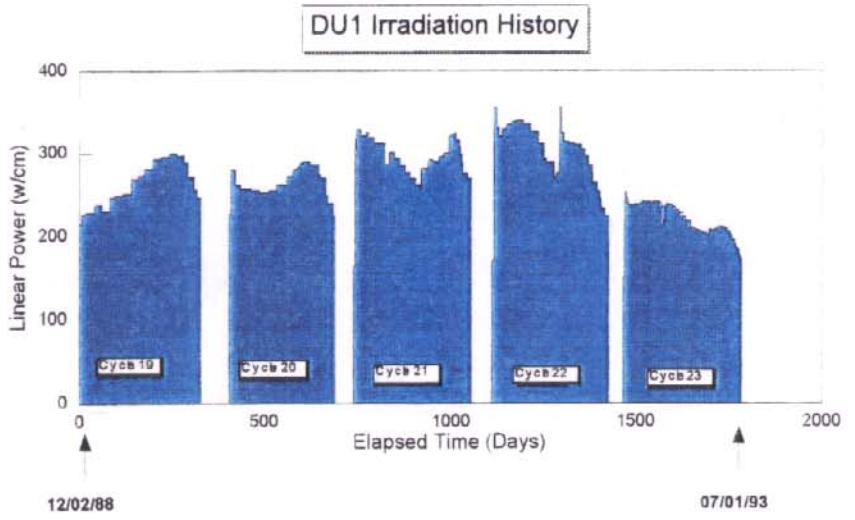
- FIGURE 3 -


BOTTOM
TOP
WELDED POINT
ROD IDENTIFICATION
See detail A
(500)
(480,6)
(400,6)
(12,8)
(48,4)
(422,6)
(58)
(55,5)
(30,3)
1968,3±2
(Length without spigots)
(2011,4)
(Length with spigots)
(all dimensions in mm)
Detail A
Scale 2/1
TIGHTENING TORQUE BEFORE TACK WELDING : 0,8 mdaN ± 0,1 mdaN
ϕ12,57Max.
MINIMUM 1 WELDED POINT

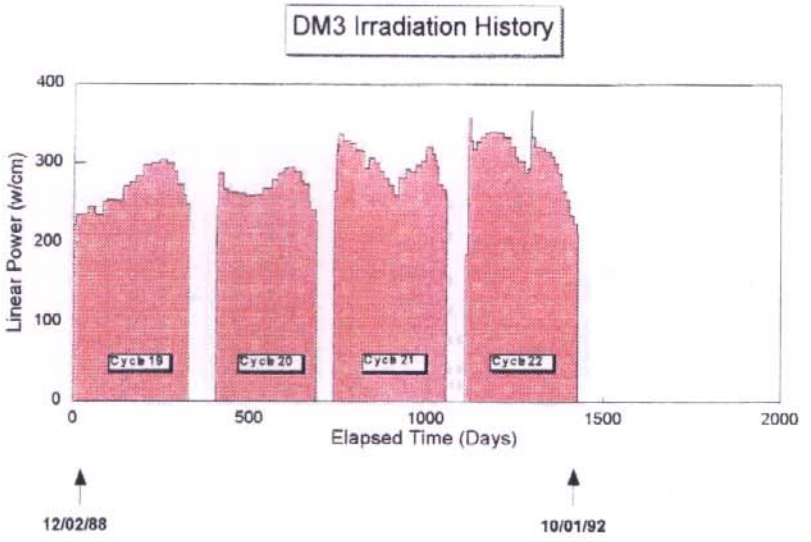
- FIGURE 4 -

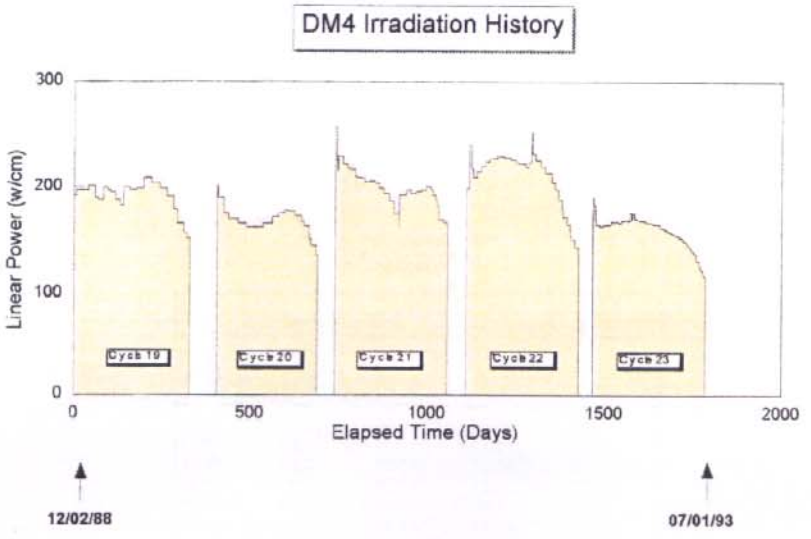

DM1 Irradiation History
Linear Power (w/cm)
400
300
200
100
0
Cycle 19
Cycle 20
Cycle 21
Cycle 22
Cycle 23
0
500
1000
1500
2000
Elapsed Time (Days)
12/02/88
07/01/93


DM2 Irradiation History
Linear Power (w/cm)
400
300
200
100
0
Cycle 19
Cycle 20
Cycle 21
Cycle 22
0
500
1000
1500
2000
Elapsed Time (Days)
12/02/88
10/01/92

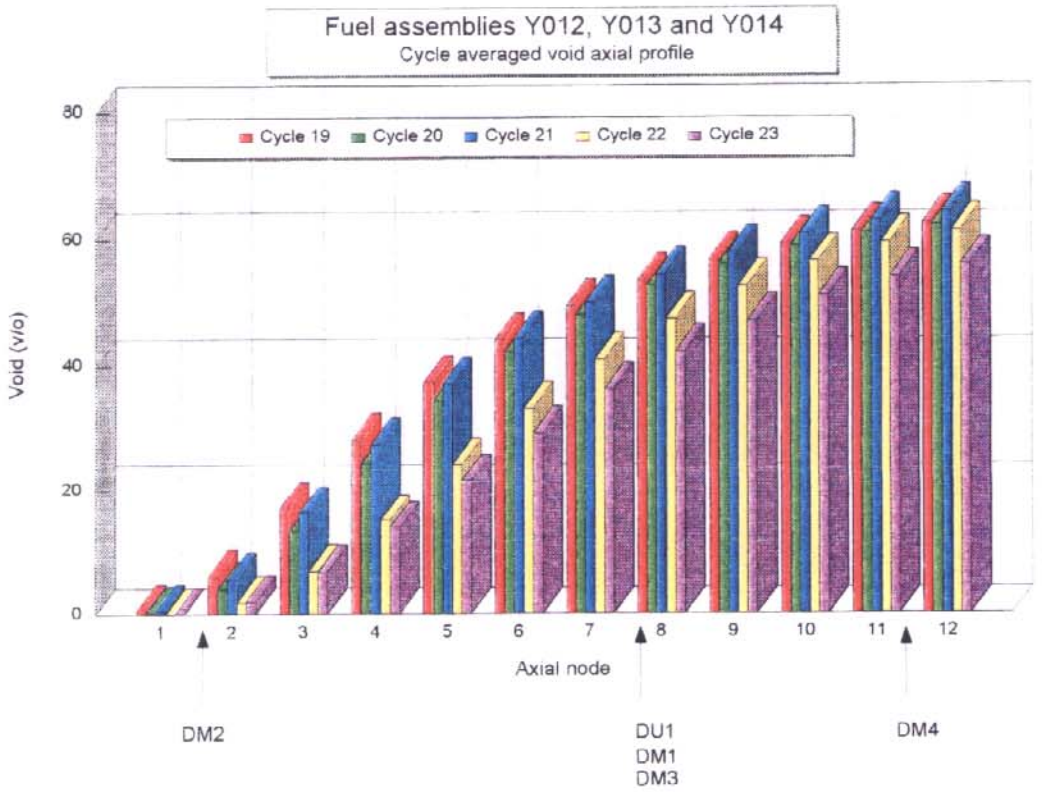

DU1 Irradiation History
Linear Power (w/cm)
400
300
200
100
0
Cycle 19
Cycle 20
Cycle 21
Cycle 22
Cycle 23
0
500
1000
1500
2000
Elapsed Time (Days)
12/02/88
07/01/93

- FIGURE 5 -


DM3 Irradiation History
Linear Power (w/cm)
400
300
200
100
0
Cycle 19
Cycle 20
Cycle 21
Cycle 22
0
500
1000
1500
2000
Elapsed Time (Days)
12/02/88
10/01/92


DM4 Irradiation History
Linear Power (w/cm)
300
200
100
0
Cycle 19
Cycle 20
Cycle 21
Cycle 22
Cycle 23
0
500
1000
1500
2000
Elapsed Time (Days)
12/02/88
07/01/93

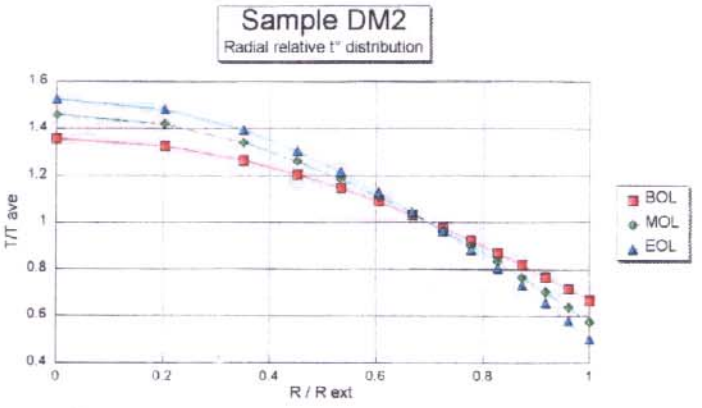
- FIGURE 6 -



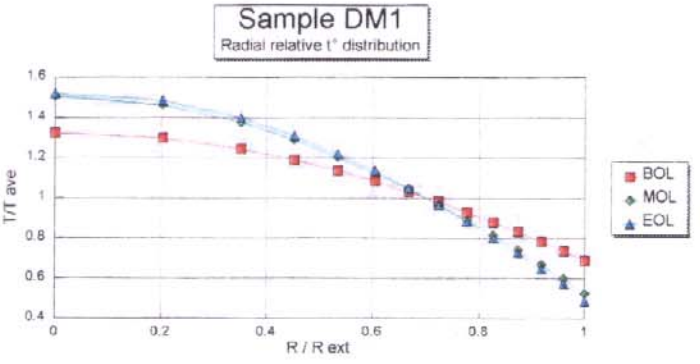
	Void profile (v/o)				
Axial Node	Cycle 19	Cycle 20	Cycle 21	Cycle 22	Cycle 23
1	0.65	0.34	0.60	0.07	0.09
2	6.16	4.15	5.72	1.92	2.03
3	17.03	13.21	16.22	7.00	6.84
4	28.26	24.51	27.55	14.97	13.81
5	37.24	34.45	37.00	24.24	21.63
6	44.06	42.11	44.30	33.16	29.29
7	49.32	47.97	49.92	40.92	36.21
8	53.43	52.53	54.37	47.33	42.16
9	56.69	56.11	57.94	52.48	47.06
10	59.22	58.88	60.79	56.45	50.98
11	61.16	60.91	62.91	59.39	53.96
12	62.51	62.22	64.31	61.28	55.92

- FIGURE 7 -

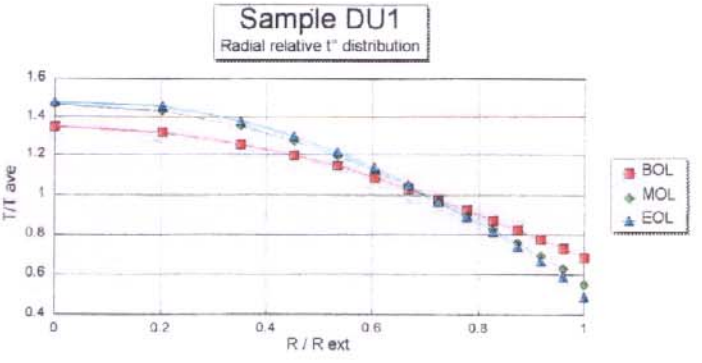
SAMPLE DM2			
R / R ext	BOL T / T ave	MOL T / T ave	EOL T / T ave
1.000	0.667	0.576	0.502
0.960	0.716	0.639	0.582
0.918	0.766	0.702	0.656
0.873	0.817	0.766	0.730
0.827	0.869	0.832	0.807
0.777	0.923	0.899	0.885
0.724	0.977	0.969	0.965
0.667	1.033	1.039	1.047
0.604	1.089	1.112	1.131
0.533	1.147	1.187	1.217
0.452	1.205	1.263	1.304
0.351	1.265	1.340	1.394
0.203	1.325	1.419	1.483
0.000	1.356	1.459	1.526



SAMPLE DM1			
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.691	0.525	0.485
0.960	0.737	0.600	0.574
0.918	0.784	0.670	0.651
0.873	0.831	0.742	0.727
0.827	0.880	0.815	0.805
0.777	0.930	0.889	0.884
0.724	0.980	0.966	0.965
0.667	1.031	1.044	1.049
0.604	1.083	1.124	1.134
0.534	1.135	1.206	1.221
0.452	1.189	1.290	1.309
0.352	1.243	1.376	1.399
0.204	1.298	1.463	1.487
0.000	1.326	1.508	1.521

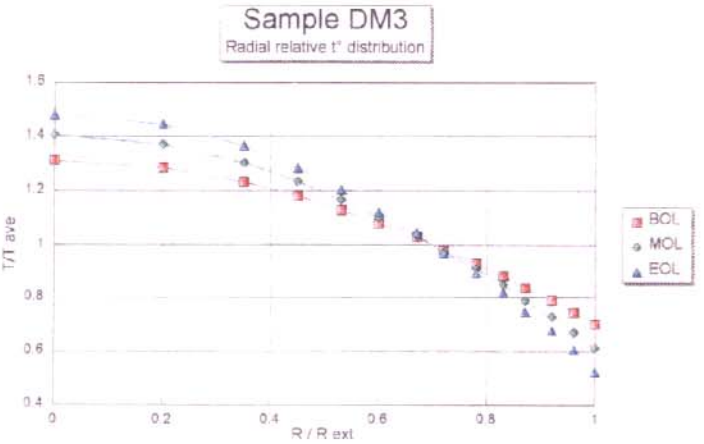


SAMPLE DU1			
R / R ext	BOL T / T ave	MOL T / T ave	EOL T / T ave
1.000	0.684	0.552	0.493
0.959	0.730	0.627	0.590
0.917	0.776	0.694	0.666
0.873	0.824	0.761	0.741
0.826	0.874	0.829	0.816
0.777	0.924	0.898	0.892
0.724	0.976	0.969	0.970
0.667	1.029	1.042	1.050
0.604	1.084	1.116	1.132
0.533	1.140	1.192	1.214
0.452	1.197	1.270	1.297
0.351	1.256	1.350	1.381
0.204	1.316	1.432	1.460
0.000	1.347	1.473	1.485

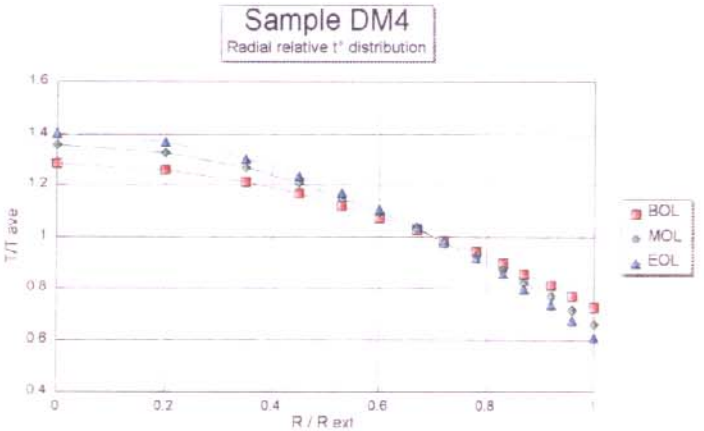


- FIGURE 8 -

SAMPLE DM3			
	BOL	MOL	EOL
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.702	0.613	0.524
0.960	0.747	0.673	0.607
0.920	0.792	0.732	0.678
0.870	0.838	0.791	0.749
0.830	0.885	0.851	0.821
0.780	0.933	0.912	0.895
0.720	0.981	0.974	0.970
0.670	1.030	1.038	1.046
0.600	1.080	1.103	1.124
0.530	1.131	1.169	1.204
0.450	1.182	1.236	1.285
0.350	1.234	1.304	1.367
0.200	1.287	1.373	1.448
0.000	1.313	1.408	1.480



SAMPLE DM4			
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.726	0.660	0.608
0.960	0.768	0.714	0.676
0.920	0.811	0.767	0.736
0.870	0.854	0.819	0.796
0.830	0.897	0.872	0.856
0.780	0.941	0.926	0.917
0.720	0.985	0.980	0.978
0.660	1.029	1.036	1.041
0.600	1.074	1.092	1.105
0.530	1.120	1.149	1.169
0.450	1.166	1.207	1.235
0.350	1.212	1.267	1.302
0.200	1.259	1.327	1.369
0.000	1.283	1.357	1.404



- FIGURE 9 -

Part II :

PWR - MOX Samples.

BEZNAU PWR

samples

BM1, BM2D, BM3 and BM4D

1. Introduction.

Four MOX samples (BM1, BM2D, BM3 and BM4D) coming from the M109 assembly irradiated in the BEZNAU-1 PWR reactor have been analysed radiochemically in the ARIANE programme.

The M109 assembly has been irradiated during 5 cycles of the BEZNAU reactor.

The 5 cycles of interest are :

- cycle 18 from july 18, 1988, till may 14,1984 ,

  fraction of MOX assemblies in the core : 10 %

- cycle 19 from july 4, 1989, till may 12, 1990,

  fraction of MOX assemblies in the core : 20 %

- cycle 20 from july 2, 1990 till may 9, 1991,

  fraction of MOX assemblies in the core : 26 %

- cycle 21 from june 29, 1991, till july 2, 1992,

  fraction of MOX assemblies in the core : 30 %

- cycle 22 from september 2, 1992, till april 1,1993,

  fraction of MOX assemblies in the core : 34 %

The location of the M109 fuel assembly inside the core during its irradiation is shown on figure 1.

Main core data are given on table 1.

2. Fuel assembly description and fabrication data

The fuel assembly is a 14 x 14 - PWR type with 179 fuel rods and three Pu-content zones. The fuel assembly data are gathered on table 2, including grids data and guide thimbles data.

Figure 2 shows the cross-section of the MOX assembly and the location of the extracted rods. Table 3 gives the as-build MOX fresh fuel characteristics. Table 4 gives the impurities.

Low and middle content of the fuel assemblies are indicated on figure 2.

A drawing of a MOX fuel rod, showing the cutting plane of the four samples is given on figure 3.

3. Irradiation follow-up.

The five cycles have been divided into several time steps where the power does not vary more than a few percent. This time step division is given on table 5.

For each sample and for each time step, are given in the tables :

- the elapsed time and the core burn-up
- the core load factor
- the M109 fuel assembly average burn-up
- the boron concentration and the local density of the coolant (averaged during the time step)
- the sample linear power and accumulated burn-up
- the fuel sample central and surface temperature

The radial temperature distributions at the beginning, middle and end of irradiation are illustrated on figure 9 for each sample.

Two sets of irradiation data are given in the report :

A first set concerns the rods E11 and G5 of the M109 fuel assembly, the second set concerns the rods D3 and B6. Initially it was foreseen that BM1 and BM2D samples became from the rod E11 and that BM3 and BM4D samples were from rod G5.
Manipulation problems during the rods shipping between BEZNAU and PSI (cask rotation) occurred in such a way that the four samples were most probably extracted from the rods D3 and B6.

In order to cover the two hypothesis, two sets of irradiation data are given :

table 6 refers to BM1 sample from rod location E11,
table 7 refers to BM2D sample from rod location E11,
table 8 refers to BM3 sample from rod location G5,
table 9 refers to BM4D sample from rod location G5,
and,

table 10 refers to BM1 sample from rod location D3,
table 11 refers to BM2D sample from rod location D3,
table 12 refers to BM3 sample from rod location B6,
table 13 refers to BM4D sample from rod location B6.

The power evolutions are illustrated on figures 5 to 8.

The sample burn-ups have been calculated with a design heavy metal weight of 6.12 gr/cm (all burn-up values are given in MWd/tM).

In order to perform macrocell of 2 x 2 assembly calculations , the environment of the M109 assembly during the irradiation has been represented according to figure 4. The UO2 assemblies have the same geometrical characteristics as the MOX fuel assemblies.

The compositions of the adjacent assemblies (UO2 or MOX) are given, as well as their average burn-ups at BOC and EOC.

The core baffle thickness is 2,86 cm of stainless steel.

The UO2 fuel effective temperature at nominal power is 840 K.

BEZNAU - UNIT 1 MAIN CORE DATA

• Type of reactor :	PWR
• Nominal thermal power :	1130 MW
• Pressure primary system :	158.2 kg/cm²
• Feedwater :	6197 kg/sec
• Coolant inlet temperature :	283.8 °C
average temperature :	300.9 °C
outlet temperature :	316.9 °C
• Fuel :	UO2 + MOX
• Oxide density :	10.3 gr/cm³
• Number of assemblies :	121
• Number of rods per assembly :	179
• Lattice type :	14 x 14
• Lattice pitch :	1.412 cm
• Cladding :	Zr-4
• Number of guide tubes :	16
• Number of instrum. tubes :	1
• Active fuel length :	3048 mm (UO2)
	3023 mm (MOX)

- TABLE 1 -

MOX Fuel Assembly Design Data

Fuel Assembly Data	• Assembly pitch (cm) : . cold	19.82
	• Array type :	14 x 14
	• Lattice pitch (mm) : . cold	14.12
	• Number of fuel rods per assembly	179
Grids Data	• Number of Zircaloy grids in active fuel length	5
	• Number of Inconel-718 grids in active fuel length	1
	• Volume of bottom Inconel-718 grid (cm^3)	68.76
	• Volume of bottom grid SS-304 inserts in active fuel length (cm^3)	24.02
	• Volume of one Zircaloy-4 grid including Zircaloy sleeves (cm^3)	200.04
Guide Thimbles Data	• Number	16
	• Material	Zr-4
	• Outer diameter (mm)	13.36
	• Inner diameter (mm)	12.50
Instrumentation Tube Data	• Number	1
	• Material	Zr-4
	• Outer diameter (mm)	10.72
	• Inner diameter (mm)	9.48

- TABLE 2 -

Fuel Characteristics

Characteristics		MOX Rod		UO2 Fuel Rod
		E11	G5	
Pellet	• Material	UO2 - PuO2	UO2 - PuO2	UO2
	• Density (% TD)	94.2 ± 0.33	95.16 ± 0.20	95.
	• Diameter (mm)	9.292 ± 0.002	9.293 ± 0.002	9.29
	• (U+Pu+Am) / oxide (w/o)	88.13	88.16	88.1
	• U-235 / U (w/o)	/	/	3.25 / 3.40
	• (Pu+Am) / (U+Pu+Am) (w/o)	6.069	6.011	/
	• Isotopic compositions (w/o)			
	U-234 / U	0.002	0.002	
	U-235 / U	0.253	0.237	/
	U-236 / U	0.002	0.001	
	U-238 / U	99.743	99.760	
	Pu-238 / (Pu + Am-241)	1.078	1.003	
	Pu-239 / (Pu + Am-241)	61.608	61.672	
	Pu-240 / (Pu + Am-241)	23.755	23.530	/
	Pu-241 / (Pu + Am-241)	8.361	8.834	
	Pu-242 / (Pu + Am-241)	4.114	3.906	
	Am-241 / (Pu + Am-241)	1.083	1.055	
	• Impurities (**)	1.041	0.529	/
	• Measuring date	MAY 1988	MAY 1988	/
Cladding	• Material	Zr-4 CWSR		Zr-4
	• Inner diameter (mm)	9.48		9.48
	• Outer diameter (mm)	10.72		10.72
Rod	• Linear weight of : U + Pu + Am (gr/cm)	6.090	6.148	6.15
	• Active length (cm) (cold)	302.4	302.3	304.8

(**) : Impurities : Equivalent Boron ppm / (U+Pu+Am)

- TABLE 3 -

Fuel Characteristics

Characteristics		MOX Rod	
		D3	B6
Pellet	• Material	UO2 - PuO2	UO2 PuO2
	• Density (% TD)	95.16 ± 0.20	95.16 ± 0.20
	• Diameter (mm)	9.293 ± 0.002	9.293 ± 0.002
	• (U+Pu+Am) / oxide (w/o)	88.16	88.16
	• U-235 / U (w/o)	/	/
	• (Pu+Am) / (U+Pu+Am) (w/o)	6.011	6.011
	• Isotopic compositions (w/o)		
	U-234 / U	0.002	0.002
	U-235 / U	0.237	0.237
	U-236 / U	0.001	0.001
	U-238 / U	99.760	99.760
	Pu-238 / (Pu + Am-241)	1.003	1.003
	Pu-239 / (Pu + Am-241)	61.672	61.672
	Pu-240 / (Pu + Am-241)	23.530	23.530
	Pu-241 / (Pu + Am-241)	8.834	8.834
	Pu-242 / (Pu + Am-241)	3.906	3.906
	Am-241 / (Pu + Am-241)	1.055	1.055
	• Impurities (**)	0.529	0.529
	• Measuring date	MAY 1988	MAY 1988
Cladding	• Material	Zr-4 CWSR	
	• Inner diameter (mm)	9.48	
	• Outer diameter (mm)	10.72	
Rod	• Linear weight of : U + Pu + Am (gr/cm)	6.153	6.149
	• Active length (cm) (cold)	302.0	301.8

(**) : Impurities . Equivalent Boron ppm / (U+Pu+Am)

Results of Metallic Impurity Analysis

Element		MOX Rod	
		E11	G5 - D3 - B6
		ppm / (U + Pu + Am)	ppm / (U + Pu + Am)
Silver	Ag	0.216	0.025
Aluminium	Al	23.864	11.818
Boron	B	0.103	0.094
Bismuth	Bi	0.017	0.006
Calcium	Ca	72.727	120.455
Cadmium	Cd	0.511	0.170
Cobalt	Co	0.057	0.016
Chromium	Cr	14.773	6.136
Copper	Cu	6.932	0.739
Iron	Fe	94.318	28.409
Indium	In	0.125	0.048
Lithium	Li	0.026	0.020
Magnesium	Mg	13.636	8.636
Manganese	Mn	1.818	0.489
Molybdenum	Mo	13.636	20.455
Nickel	Ni	7.727	2.045
Lead	Pb	1.591	0.455
Silicon	Si	15.909	15.909
Tin	Sn	0.955	0.216
Tantalum	Ta	0.034	0.011
Titanium	Ti	26.136	8.182
Thorium	Th	0.136	0.045
Vanadium	V	0.443	0.227
Tungsten	W	0.102	0.318
Zinc	Zn	14.773	2.159
Samarium	Sm	0.102	0.034
Europium	Eu	0.034	0.011
Gadolinium	Gd	0.114	0.040
Dysprosium	Dy	0.114	0.040

- TABLE 4 -

BEZNAU - CYCLES 18 TO 22
LOAD DIAGRAM AND TIME STEPS SUBDIVISION

Cycle 18 Begin : 18.07.88 End : 14.05.89
EFPD : 295

Time Step	Days	Power from	Power to	Power constant
1	1.5	0	840	0
2	2.5			840
3	2.5			985
4	29.5			1118
5	52			1124
6	2			875
7	104.5			1124
8	104.5			1124

Cycle 19 Begin : 04.07.89 End : 12.05.90
EFPD : 285

Time Step	Days	Power from	Power to	Power constant
1	1	0	840	0
2	2.5			840
3	2	840	1075	840
4	2			1075
END of CYCLE 19 - BEGINNING of CYCLE 19 A				
1	1	0	840	0
2	1.5			840
3	1	840	1090	840
4	2.5			1090
5	0.1			505
6	22			1100
7	169			1120
8	0.2			560
9	45			1120
10	1			560
11	30			1120
12	10	1120	1024	1024

Cycle 20 Begin : 02.07.90 End : 09.05.91
EFPD : 297

Time Step	Days	Power from	Power to	Power constant
1	1	0	550	0
2	1.5			550
3	2	550	1090	550
4	1			1090
5	1			550
6	110			1090
7	0.5			820
	1			0
8	76			1100
9	0.5			550
10	23			1105
11	0.2			550
12	3.5			1105
13	0.5			810
14	69.5			1105
15	18	1105	1012	1105

Cycle 21 Begin : 29.06.91 End : 02.07.92
EFPD : 351

Time Step	Days	Power from	Power to	Power constant
1	0.5	0	550	0
2	2			550
3	1.5			840
4	1			1010
5	1			1065
	0.5			0
6	2.5			1065
7	0.5			806
8	12			1080
9	0.5			806
10	51.5			1085
11	1			806
	4			0
12	138			1090
13	0.2			850
14	83			1093
15	1			550
16	66			1122

Cycle 22 Begin : 02.09.92 End : 01.04.93
EFPD : 198

Time Step	Days	Power from	Power to	Power constant
1	0.5	0	550	0
2	2			550
3	2			840
4	2			1010
5	35			1085
	2			0
6	38			1080
7	1			550
8	129			1078

- TABLE 5 -

ARIANE - Sample BM1_E11

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88	End : 14.05.89							
1.5	16	37.2	14	1121	84	0.7509	288	21	503	381
2.5	67	74.3	60	949	173	0.7422	292	91	754	473
2.5	128	87.2	115	894	208	0.7385	294	177	855	500
29.5	938	98.9	850	804	239	0.7351	296	1329	942	516
52	2375	99.5	2154	678	236	0.7349	296	3339	940	506
2	2418	77.4	2193	675	176	0.7410	293	3396	767	464
104.5	5306	99.5	4824	447	227	0.7351	296	7268	918	481
104.5	8194	99.5	7466	159	221	0.7348	296	11040	900	456
Cycle 19		Begin : 04.07.89	End : 12.05.90							
1	10	37.2	7472	1162	30	0.7559	285	11054	359	314
2.5	62	74.3	7503	987	64	0.7526	287	11081	457	352
2	109	84.7	7531	941	76	0.7514	287	11105	491	363
2	162	95.1	7563	898	87	0.7503	288	11134	521	372
12					0			11134		
1	10	37.2	7569	1062	29	0.7560	285	11139	356	313
1.5	41	74.3	7587	888	63	0.7526	287	11154	455	351
1	65	85.4	7601	841	76	0.7514	287	11166	491	363
2.5	132	96.5	7641	795	88	0.7502	288	11202	524	373
0.1	133	44.7	7642	1007	36	0.7552	285	11203	377	322
22	727	97.3	7996	754	87	0.7503	288	11516	521	371
169	5376	99.1	10739	465	88	0.7498	288	13943	522	365
0.2	5378	49.6	10740	422	38	0.7548	285	13945	384	322
45	6610	99.1	11467	160	83	0.7500	288	14552	508	360
1	6630	49.6	11475	300	39	0.7547	286	14558	387	323
30	7455	99.1	11961	45	84	0.7498	288	14970	511	359
11.1	7748	94.9	12134	6	82	0.7499	288	15120	505	357
Cycle 20		Begin : 02.07.90	End : 09.05.91							
1	7	24.3	12142	1196	54	0.7539	286	15129	428	335
1.5	27	48.7	12166	1042	112	0.7485	289	15156	586	376
2	67	72.6	12215	921	175	0.7423	292	15214	759	408
1	94	96.5	12248	813	245	0.7353	296	15254	971	443
1	108	48.7	12264	1031	116	0.7479	289	15273	596	378
110	3066	96.5	15877	657	240	0.7352	296	19598	950	414
0.5	3066	72.6	15890	586	177	0.7410	293	19613	763	387
1					0			19613		
76	5119	97.3	18421	380	241	0.7338	296	22604	951	397
0.5	5126	48.7	18429	503	111	0.7477	289	22613	575	346
23	5751	97.8	19201	238	235	0.7342	296	23499	934	390
0.2	5753	48.7	19205	443	111	0.7476	289	23502	574	342
3.5	5848	97.8	19322	201	236	0.7341	296	23637	936	389
0.5	5858	71.7	19335	314	171	0.7412	293	23651	744	366
69.5	7746	97.8	21670	112	238	0.7335	297	26356	943	376
10.3	8248	93.7	22293	13	229	0.7342	296	27079	918	371
Cycle 21		Begin : 29.06.91	End : 02.07.92							
0.5	3	24.3	22297	1463	57	0.7539	286	27083	436	314
2	30	48.7	22330	1307	115	0.7485	289	27121	582	330
1.5	61	74.3	22368	1177	183	0.7420	292	27166	780	355
1	86	89.4	22398	1108	227	0.7375	295	27203	911	368
1	112	94.2	22430	1084	243	0.7358	295	27243	956	371
0.5					0			27243		
2.5	178	94.2	22509	1078	244	0.7357	295	27343	959	371
0.5	188	71.3	22521	1174	180	0.7421	292	27357	772	354
12	506	95.6	22908	1049	245	0.7355	296	27839	963	369
0.5	516	71.3	22920	1134	179	0.7420	292	27853	769	352
51.5	1888	96	24587	951	245	0.7352	296	29917	966	360
1	1908	71.3	24611	974	178	0.7417	292	29946	769	344
4					0			29946		
138	5604	96.5	29091	676	242	0.7345	296	35409	979	346
0.2	5609	75.2	29096	561	184	0.7400	293	35415	802	334
83	7837	96.7	31789	361	239	0.7336	297	38655	992	345
1	7850	48.7	31806	488	112	0.7476	289	38673	594	312
68.7	9743	99.3	34088	152	239	0.7334	297	41362	1017	348
Cycle 22		Begin : 02.09.92	End : 01.04.93							
0.5	3	24.3	34092	1101	49	0.7542	286	41366	422	310
2	30	48.7	34121	946	98	0.7491	289	41399	565	314
2	72	74.3	34164	814	157	0.7429	292	41450	745	325
2	122	89.4	34217	741	195	0.7385	294	41514	869	335
35	1057	96	35210	654	216	0.7361	295	42748	950	343
2					0			42748		
38	2068	95.6	36290	543	216	0.7358	295	44089	962	346
1	2082	48.7	36305	712	103	0.7484	289	44106	597	322
129.2	5511	95.4	39988	302	209	0.7364	295	48516	985	361

- TABLE 6 -

ARIANE - Sample BM2D_E11

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88	End : 14.05.89							
1.5	16	37.2	14	1121	52	0.7571	284	13	427	340
2.5	67	74.3	60	949	113	0.7549	285	59	577	411
2.5	128	87.2	115	894	140	0.7540	286	116	653	438
29.5	938	98.9	850	804	167	0.7531	286	921	732	460
52	2375	99.5	2154	678	173	0.7530	286	2390	751	460
2	2418	77.4	2193	675	128	0.7544	286	2432	624	423
104.5	5306	99.5	4824	447	176	0.7529	287	5446	761	450
104.5	8194	99.5	7466	159	186	0.7526	287	8629	789	441
Cycle 19		Begin : 04.07.89	End : 12.05.90							
1	10	37.2	7472	1162	17	0.7579	284	8632	321	295
2.5	62	74.3	7503	987	39	0.7566	285	8648	386	325
2	109	84.7	7531	941	47	0.7562	285	8664	409	335
2	162	95.1	7563	898	56	0.7558	285	8682	434	345
12					0			8682		
1	10	37.2	7569	1062	17	0.7579	284	8685	321	295
1.5	41	74.3	7587	888	39	0.7566	285	8694	386	325
1	65	85.4	7601	841	48	0.7561	285	8702	411	336
2.5	132	96.5	7641	795	58	0.7557	285	8726	440	347
0.1	133	44.7	7642	1007	22	0.7576	284	8726	336	303
22	727	97.3	7996	754	57	0.7557	285	8930	437	346
169	5376	99.1	10739	465	64	0.7555	285	10694	456	351
0.2	5378	49.6	10740	422	28	0.7573	284	10694	353	311
45	6616	99.1	11467	150	65	0.7555	285	11174	459	351
1	6630	49.6	11475	300	29	0.7573	284	11179	356	312
30	7455	99.1	11961	45	68	0.7554	285	11511	467	353
11.1	7748	94.9	12134	6	68	0.7555	285	11636	467	353
Cycle 20		Begin : 02.07.90	End : 09.05.91							
1	7	24.3	12142	1196	35	0.7577	284	11641	373	319
1.5	27	48.7	12166	1042	76	0.7563	285	11660	488	359
2	67	72.6	12215	921	124	0.7547	286	11701	617	393
1	94	96.5	12248	813	182	0.753	286	11730	776	423
1	108	48.7	12264	1031	81	0.7562	285	11743	502	363
110	3056	96.5	15877	657	186	0.7529	287	15089	765	406
0.5	3066	72.6	15890	586	144	0.7543	286	15101	668	389
1					0			15101		
76	5119	97.3	18421	380	206	0.7523	287	17667	841	403
0.5	5126	48.7	18429	503	90	0.7560	285	17674	521	350
23	5751	97.8	19201	238	204	0.7523	287	18442	835	398
0.2	5753	48.7	19205	443	91	0.7560	285	18445	522	348
3.5	5848	97.8	19322	201	206	0.7523	287	18563	841	398
0.5	5858	71.7	19335	314	146	0.7542	286	18575	670	373
69.5	7746	97.8	21670	112	213	0.7521	287	21000	861	387
19.3	8248	93.7	22293	13	209	0.7523	287	21659	849	383
Cycle 21		Begin : 29.06.91	End : 02.07.92							
0.5	3	24.3	22297	1463	35	0.7577	284	21662	382	313
2	30	48.7	22330	1307	75	0.7564	285	21686	478	330
1.5	61	74.3	22368	1177	124	0.7547	286	21716	607	351
1	85	89.4	22398	1108	160	0.7536	286	21743	707	365
1	112	94.2	22430	1084	174	0.7532	286	21771	747	370
0.5					0			21771		
2.5	178	94.2	22509	1078	175	0.7532	286	21843	750	370
0.5	188	71.3	22521	1174	125	0.7547	286	21853	609	350
12	506	95.6	22908	1049	177	0.7531	286	22200	756	369
0.5	516	71.3	22920	1134	126	0.7547	286	22210	612	349
51.5	1888	96.0	24587	951	182	0.7529	287	23742	770	364
1	1908	71.3	24611	974	132	0.7546	286	23764	627	345
4					0			23764		
138	5604	96.5	29091	676	195	0.7526	287	28100	811	349
0.2	5609	75.2	29096	561	154	0.7539	286	28165	690	336
83	7837	96.7	31789	361	210	0.7522	287	31011	861	343
1	7850	48.7	31806	488	92	0.7559	285	31026	518	311
68.7	9743	99.3	34088	152	213	0.7520	287	33423	876	338
Cycle 22		Begin : 02.09.92	End : 01.04.93							
0.5	3	24.3	34092	1101	36	0.7577	284	33426	395	307
2	30	48.7	34121	946	73	0.7563	285	33450	473	305
2	72	74.3	34164	814	122	0.7546	286	33490	603	313
2	122	89.4	34217	741	158	0.7534	286	33542	710	323
35	1057	96.0	35210	654	179	0.7528	287	34567	777	327
2					0			34567		
38	2068	95.6	36290	543	183	0.7527	287	35706	793	327
1	2082	48.7	36305	712	82	0.7561	285	35720	498	304
129.2	5511	95.4	39988	302	181	0.7528	287	39543	804	324

- TABLE 7 -

ARIANE - Sample BM3_G5

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88	End : 14.05.89							
1.5	16	37.2	14	1121	60	0.7521	287	15	446	353
2.5	67	74.3	60	949	124	0.7446	291	65	613	427
2.5	128	87.2	115	894	149	0.7414	293	126	685	453
29.5	938	98.9	850	804	171	0.7385	294	952	751	471
52	2375	99.5	2154	678	170	0.7381	294	2396	750	465
2	2418	77.4	2193	675	127	0.7434	292	2438	627	428
104.5	5306	99.5	4824	447	164	0.7382	294	5247	735	451
104.5	8194	99.5	7466	159	162	0.7376	294	8023	730	438
Cycle 19		Begin : 04.07.89	End : 12.05.90							
1	10	37.2	7472	1162	43	0.7550	285	8030	398	331
2.5	62	74.3	7503	987	91	0.7507	288	8067	532	382
2	109	84.7	7531	941	107	0.7492	288	8102	576	396
2	162	95.1	7563	898	123	0.7478	289	8143	620	408
12					0			8143		
1	10	37.2	7569	1062	42	0.7551	285	8150	395	330
1.5	41	74.3	7587	888	89	0.7508	288	8171	527	380
1	65	85.4	7601	841	106	0.7492	288	8189	573	395
2.5	132	96.5	7641	795	123	0.7477	289	8239	620	408
0.1	133	44.7	7642	1007	52	0.7542	286	8240	424	342
22	727	97.3	7996	754	121	0.7478	289	8676	614	405
169	5376	99.1	10739	465	121	0.7472	290	12017	613	394
0.2	5378	49.6	10740	422	53	0.7537	286	12018	426	339
45	6616	99.1	11467	150	112	0.7475	289	12844	588	388
1	6630	49.6	11475	300	54	0.7535	286	12853	429	339
30	7455	99.1	11961	45	113	0.7472	290	13409	591	384
11.1	7748	94.9	12134	6	111	0.7473	289	13612	585	382
Cycle 20		Begin : 02.07.90	End : 09.05.91							
1	7	24.3	12142	1196	49	0.7540	286	13620	415	333
1.5	27	48.7	12166	1042	100	0.7486	289	13644	555	374
2	67	72.6	12215	921	156	0.7425	292	13695	708	407
1	94	96.5	12248	813	218	0.7355	296	13731	888	439
1	108	48.7	12264	1031	104	0.7480	289	13748	566	377
110	3056	96.5	15877	657	216	0.7353	296	17635	880	410
0.5	3066	72.6	15890	586	160	0.7409	293	17648	717	390
1					0			17648		
76	5119	97.3	18421	380	218	0.7337	296	20363	885	402
0.5	5126	48.7	18429	503	102	0.7476	289	20372	553	351
23	5751	97.8	19201	238	215	0.7340	296	21179	876	397
0.2	5753	48.7	19205	443	102	0.7475	289	21182	552	348
3.5	5848	97.8	19322	201	215	0.7339	296	21305	876	396
0.5	5858	71.7	19335	314	156	0.7409	293	21318	703	372
69.5	7746	97.8	21670	112	217	0.7332	297	23789	882	384
19.3	8248	93.7	22293	13	210	0.7339	296	24452	861	379
Cycle 21		Begin : 29.06.91	End : 02.07.92							
0.5	3	24.3	22297	1463	51	0.7540	286	24457	422	317
2	30	48.7	22330	1307	104	0.7487	289	24490	554	336
1.5	61	74.3	22368	1177	163	0.7422	292	24530	721	359
1	86	89.4	22396	1108	202	0.7377	294	24563	836	374
1	112	94.2	22430	1084	216	0.7360	295	24599	878	379
0.5					0			24599		
2.5	178	94.2	22509	1078	216	0.7359	295	24687	878	378
0.5	188	71.3	22521	1174	160	0.7423	292	24700	712	358
12	506	95.6	22908	1049	218	0.7358	295	25127	884	377
0.5	516	71.3	22920	1134	160	0.7422	292	25140	712	356
51.5	1888	96	24587	951	218	0.7354	296	26974	886	369
1	1908	71.3	24611	974	159	0.7418	292	27000	710	349
4					0			27000		
138	5604	96.5	29091	676	217	0.7340	296	31667	892	351
0.2	5609	75.2	29096	561	165	0.7400	293	31892	734	336
83	7837	96.7	31789	361	215	0.7336	297	34808	897	345
1	7850	48.7	31806	488	101	0.7475	289	34824	551	311
68.7	9743	99.3	34088	152	216	0.7332	297	37254	912	342
Cycle 22		Begin : 02.09.92	End : 01.04.93							
0.5	3	24.3	34092	1101	46	0.7541	286	37258	416	307
2	30	48.7	34121	946	91	0.7491	289	37287	529	309
2	72	74.3	34164	814	144	0.7428	292	37335	685	321
2	122	89.4	34217	741	180	0.7384	294	37393	798	332
35	1057	96	35210	654	196	0.7360	295	38520	861	336
2					0			38528		
38	2068	95.6	36290	543	198	0.7357	295	39761	868	336
1	2082	48.7	36305	712	95	0.7483	289	39777	549	311
129.2	5511	95.4	39988	302	192	0.7363	295	43839	877	339

- TABLE 8 -

ARIANE - Sample BM4D_G5

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88		End : 14.05.89						
1.5	16	37.2	14	1121	37	0.7572	284	9	397	322
2.5	67	74.3	60	949	80	0.7553	285	42	491	375
2.5	128	87.2	115	894	100	0.7545	286	83	543	397
29.5	938	98.9	850	804	119	0.7537	286	657	596	417
52	2375	99.5	2154	678	124	0.7535	286	1707	612	421
2	2418	77.4	2193	675	92	0.7549	285	1737	526	389
104.5	5306	99.5	4824	447	127	0.7534	286	3910	625	420
104.5	8194	99.5	7466	159	130	0.7531	286	6227	651	420
Cycle 19		Begin : 04.07.89		End : 12.05.90						
1	10	37.2	7472	1162	25	0.7577	284	6232	348	307
2.5	62	74.3	7503	987	55	0.7563	285	6254	431	346
2	109	84.7	7531	941	67	0.7558	285	6276	464	359
2	162	95.1	7563	898	79	0.7554	285	6302	497	372
12					0			6302		
1	10	37.2	7569	1062	25	0.7577	284	6306	348	307
1.5	41	74.3	7587	888	55	0.7563	285	6320	431	346
1	65	85.4	7601	841	68	0.7558	285	6331	467	360
2.5	132	96.5	7641	795	80	0.7553	285	6364	500	373
0.1	133	44.7	7642	1007	31	0.7574	284	6364	365	315
22	727	97.3	7996	754	79	0.7553	285	6648	497	372
169	5376	99.1	10739	465	88	0.7551	285	9083	522	375
0.2	5378	49.6	10740	422	39	0.7572	284	9084	385	325
45	5616	99.1	11407	150	89	0.7550	286	9737	524	375
1	6630	49.6	11475	300	41	0.7571	284	9744	391	327
30	7455	99.1	11961	45	92	0.7550	285	10195	532	376
11.1	7748	94.9	12134	6	92	0.7551	285	10364	532	375
Cycle 20		Begin : 02.07.90		End : 09.05.91						
1	7	24.3	12142	1196	32	0.7577	284	10369	364	316
1.5	27	48.7	12166	1042	69	0.7563	285	10386	469	355
2	67	72.6	12215	921	112	0.7547	286	10422	586	390
1	94	96.5	12248	813	164	0.7530	286	10449	727	420
1	108	48.7	12264	1031	73	0.7562	285	10461	480	359
110	3050	96.5	15877	657	169	0.7528	287	13501	739	408
0.5	3066	72.6	15890	586	132	0.7542	286	13512	637	390
1					0			13512		
76	5119	97.3	18421	380	189	0.7523	287	15858	793	405
0.5	5126	48.7	18429	503	83	0.7559	285	15865	504	352
23	5751	97.8	19201	238	187	0.7523	287	16570	787	401
0.2	5753	48.7	19205	443	84	0.7559	285	16572	506	351
3.5	5848	97.8	19322	201	189	0.7522	287	16681	793	401
0.5	5858	71.7	19335	314	135	0.7541	286	16692	642	377
69.5	7746	97.8	21670	112	196	0.7520	287	18919	812	392
19.3	8240	93.7	22203	13	193	0.7522	287	19526	803	388
Cycle 21		Begin : 29.06.91		End : 02.07.92						
0.5	3	24.3	22297	1463	33	0.7577	284	19529	375	313
2	30	48.7	22330	1307	68	0.7564	285	19551	462	333
1.5	61	74.3	22368	1177	112	0.7547	286	19579	577	354
1	86	89.4	22398	1108	144	0.7536	286	19602	664	368
1	112	94.2	22430	1084	156	0.7532	286	19627	697	373
0.5					0			19627		
2.5	178	94.2	22509	1078	157	0.7531	286	19692	700	373
0.5	188	71.3	22521	1174	112	0.7548	285	19701	577	354
12	506	95.6	22908	1049	158	0.7531	286	20011	703	372
0.5	516	71.3	22920	1134	114	0.7547	286	20020	582	353
51.5	1888	96.0	24587	951	163	0.7529	287	21393	716	368
1	1908	71.3	24611	974	120	0.7546	286	21413	596	350
4					0			21413		
130	5604	96.6	29001	676	175	0.7526	287	25372	750	354
0.2	5609	75.2	29096	561	140	0.7539	286	25377	649	342
83	7837	96.7	31789	361	190	0.7522	287	27951	796	349
1	7850	48.7	31806	488	84	0.7559	285	27965	497	316
68.7	9743	99.3	34088	152	194	0.7520	287	30141	812	343
Cycle 22		Begin : 02.09.92		End : 01.04.93						
0.5	3	24.3	34092	1101	33	0.7577	284	30144	388	308
2	30	48.7	34121	946	68	0.7563	285	30166	459	309
2	72	74.3	34164	814	113	0.7546	286	30203	574	318
2	122	89.4	34217	741	145	0.7534	286	30251	665	327
35	1057	96.0	36210	654	164	0.7528	287	31191	723	331
2					0			31191		
38	2068	95.6	36290	543	168	0.7527	287	32237	737	329
1	2082	48.7	36305	712	76	0.7561	285	32249	479	307
129.2	5511	95.4	39988	302	166	0.7528	287	35763	741	322

- TABLE 9 -

ARIANE - Sample BM1_D3

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88	End : 14.05.89							
1.5	16	37.2	14	1121	69	0.7521	287	17	467	363
2.5	67	74.3	60	949	143	0.7446	291	76	667	446
2.5	128	87.2	115	894	173	0.7414	293	146	754	473
29.5	938	98.9	850	804	199	0.7385	294	1109	831	490
52	2375	99.5	2154	678	199	0.7381	294	2797	833	484
2	2418	77.4	2193	675	148	0.7434	292	2845	686	444
104.5	5306	99.5	4824	447	193	0.7382	294	6142	817	465
104.5	8194	99.5	7466	159	192	0.7376	294	9416	814	448
Cycle 19		Begin : 04.07.89	End : 12.05.90							
1	10	37.2	7472	1162	36	0.7550	285	9422	377	322
2.5	62	74.3	7503	988	77	0.7507	288	9454	494	367
2	109	84.7	7531	941	90	0.7492	288	9483	530	379
2	162	95.1	7563	898	104	0.7478	289	9517	569	391
12					0			9517		
1	10	37.2	7569	1059	35	0.7551	285	9523	374	321
1.5	41	74.3	7587	884	75	0.7508	288	9541	489	365
1	65	85.4	7601	837	89	0.7492	288	9556	528	378
2.5	132	96.5	7641	791	104	0.7477	289	9598	569	390
0.1	133	44.7	7642	1003	43	0.7542	286	9599	398	331
22	727	97.3	7997	751	102	0.7478	289	9967	563	388
169	5376	99.1	10750	461	103	0.7472	290	12817	565	380
0.2	5378	49.6	10752	419	45	0.7537	286	12818	404	331
45	6616	99.1	11480	146	96	0.7474	289	13526	545	373
1	6630	49.6	11488	297	46	0.7535	286	13534	407	331
30	7455	99.1	11975	41	98	0.7472	290	14012	550	372
10	7718	94.9	12130	3	96	0.7473	289	14169	545	371
Cycle 20		Begin : 02.07.90	End : 09.05.91							
1	7	24.3	12138	1099	51	0.7540	286	14178	420	334
1.5	27	48.7	12163	944	106	0.7488	289	14204	570	376
2	67	72.6	12211	822	167	0.7426	292	14258	738	409
1	94	96.5	12243	712	234	0.7356	296	14296	937	444
1	108	48.7	12260	933	111	0.7481	289	14314	584	379
110	3056	96.5	15850	560	233	0.7354	296	18502	930	417
0.5	3066	72.6	15862	492	173	0.7410	293	18516	752	391
1					0			18516		
76	5119	97.3	18385	286	238	0.7337	296	21470	943	402
0.5	5126	48.7	18393	415	110	0.7476	289	21479	573	350
23	5751	97.8	19163	147	235	0.7340	296	22362	934	396
0.2	5753	48.7	19167	356	111	0.7476	289	22366	575	347
3.5	5848	97.8	19284	111	235	0.7339	296	22501	934	395
0.5	5858	71.7	19296	225	171	0.7410	293	22515	745	372
69.5	7746	97.8	21627	24	238	0.7332	297	25224	943	382
17.6	8210	94	22203	90	232	0.7340	296	25893	925	377
Cycle 21		Begin : 29.06.91	End : 02.07.92							
0.5	3	24.3	22207	1400	56	0.7540	286	25898	433	316
2	30	48.7	22239	1244	113	0.7486	289	25935	577	334
1.5	61	74.3	22276	1114	179	0.7421	292	25979	768	359
1	86	89.4	22306	1044	222	0.7376	294	26015	895	373
1	112	94.2	22337	1020	238	0.7359	295	26054	942	376
0.5					0			26054		
2.5	178	94.2	22415	1015	239	0.7357	295	26152	945	376
0.5	188	71.3	22427	1111	176	0.7422	292	26166	759	357
12	506	95.6	22808	986	240	0.7356	296	26637	948	374
0.5	516	71.3	22820	1072	176	0.7421	292	26652	759	355
51.5	1888	96	24460	889	240	0.7353	296	28676	950	365
1	1908	71.3	24484	915	175	0.7418	292	28705	758	348
4					0			28705		
136	5604	96.5	28902	617	239	0.7346	296	34107	964	348
0.2	5609	75.2	28907	506	182	0.7401	293	34113	791	336
83	7837	96.7	31568	306	238	0.7337	296	37337	980	344
1	7850	48.7	31584	435	111	0.7477	289	37355	586	312
66	9669	99.3	33753	102	240	0.7334	297	39941	1007	346
Cycle 22		Begin : 02.09.92	End : 01.04.93							
0.5	3	24.3	33757	1101	48	0.7541	286	39945	420	308
2	30	48.7	33786	946	97	0.7491	289	39977	555	311
2	72	74.3	33829	814	155	0.7428	292	40028	731	324
2	122	89.4	33882	741	193	0.7384	294	40091	853	334
35	1057	96	34875	654	213	0.7360	295	41313	928	340
2					0			41313		
38	2068	95.6	35955	543	214	0.7357	295	42640	942	343
1	2082	48.7	35970	712	102	0.7483	289	42656	584	318
129.2	5511	95.4	39653	302	207	0.7363	295	47020	960	353

- TABLE 10 -

ARIANE - Sample BM2D_D3

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88		End : 14.05.89						
1.5	16	37.2	14	1121	39	0.7575	284	10	401	324
2.5	67	74.3	60	949	86	0.7557	285	45	506	381
2.5	128	87.2	115	894	108	0.7550	285	89	564	405
29.5	938	98.9	850	804	129	0.7544	286	710	623	426
52	2375	99.5	2154	678	135	0.7542	286	1855	643	430
2	2418	77.4	2193	675	100	0.7554	285	1888	547	397
104.5	5306	99.5	4824	447	140	0.7541	286	4280	660	429
104.5	8194	99.5	7466	159	151	0.7539	286	6865	692	428
Cycle 19		Begin : 04.07.89		End : 12.05.90						
1	10	37.2	7472	1162	19	0.7578	284	6868	330	298
2.5	62	74.3	7503	988	43	0.7565	285	6885	398	331
2	109	84.7	7531	941	52	0.7561	285	6902	423	342
2	162	95.1	7563	898	61	0.7557	285	6923	448	352
12					0			6923		
1	10	37.2	7569	1059	19	0.7578	284	6926	330	298
1.5	41	74.3	7587	884	43	0.7565	285	6936	398	331
1	65	85.4	7601	837	53	0.7561	285	6945	426	343
2.5	132	96.5	7641	791	63	0.7556	285	6970	454	355
0.1	133	44.7	7642	1003	24	0.7576	284	6971	344	305
22	727	97.3	7997	751	62	0.7556	285	7193	451	353
169	5376	99.1	10750	461	70	0.7554	285	9129	473	359
0.2	5378	49.6	10752	419	31	0.7573	284	9130	362	315
45	6616	99.1	11480	146	72	0.7554	285	9657	478	360
1	6630	49.6	11488	297	32	0.7573	284	9662	365	316
30	7455	99.1	11975	41	74	0.7553	285	10028	484	361
10	7718	94.9	12130	3	75	0.7554	285	10150	486	362
Cycle 20		Begin : 02.07.90		End : 09.05.91						
1	7	24.3	12138	1099	33	0.7579	284	10156	367	317
1.5	27	48.7	12163	944	70	0.7567	284	10173	472	357
2	67	72.6	12211	822	116	0.7553	285	10211	596	393
1	94	96.5	12243	712	171	0.7537	286	10239	746	425
1	108	48.7	12260	933	75	0.7566	285	10251	486	361
110	3056	96.5	15850	560	176	0.7536	286	13425	758	412
0.5	3066	72.6	15862	492	138	0.7549	285	13437	653	393
1					0			13437		
76	5119	97.3	18385	286	199	0.7532	286	15911	822	409
0.5	5126	48.7	18393	415	87	0.7563	285	15918	514	354
23	5751	97.8	19163	147	199	0.7532	286	16666	821	405
0.2	5753	48.7	19167	356	88	0.7563	285	16669	516	353
3.5	5848	97.8	19284	111	201	0.7531	286	16783	827	405
0.5	5858	71.7	19296	225	142	0.7548	285	16795	661	380
69.5	7746	97.8	21627	24	208	0.7530	286	19163	846	395
17.6	8210	94	22203	90	202	0.7532	286	19747	828	390
Cycle 21		Begin : 29.06.91		End : 02.07.92						
0.5	3	24.3	22207	1400	34	0.7579	284	19749	377	314
2	30	48.7	22239	1244	71	0.7567	284	19773	469	334
1.5	61	74.3	22276	1114	119	0.7552	285	19802	595	356
1	86	89.4	22306	1044	153	0.7542	286	19827	688	370
1	112	94.2	22337	1020	167	0.7539	286	19854	728	376
0.5					0			19854		
2.5	178	94.2	22415	1015	168	0.7538	286	19923	730	376
0.5	188	71.3	22427	1111	120	0.7553	285	19933	598	356
12	506	95.6	22808	986	169	0.7538	286	20265	733	375
0.5	516	71.3	22820	1072	121	0.7552	285	20274	600	355
51.5	1888	96	24460	889	174	0.7537	286	21743	747	370
1	1908	71.3	24484	915	127	0.7551	285	21764	615	351
4					0			21764		
138	5604	96.5	28902	617	188	0.7534	286	26000	788	355
0.2	5609	75.2	28907	506	149	0.7546	286	26005	674	342
83	7837	96.7	31568	306	203	0.7531	286	28757	835	349
1	7850	48.7	31584	435	89	0.7563	285	28772	509	315
66	9669	99.3	33753	102	208	0.7530	286	31014	854	343
Cycle 22		Begin : 02.09.92		End : 01.04.93						
0.5	3	24.3	33757	1101	33	0.7579	284	31016	389	308
2	30	48.7	33786	946	68	0.7566	285	31039	460	307
2	72	74.3	33829	814	115	0.7551	285	31076	580	316
2	122	89.4	33882	741	148	0.7542	286	31125	675	326
35	1057	96	34875	654	168	0.7536	286	32088	737	329
2					0			32088		
38	2068	95.6	35955	543	173	0.7535	286	33160	754	328
1	2082	48.7	35970	712	77	0.7565	285	33172	482	305
129.2	5511	95.4	39653	302	171	0.7536	286	36779	760	322

- TABLE 11 -

ARIANE - Sample BM3_B6

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88		End : 14.05.89						
1.5	16	37.2	14	1121	84	0.7521	287	21	503	381
2.5	67	74.3	60	949	175	0.7446	291	92	758	473
2.5	128	87.2	115	894	212	0.7414	293	179	864	501
29.5	938	98.9	850	804	244	0.7385	294	1355	954	517
52	2375	99.5	2154	678	242	0.7381	294	3412	956	508
2	2418	77.4	2193	675	180	0.7434	292	3471	777	466
104.5	5306	99.5	4824	447	234	0.7382	294	7465	938	482
104.5	8194	99.5	7466	159	230	0.7376	294	11400	926	458
Cycle 19		Begin : 04.07.89		End : 12.05.90						
1	10	37.2	7472	1162	26	0.7550	285	11405	348	310
2.5	62	74.3	7503	988	56	0.7507	288	11428	436	345
2	109	84.7	7531	941	66	0.7492	288	11449	465	355
2	162	95.1	7563	898	76	0.7478	289	11474	493	364
12					0			11474		
1	10	37.2	7569	1059	26	0.7551	285	11479	348	310
1.5	41	74.3	7587	884	55	0.7508	288	11492	433	344
1	65	85.4	7601	837	66	0.7492	288	11503	465	355
2.5	132	96.5	7641	791	77	0.7477	289	11534	495	365
0.1	133	44.7	7642	1003	32	0.7542	286	11535	366	317
22	727	97.3	7997	751	76	0.7478	289	11808	492	363
169	5376	99.1	10750	461	77	0.7472	290	13946	494	359
0.2	5378	49.6	10752	419	34	0.7537	286	13947	373	319
45	6616	99.1	11480	146	73	0.7474	289	14487	483	354
1	6630	49.6	11488	297	34	0.7535	286	14492	374	319
30	7455	99.1	11975	41	75	0.7472	290	14861	488	355
10	7718	94.9	12130	3	74	0.7473	289	14982	485	354
Cycle 20		Begin : 02.07.90		End : 09.05.91						
1	7	24.3	12138	1099	53	0.7540	286	14990	426	335
1.5	27	48.7	12163	944	110	0.7488	289	15017	580	375
2	67	72.6	12211	822	173	0.7426	292	15074	754	408
1	94	96.5	12243	712	243	0.7356	296	15113	964	443
1	108	48.7	12260	933	114	0.7481	289	15132	591	377
110	3056	96.5	15850	560	241	0.7354	296	19470	953	415
0.5	3066	72.6	15862	492	179	0.7410	293	19485	769	389
1					0			19485		
76	5119	97.3	18385	286	245	0.7337	296	22533	963	398
0.5	5126	48.7	18393	415	113	0.7476	289	22542	580	347
23	5751	97.8	19163	147	242	0.7340	296	23451	954	392
0.2	5753	48.7	19167	356	113	0.7476	289	23455	579	343
3.5	5848	97.8	19284	111	242	0.7339	296	23594	954	391
0.5	5858	71.7	19296	225	175	0.7410	293	23608	756	368
69.5	7746	97.8	21627	24	245	0.7332	297	26396	963	377
17.6	8210	94	22203	90	239	0.7340	296	27083	946	373
Cycle 21		Begin : 29.06.91		End : 02.07.92						
0.5	3	24.3	22207	1400	57	0.7540	286	27088	436	314
2	30	48.7	22239	1244	115	0.7486	289	27126	582	330
1.5	61	74.3	22276	1114	183	0.7421	292	27171	780	355
1	86	89.4	22306	1044	229	0.7376	294	27208	916	369
1	112	94.2	22337	1020	245	0.7359	295	27248	962	371
0.5					0			27248		
2.5	178	94.2	22415	1015	246	0.7357	295	27349	965	371
0.5	188	71.3	22427	1111	181	0.7422	292	27363	774	354
12	506	95.6	22808	986	247	0.7356	296	27848	968	369
0.5	516	71.3	22820	1072	180	0.7421	292	27863	772	352
51.5	1888	96	24460	889	247	0.7353	296	29944	971	360
1	1908	71.3	24484	915	179	0.7418	292	29974	772	344
4					0			29974		
138	5604	96.5	28902	617	246	0.7346	296	35521	991	346
0.2	5609	75.2	28907	506	187	0.7401	293	35528	811	334
83	7837	96.7	31568	306	244	0.7337	296	38836	1010	345
1	7850	48.7	31584	435	114	0.7477	289	38854	600	313
66	9669	99.3	33753	102	246	0.7334	297	41507	1044	350
Cycle 22		Begin : 02.09.92		End : 01.04.93						
0.5	3	24.3	33757	1101	48	0.7541	286	41511	419	310
2	30	48.7	33786	946	96	0.7491	289	41542	560	314
2	72	74.3	33829	814	153	0.7428	292	41592	734	325
2	122	89.4	33882	741	190	0.7384	294	41654	853	334
35	1057	96	34875	654	210	0.7360	295	42858	930	342
2					0			42858		
38	2068	95.6	35955	543	210	0.7357	295	44165	942	345
1	2082	48.7	35970	712	100	0.7483	289	44181	588	323
129.2	5511	95.4	39653	302	204	0.7363	295	48480	965	358

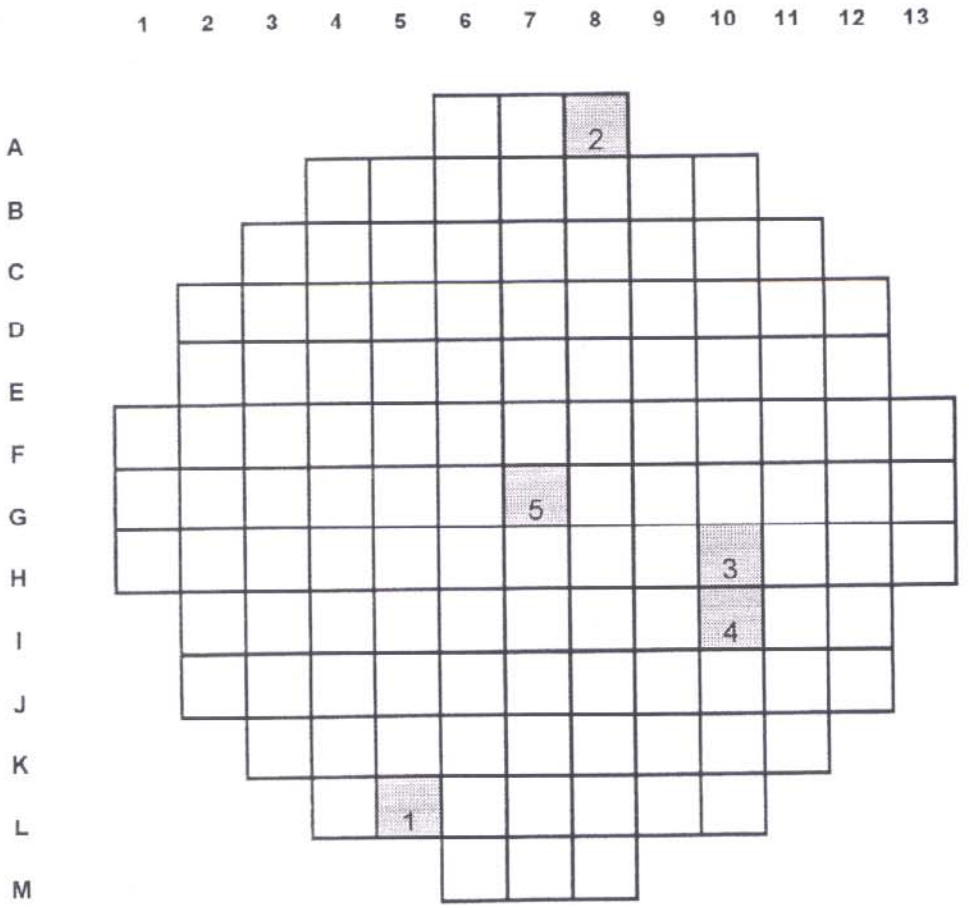
- TABLE 12 -

ARIANE - Sample BM4D_B6

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M109 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (gr/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 18		Begin : 18.07.88		End : 14.05.89						
1.5	16	37.2	14	1121	48	0.7575	284	12	418	335
2.5	67	74.3	60	949	105	0.7557	285	55	555	402
2.5	128	87.2	115	894	132	0.7550	285	109	630	430
29.5	938	98.9	850	804	157	0.7544	286	868	703	451
52	2375	99.5	2154	678	164	0.7542	286	2263	725	453
2	2418	77.4	2193	675	122	0.7554	285	2303	607	417
104.5	5306	99.5	4824	447	170	0.7541	286	5201	744	446
104.5	8194	99.5	7466	159	182	0.7539	286	8307	777	440
Cycle 19		Begin : 04.07.89		End : 12.05.90						
1	10	37.2	7472	1162	14	0.7578	284	8310	312	291
2.5	62	74.3	7503	988	31	0.7565	285	8323	363	315
2	109	84.7	7531	941	38	0.7561	285	8335	383	325
2	162	95.1	7563	898	45	0.7557	285	8350	403	333
12					0			8350		
1	10	37.2	7569	1059	14	0.7578	284	8352	312	291
1.5	41	74.3	7587	884	32	0.7565	285	8360	366	317
1	65	85.4	7601	837	39	0.7561	285	8366	386	326
2.5	132	96.5	7641	791	47	0.7556	285	8385	409	336
0.1	133	44.7	7642	1003	18	0.7576	284	8386	324	297
22	727	97.3	7997	751	46	0.7556	285	8550	406	334
169	5376	99.1	10750	461	53	0.7554	285	10003	425	341
0.2	5378	49.6	10752	419	23	0.7573	284	10004	338	305
45	6616	99.1	11480	146	55	0.7554	285	10405	431	343
1	6630	49.6	11488	297	24	0.7573	284	10409	341	306
30	7455	99.1	11975	41	57	0.7553	285	10690	437	344
10	7718	94.9	12130	3	58	0.7554	285	10785	439	345
Cycle 20		Begin : 02.07.90		End : 09.05.91						
1	7	24.3	12138	1099	34	0.7579	284	10791	370	318
1.5	27	48.7	12163	944	72	0.7567	284	10808	477	357
2	67	72.6	12211	822	120	0.7553	285	10848	607	393
1	94	96.5	12243	712	177	0.7537	286	10877	762	425
1	108	48.7	12260	933	78	0.7566	285	10889	494	362
110	3056	96.5	15850	560	183	0.7536	286	14178	777	411
0.5	3066	72.6	15862	492	142	0.7549	285	14190	663	391
1					0			14190		
76	5119	97.3	18385	286	205	0.7532	286	16743	839	407
0.5	5126	48.7	18393	415	89	0.7563	285	16750	519	353
23	5751	97.8	19163	147	205	0.7532	286	17520	838	403
0.2	5753	48.7	19167	356	90	0.7563	285	17523	521	351
3.5	5848	97.8	19284	111	207	0.7531	286	17641	844	403
0.5	5858	71.7	19296	225	146	0.7548	285	17653	671	377
69.5	7746	97.8	21627	24	214	0.7530	286	20090	863	392
17.6	8210	94	22203	90	208	0.7532	286	20689	846	387
Cycle 21		Begin : 29.06.91		End : 02.07.92						
0.5	3	24.3	22207	1400	35	0.7579	284	20692	381	313
2	30	48.7	22239	1244	73	0.7567	284	20716	474	332
1.5	61	74.3	22276	1114	122	0.7552	285	20746	602	354
1	86	89.4	22306	1044	158	0.7542	286	20771	702	368
1	112	94.2	22337	1020	171	0.7539	286	20799	738	373
0.5					0			20799		
2.5	178	94.2	22415	1015	173	0.7538	286	20870	744	373
0.5	188	71.3	22427	1111	123	0.7553	285	20880	605	353
12	506	95.6	22808	986	174	0.7538	286	21221	747	372
0.5	516	71.3	22820	1072	124	0.7552	285	21231	607	352
51.5	1888	96	24460	889	179	0.7537	286	22741	761	367
1	1908	71.3	24484	915	130	0.7551	285	22763	622	348
4					0			22763		
138	5604	96.5	28902	617	193	0.7534	286	27113	804	352
0.2	5609	75.2	28907	506	152	0.7546	286	27118	683	339
83	7837	96.7	31568	306	208	0.7531	286	29942	852	346
1	7850	48.7	31584	435	91	0.7563	285	29957	515	312
66	9669	99.3	33753	102	213	0.7530	286	32256	872	340
Cycle 22		Begin : 02.09.92		End : 01.04.93						
0.5	3	24.3	33757	1101	33	0.7579	284	32259	389	308
2	30	48.7	33786	946	68	0.7566	285	32281	460	306
2	72	74.3	33829	814	113	0.7551	285	32318	576	313
2	122	89.4	33882	741	146	0.7542	286	32366	671	322
35	1057	96	34875	654	166	0.7536	286	33314	733	326
2					0			33314		
38	2068	95.6	35955	543	170	0.7535	286	34370	748	325
1	2082	48.7	35970	712	76	0.7565	285	34383	481	304
129.2	5511	95.4	39653	302	168	0.7536	286	37935	755	320

- TABLE 13 -

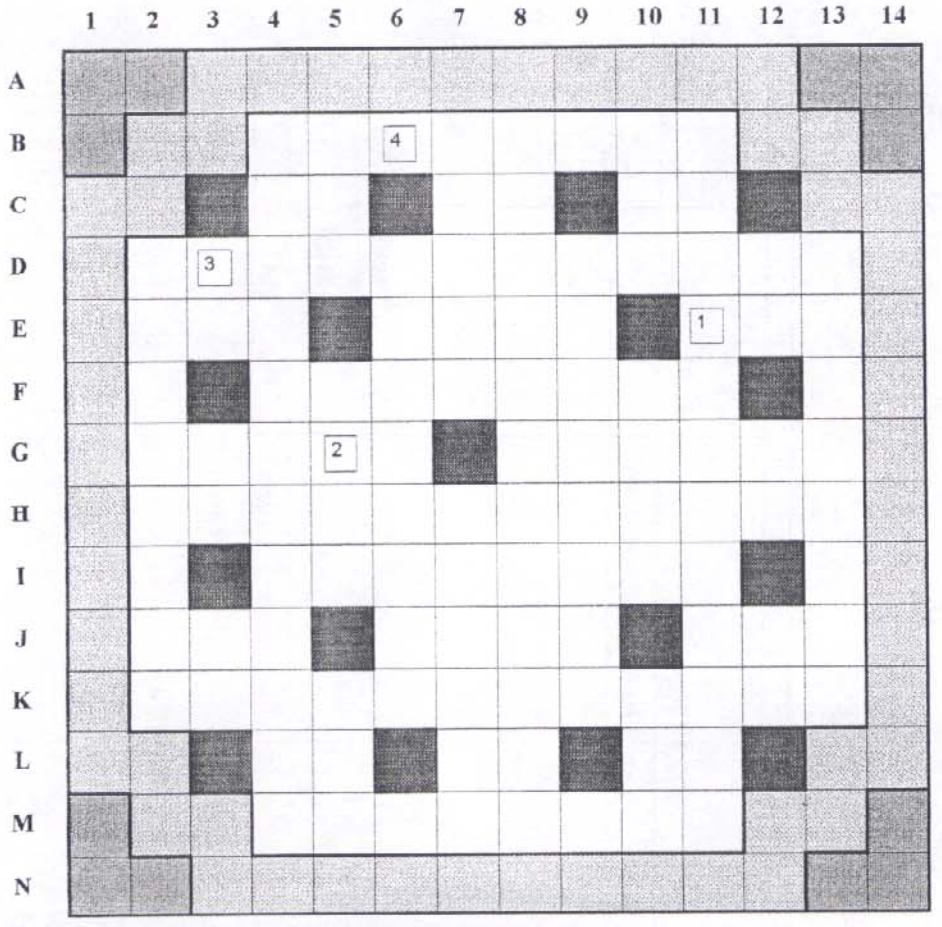
BEZNAU - Unit 1 - 1130 MWth PWR reactor
Irradiation of M109 MOX fuel assembly



Assembly	M109	Cy 18	L 5	Irradiation cycle 1
		Cy 19	A 8	Irradiation cycle 2
		Cy 20	H 10	Irradiation cycle 3
		Cy 21	I 10	Irradiation cycle 4
		Cy 22	G 7	Irradiation cycle 5

- FIGURE 1 -

MOX Fuel Assembly M109 (Top view)



1 Rod E11 : Initial location of BM1, BM2D

2 Rod G5 : Initial location of BM3, BM4D

3 Rod D3 : location of BM1 and BM2D (cask rotation)

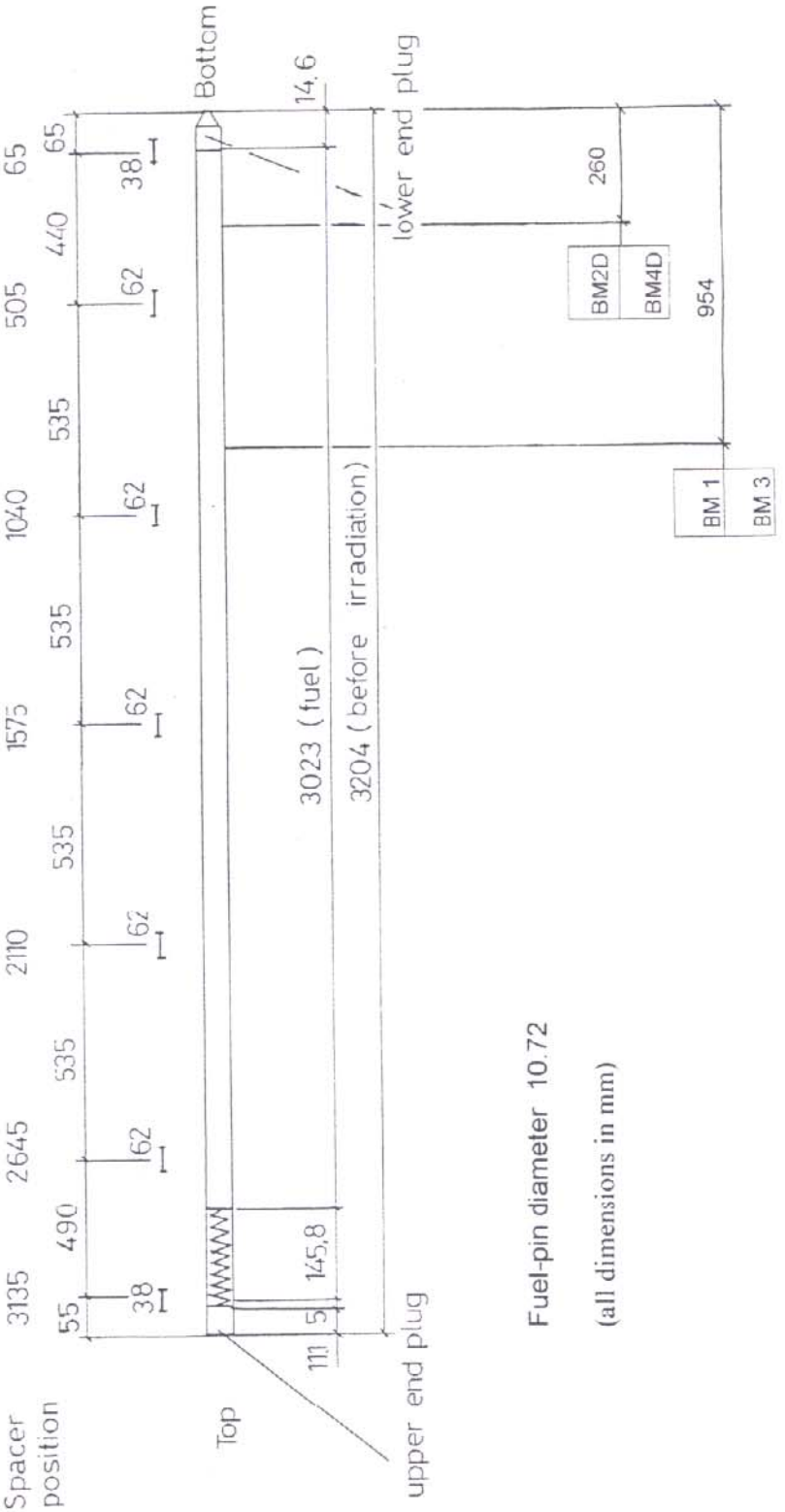
4 Rod B6 : location of BM3 and BM4D (cask rotation)

Pu low content : 3.36 w/o (Pu+Am) / (U+Pu+Am)

Pu medium content : 4.28 w/o (Pu+Am) / (U+Pu+Am)

Pu high content : see table 3

- FIGURE 2 -



Fuel-pin diameter 10.72

(all dimensions in mm)

- FIGURE 3 -

Assembly M 109 : environment

Cycle 18

UO2 3.4	UO2 3.4	UO2 3.4
27.49	5.69	27.63
33.78	15.14	36.07
UO2 3.4		UO2 3.4
17.72	M 109	6.49
21.29		15.52
		UO2 3.4
		0.00
		6.20

Cycle 20

UO2 3.4	UO2 3.4	MOX
16.83	28.46	0.00
26.34	36.27	10.94
UO2 3.4		UO2 3.4
24.54	M 109	33.01
32.95		40.91
UO2 3.4	UO2 3.4	UO2 3.4
15.59	29.12	9.33
24.83	37.31	19.30

Cycle 19

MOX		
0.00	M 109	
0.12		
UO2 3.4	UO2 3.4	MOX
15.17	0.00	0.00
15.34	0.20	0.15

Cycle 21

UO2 3.25	UO2 3.4	MOX
10.21	19.25	12.55
22.22	30.40	24.81
UO2 3.4		UO2 3.4
17.44	M 109	8.74
28.39		20.13
MOX	MOX	UO2 3.25
22.04	16.42	0.00
33.37	27.88	11.38

Cycle 19a

MOX		
0.12	M 109	
5.63		
UO2 3.4	UO2 3.4	MOX
29.30	0.20	0.15
36.52	9.51	7.28

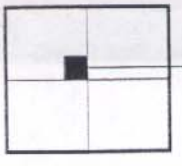
Cycle 22

UO2 3.25	MOX	UO2 3.25
7.80	27.88	7.70
15.02	34.29	14.94
MOX		MOX
27.93	M 109	27.87
34.34		34.29
UO2 3.25	MOX	UO2 3.25
7.70	27.92	7.68
14.94	34.33	14.92

--> Assembly type
--> BU BOC (GWd/t)
--> BU EOC (GWd/t)

--> MOX Assembly

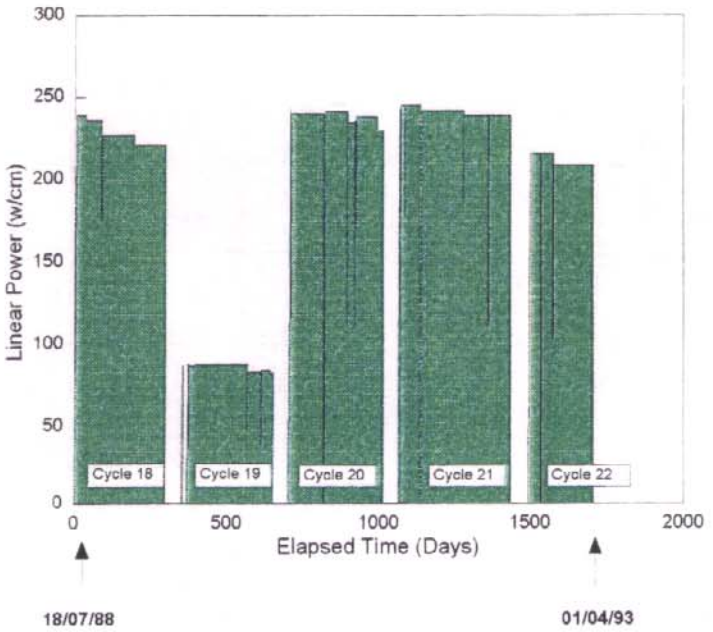
Assembly orientation :



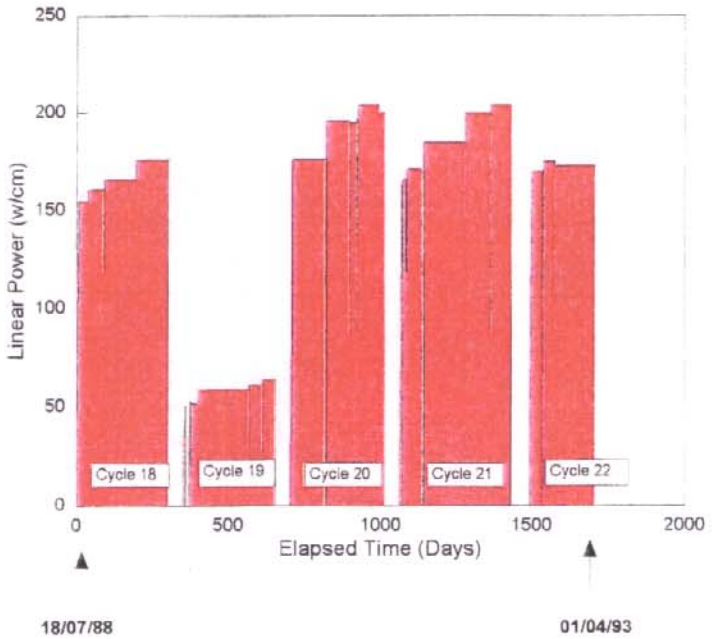
Guide tube

- FIGURE 4 -

BM1_E11 Irradiation History

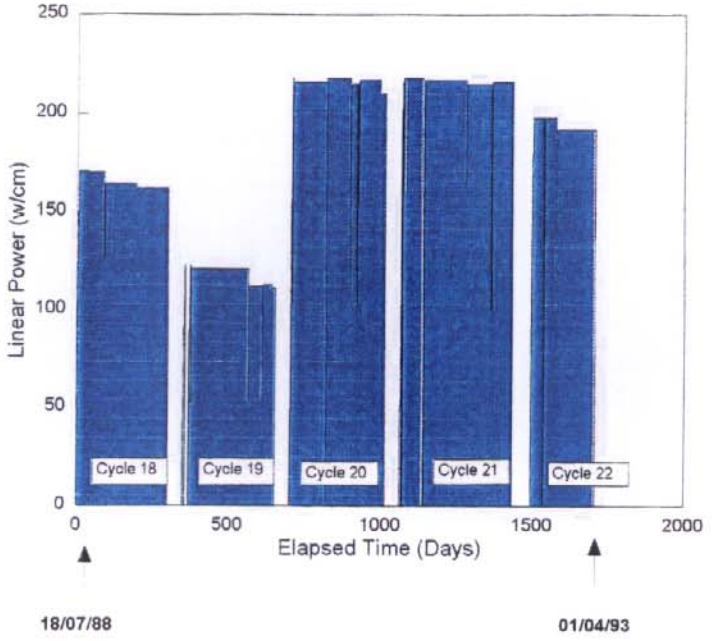


BM2D_E11 Irradiation History

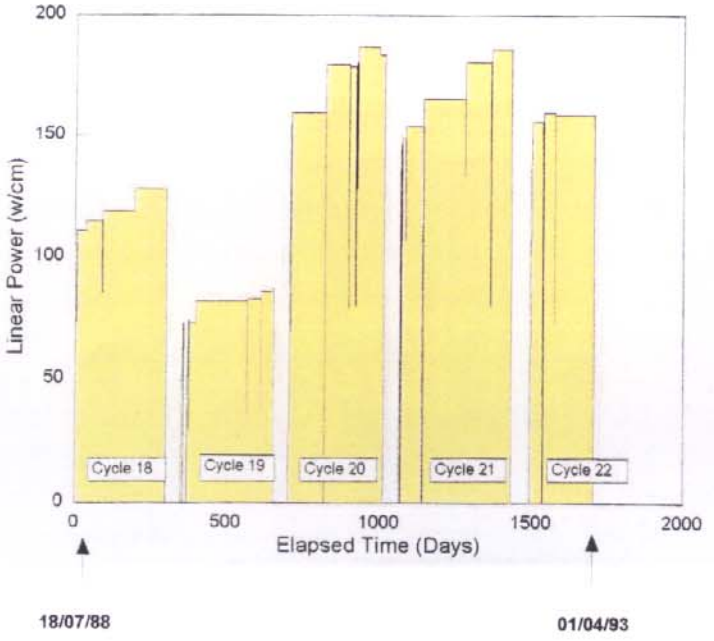


- FIGURE 5 -

BM3_G5 Irradiation History

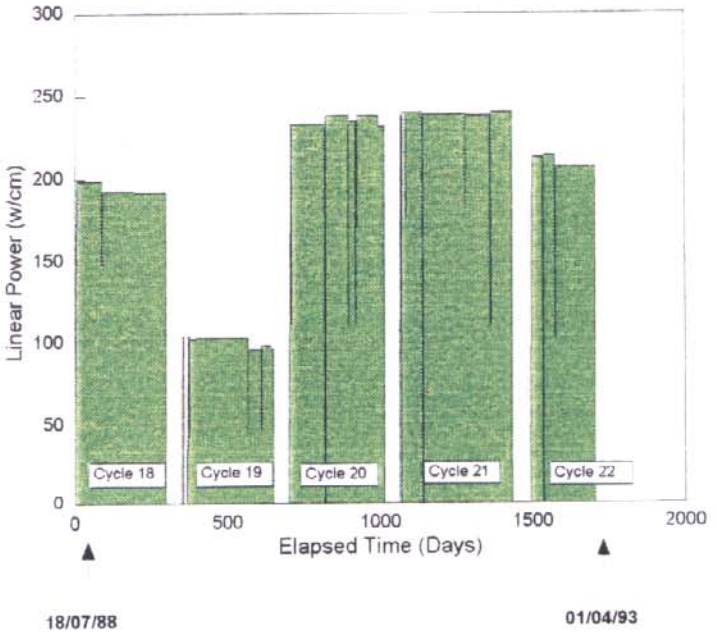


BM4D_G5 Irradiation History

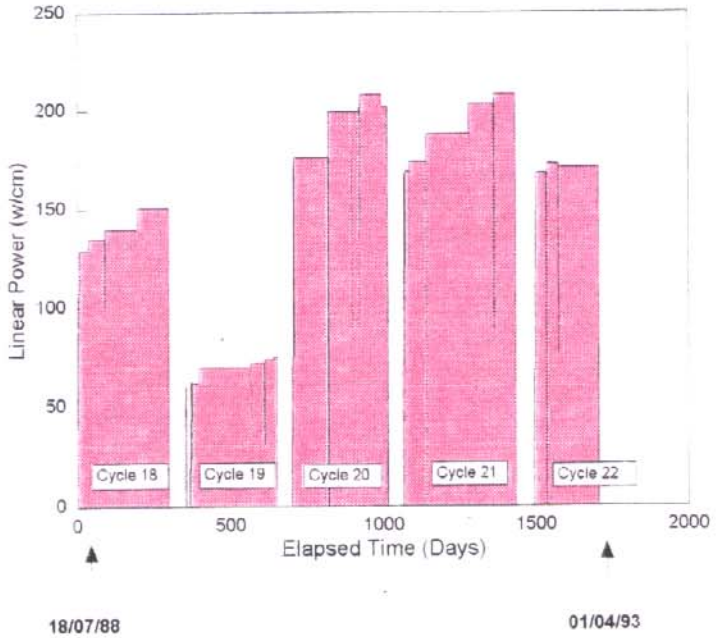


- FIGURE 6 -

BM1_D3 Irradiation History

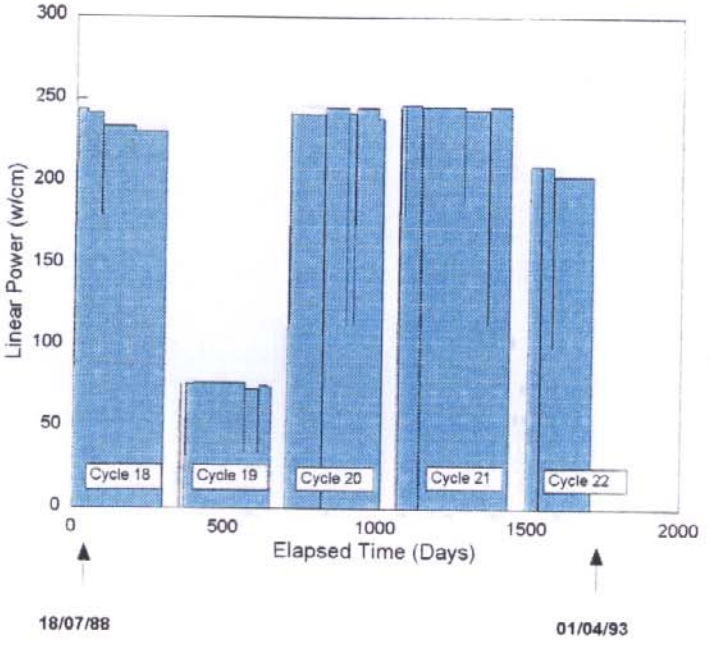


BM2D_D3 Irradiation History

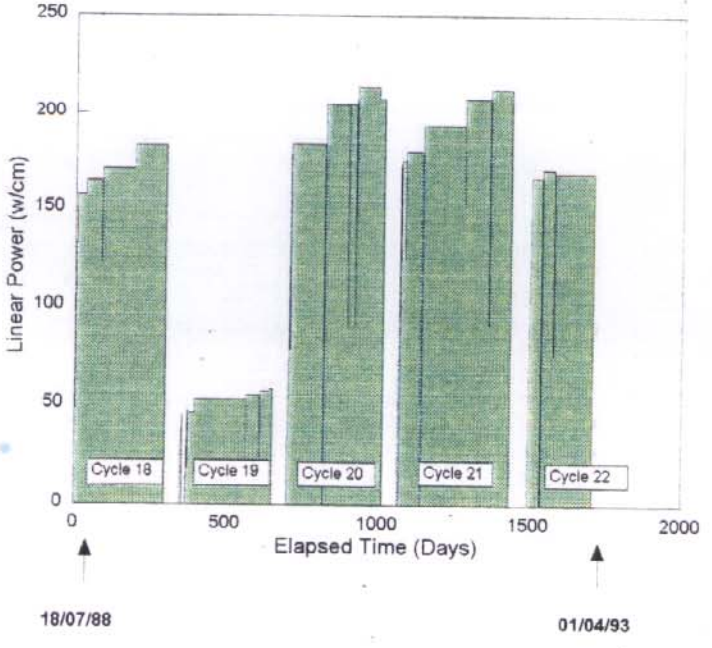


- FIGURE 7 -

BM3_B6 Irradiation History

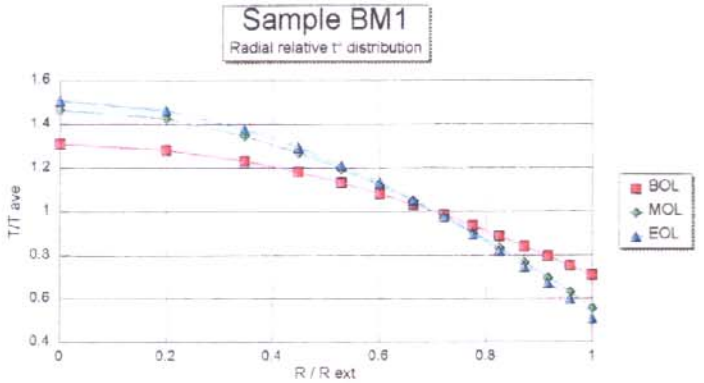


BM4D_B6 Irradiation History

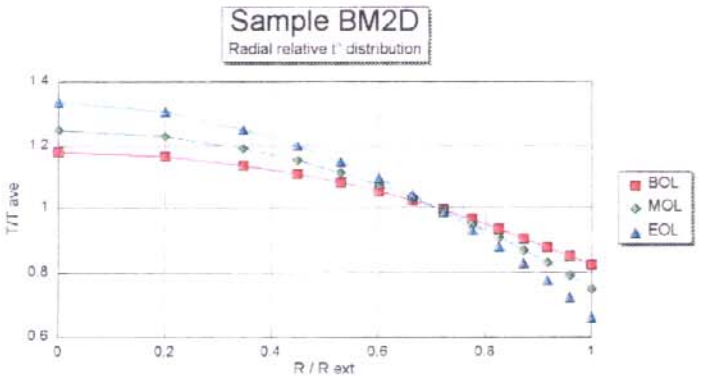


- FIGURE 8 -

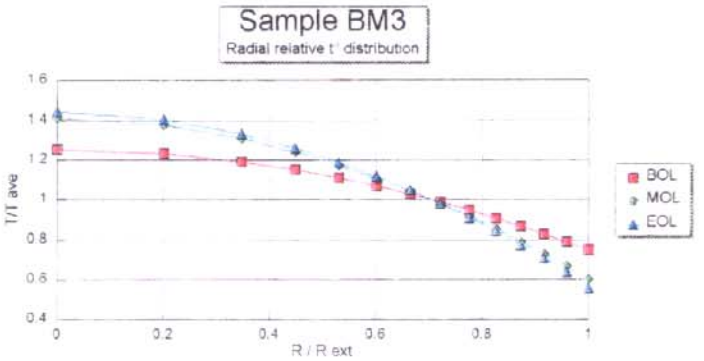
SAMPLE BM1			
	BOL	MOL	EOL
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.708	0.554	0.507
0.959	0.752	0.629	0.596
0.917	0.796	0.697	0.672
0.872	0.842	0.765	0.746
0.825	0.888	0.834	0.821
0.775	0.935	0.904	0.896
0.722	0.983	0.975	0.973
0.664	1.031	1.047	1.051
0.601	1.080	1.120	1.130
0.530	1.130	1.194	1.211
0.448	1.181	1.270	1.293
0.347	1.232	1.347	1.377
0.200	1.284	1.426	1.462
0.000	1.310	1.465	1.507



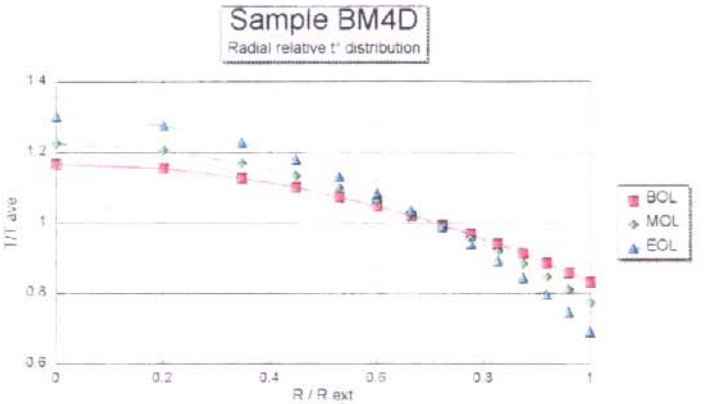
SAMPLE BM2D			
	BOL	MOL	EOL
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.823	0.748	0.660
0.959	0.851	0.790	0.721
0.917	0.879	0.830	0.775
0.872	0.907	0.870	0.828
0.825	0.936	0.910	0.880
0.775	0.964	0.949	0.933
0.721	0.993	0.989	0.986
0.664	1.021	1.029	1.039
0.600	1.050	1.070	1.092
0.529	1.078	1.110	1.146
0.447	1.107	1.150	1.199
0.347	1.135	1.191	1.254
0.200	1.164	1.231	1.308
0.000	1.178	1.252	1.336



SAMPLE BM3			
	BOL	MOL	EOL
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.750	0.602	0.557
0.959	0.790	0.668	0.640
0.917	0.829	0.730	0.709
0.872	0.869	0.791	0.776
0.825	0.908	0.853	0.843
0.775	0.948	0.916	0.911
0.721	0.988	0.979	0.979
0.664	1.029	1.043	1.048
0.600	1.069	1.108	1.117
0.529	1.110	1.174	1.188
0.448	1.151	1.241	1.259
0.347	1.192	1.308	1.332
0.200	1.234	1.377	1.406
0.000	1.254	1.411	1.445



SAMPLE BM4D			
	BOL	MOL	EOL
R / R ext	T / T ave	T / T ave	T / T ave
1.000	0.831	0.773	0.693
0.959	0.858	0.811	0.748
0.917	0.885	0.847	0.796
0.872	0.912	0.883	0.844
0.825	0.939	0.919	0.892
0.775	0.967	0.955	0.940
0.721	0.994	0.991	0.988
0.664	1.021	1.027	1.036
0.600	1.047	1.063	1.084
0.529	1.074	1.099	1.132
0.447	1.101	1.135	1.180
0.347	1.128	1.171	1.229
0.200	1.154	1.207	1.278
0.000	1.167	1.225	1.302



- FIGURE 9 -

Part III :

PWR - UO2 Samples.

GÖSGEN PWR
samples
GU1 and GU2

The two UO2 samples GU1 and GU2 have been irradiated in the GÖSGEN reactor during 4 and 2 cycles respectively in the fuel assembly N° 12-40.

The initial enrichment of the samples was 0.036 wt % in U234/U-tot. and 3.5 wt % in U235/U-tot. with an initial fuel density of 10.4 gr/cm³, giving a linear fuel weight of 6.7 g/cm, assuming a dishes volume of 1.5 %.

Main core and fuel assembly data are given on table 1.

Figure 1 shows the irradiation history of the fuel assembly.

This fuel assembly has been irradiated during 4 cycles :

- cycle 12 from july 6, 1990 till june 1,1991
- cycle 13 from july 3, 1991 till may 30, 1992
- cycle 14 from june 15, 1992 till june 5, 1993
- cycle 15 from july 1, 1993 till june 4, 1994

The sample GU2 has been unloaded from the assembly after 2 cycles.

The sample GU1 has been irradiated during the four cycles.

The fuel assembly 12-40 rod loading was modified for cycle 14 and cycle 15, as shown on figure 3.

Table 2 gives the complete irradiation history for the ARIANE samples including :

- the core burn-up, load factor and boron concentration in the coolant
- the fuel assembly average burn-up
- the sample linear power and effective temperature
- the sample burn-up
- the water density and temperature

For the Gösgen samples, the values given in table 2 are pointwise values (not time-step averaged), as provided by SIEMENS.

As it can be shown on the table, after the natural end of cycle (time when the critical boron at 100 % power becomes close to 0.), the power of the core is reduced and the cycle is prolongated a few weeks.

GÖSGEN MAIN CORE DATA

• Type of reactor :	PWR
• Nominal thermal power :	3002 MW
• Pressure primary system :	153 kg/cm²
• Coolant inlet temperature :	292.0 °C
average temperature :	309.0 °C
outlet temperature :	326.0 °C
• Number of assemblies :	177
• Number of rods per assembly :	205
• Lattice type :	15 x 15
• Lattice pitch :	1.43 cm
• Assembly pitch :	21.56 cm
• Number of guide tubes :	20
FUEL RODS (cold values)	
• Fuel :	UO2
• Oxide density :	10.4 gr/cm³
• Cladding :	Zr-4
• Outer diameter :	10.75 mm
• Inner cladding diameter :	9.30 mm
• Pellet diameter :	9.13 mm
• Active fuel length :	3400 mm
GUIDE TUBE	
• Inner diameter :	12.4 mm
• Outer diameter :	13.8 mm
• Material :	Zr-4

- TABLE 1 -

ARIANE - Sample GU1
(SIEMENS DATA)

Elapsed time (Cumulative Full Power Days)	Core Burn-up (MWd/t)	Core Load Fact. (%)	12-40 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Sample Temp. (K)	Core average values: Water Density (gr/cc)	Core average values: Water Temp. (°C)	Sample Burn-up (MWd/t)
Cycle 12		Begin : 06.07.90		End : 01.06.91					
0	0	100.0	0	1511	346.3	1151.3	0.7076	307.6	0
6	240	100.0	295	1179	357.4	1171.5	0.7065	308.1	364
150	5983	100.0	7663	565	334.9	1136.0	0.7071	308.0	9195
294.9	11763 (*)	100.0	14774	8	321.0	1078.3	0.7065	308.3	17454
317	12646	90.4	15886	8	311.7	1046.7	0.7283	298.6	18649
Cycle 13		Begin : 03.07.91		End : 30.05.92					
0	0	100.0	15886	1477	227.4	919.3	0.7094	306.9	18649
6	236	100.0	16094	1145	258.8	967.7	0.7086	307.3	18899
150	5899	100.0	21690	542	269.4	957.9	0.7092	307.1	25572
292.3	11484 (*)	100.0	27760	7	272.3	943.1	0.7085	307.5	32262
321.3	12634	87.3	29034	7	213.9	842.0	0.7369	294.4	33594
Cycle 14		Begin : 15.06.92		End : 05.06.93					
0	0	100.0	29034	1517	237.6	888.9	0.7060	308.2	33594
6	240	100.0	29256	1178	241.6	894.4	0.7049	308.7	33789
150	6008	100.0	34704	549	221.1	854.8	0.7055	308.6	39879
290.1	11620 (*)	100.0	40151	5	216.3	841.4	0.7050	308.9	45757
331.3	13270	72.0	41761	5	139.4	709.8	0.7467	289.5	47911
Cycle 15		Begin : 01.07.93		End : 04.06.94					
0	0	100.0	41761	1594	191.7	806.6	0.7030	309.4	47911
6	237	100.0	41950	1243	209.5	829.8	0.7022	309.8	48121
150	5927	100.0	46810	605	200.9	810.6	0.7031	309.6	53506
301.9	11929 (*)	100.0	52104	5	200.8	804.0	0.7027	309.9	58842
326.7	12910	87.0	52958	5	157.9	738.9	0.7303	297.6	59656

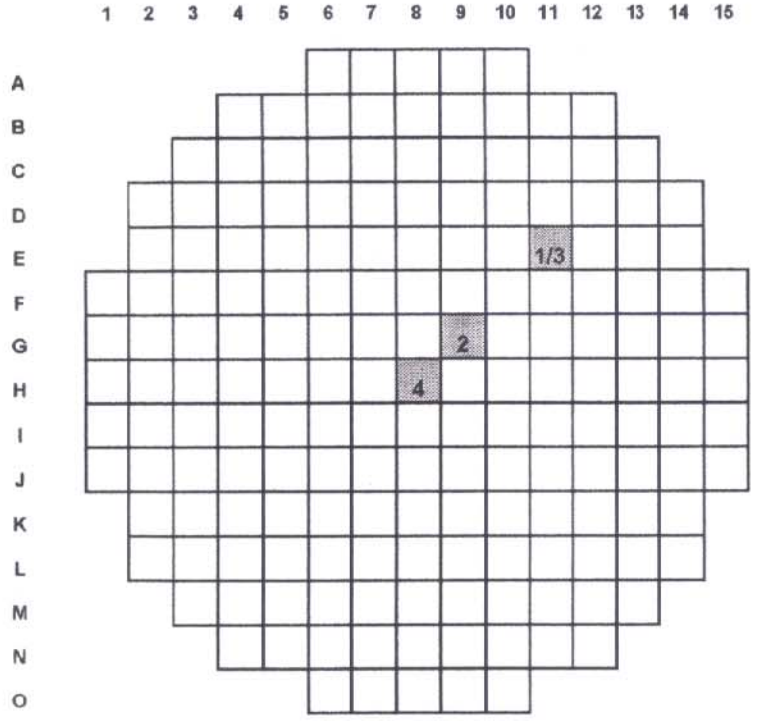
ARIANE - Sample GU2
(SIEMENS DATA)

Elapsed time (Cumulative Full Power Days)	Core Burn-up (MWd/t)	Core Load Fact. (%)	12-40 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Sample Temp. (K)	Core average values: Water Density (gr/cc)	Core average values: Water Temp. (°C)	Sample Burn-up (MWd/t)
Cycle 12		Begin : 06.07.90		End : 01.06.91					
0	0	100.0	0	1511	342.8	1145.4	0.7076	307.6	0
6	240	100.0	295	1179	353.7	1165.2	0.7065	308.1	370
150	5983	100.0	7663	565	325.3	1119.4	0.7071	308.0	9175
294.9	11763 (*)	100.0	14774	8	312.0	1063.3	0.7065	308.3	17223
317	12646	90.4	15886	8	264.3	970.0	0.7283	298.6	18379
Cycle 13		Begin : 03.07.91		End : 30.05.92					
0	0	100.0	15886	1477	205.4	886.4	0.7094	306.9	18379
6	236	100.0	16094	1145	236.3	933.6	0.7086	307.3	18607
150	5899	100.0	21690	542	254.1	937.1	0.7092	307.1	24821
292.3	11484 (*)	100.0	27760	7	262.6	931.2	0.7085	307.5	31226
321.3	12634	87.3	29034	7	206.3	834.0	0.7369	294.4	32516

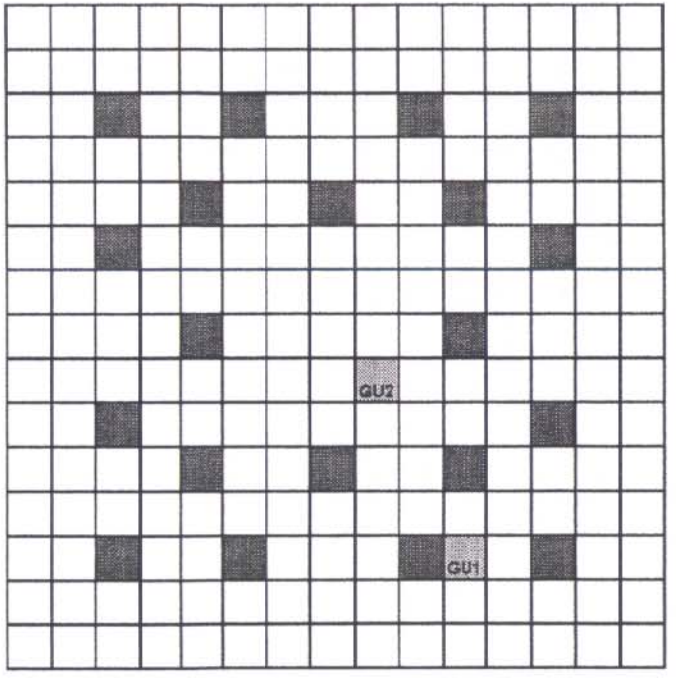
(*) : Natural End of Cycle

- TABLE 2 -

CROSS SECTION OF GÖSGEN NPP
IRRADIATION OF FA-No. 12-40 UO2 ASSEMBLY



GÖSGEN UO2 FUEL ASSEMBLY 12-40



Assembly FA-No. 12-40	E 11	Irradiation cycle 1
	G 9	Irradiation cycle 2
	E 11	Irradiation cycle 3
	H 8	Irradiation cycle 4

Fuel Rod

Control Rod guide tube

- FIGURE 1 -

Report

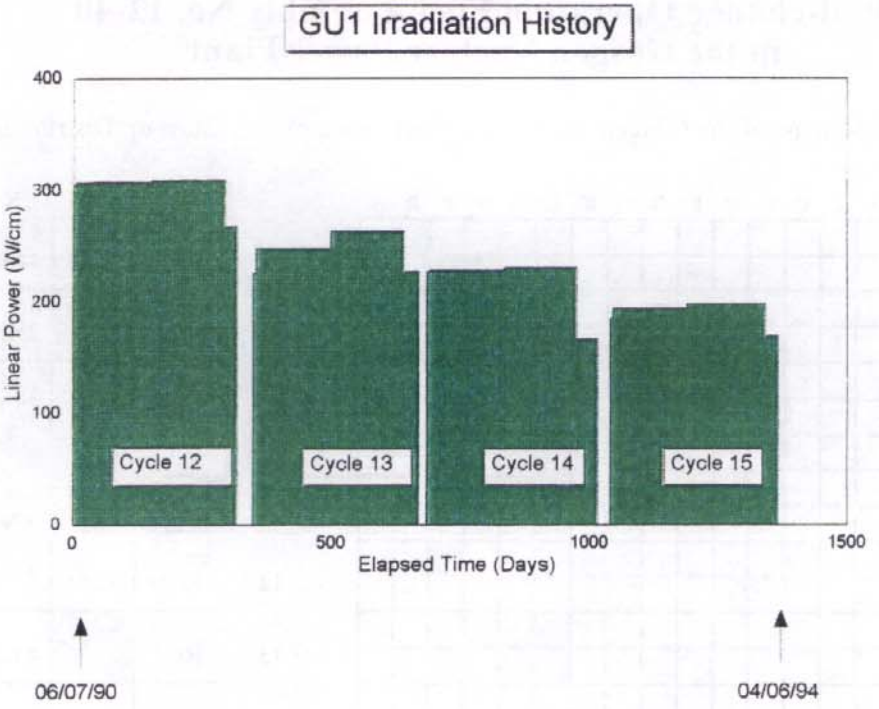
BN reference No / File - "Rev" - Page

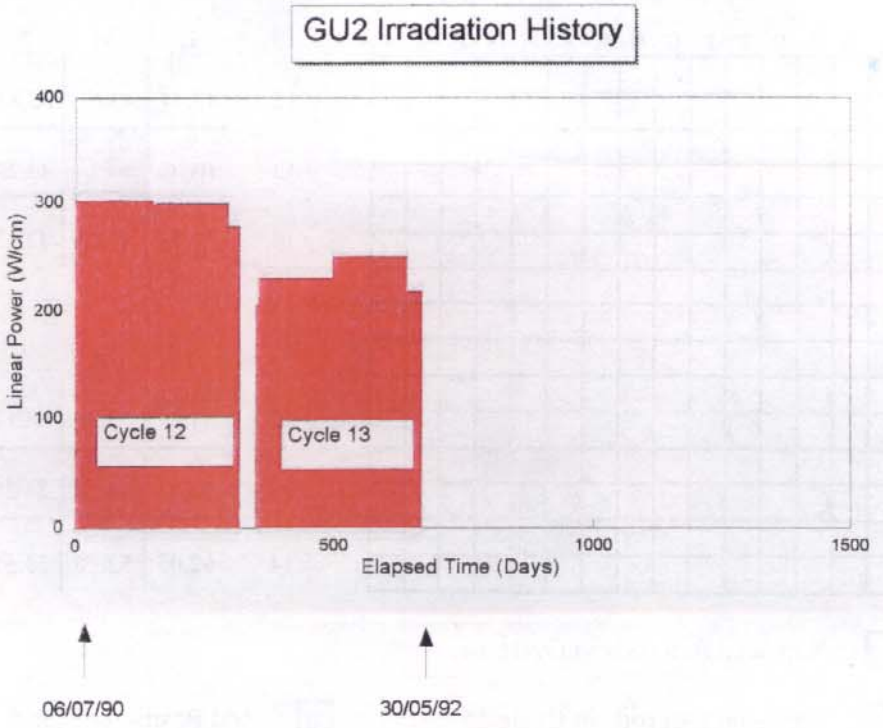
9606546/221 - "B" - 62

Other reference:

AR 96 / 05
Rev. B

JJP110196 bmpagea3.ppt


GU1 Irradiation History
Linear Power (W/cm)
400
300
200
100
0
Cycle 12
Cycle 13
Cycle 14
Cycle 15
0
500
1000
1500
Elapsed Time (Days)
06/07/90
04/06/94


GU2 Irradiation History
Linear Power (W/cm)
400
300
200
100
0
Cycle 12
Cycle 13
0
500
1000
1500
Elapsed Time (Days)
06/07/90
30/05/92

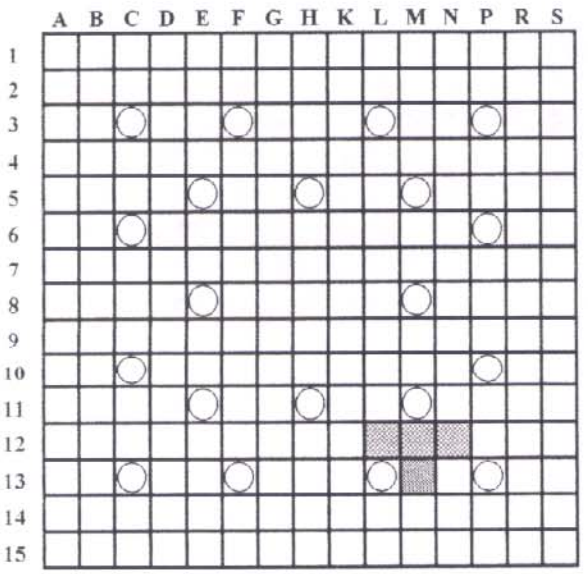
- FIGURE 2 -

Rod-change Operation Fuel Assembly No. 12-40 in the Gösgen Nuclear Power Plant

Fuel Rod Scheme of the Gösgen 15x15 - 20 Fuel Assembly

Burn-up Distribution :

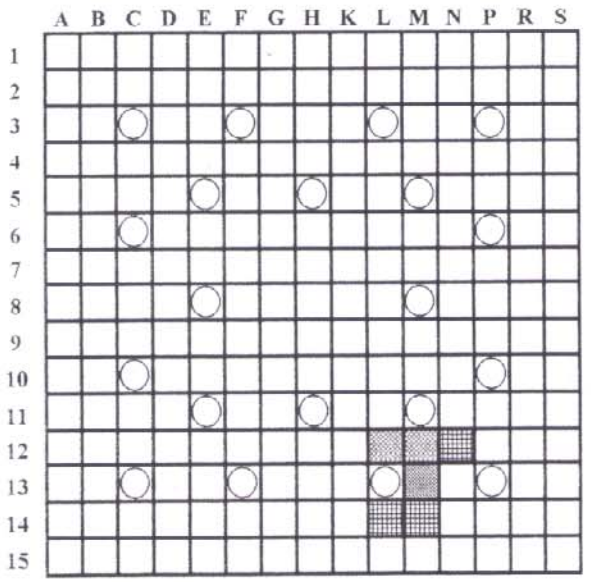
Cycle 14



	L	M	N	
12	30.25	30.29	42.85	*BOC*
13	RCC	30.03	29.94	
14	29.49	29.11	29.10	

	L	M	N	
12	43.44	43.61	54.60	*EOC*
13	RCC	43.26	43.25	
14	42.70	42.33	42.37	

Cycle 15



	L	M	N	
12	43.44	43.61	53.81	*BOC*
13	RCC	43.26	43.25	
14	51.78	41.64	42.37	

	L	M	N	
12	54.09	53.96	64.14	*EOC*
13	RCC	54.37	54.38	
14	62.03	52.70	53.51	

Replaced fuel rods in Cycle 14

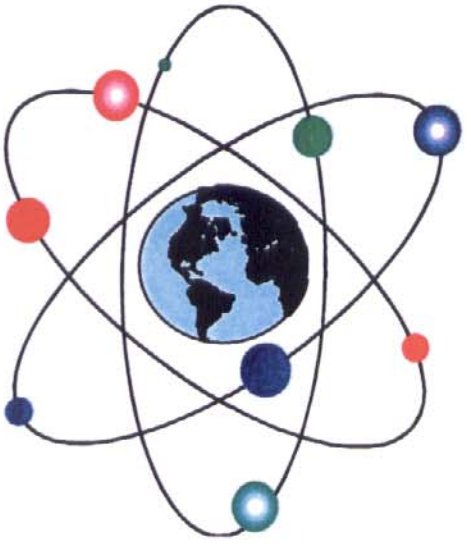
Replaced fuel rods in Cycle 15

Rod Position of the Sample GU1

- FIGURE 3 -

AR 99/13
BN Ref. 9904537/221

ARIANE
International Programme



Irradiation Data Report
Part 2

Issued July, 1999

BELGONUCLEAIRE
Avenue Ariane, 4 - 1200 Brussels.

	Type of document : REPORT	BN reference N° / File - « Rev. » - Page 9904537/221 - « - » 1
		Other reference : AR 99/13
Client :		Author(s) : T. Aoust

Project: ARIANE

Subject:

ARIANE PROGRAMME

IRRADIATION DATA REPORT

Part 2

With the contribution of NOK and SIEMENS

Rev.	Date	Chrono Filing n°	Status	Typist's Initials	Initials (Author)	Visa N°1 (Author)	Initials (Verified by)	Visa N°2 (Verified by)	Initials (Approved by)	Visa N°3 (Approved by)	Initials (Q.A.)	Visa N°4 (Q.A.)	Initials (Issued by)	Visa N°5 (Issued by)	Number of Pages
C															
B															
A															
--	20/07/99	9904537	FIN	TA	TA		ML						HBe		28

Distribution :

ARIANE Programme Participants

BN : Mrs. Boulanger

MM. Vanderborck, Lippens, Mertens, Renard, Lance, Basselier, Brusselaers

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use of exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, withjout prejudice to any other right.

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 - 1200 Bruxelles
TVA : BE 403.126.258
RCB : 271.300
TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

LIST OF MODIFICATIONS

DATE	REVISION	OBJECT
20/07/99	-	Final issue

NOTICE

LIABILITY

This document was prepared by BELGONUCLEAIRE (BN). Neither BN or any person acting on behalf of BN:

(a) gives any warranty, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this document, or that the use of any information, apparatus, method or process disclosed in this document may not infringe third party, or

(b) assumes any liabilities with respect to the use of, or for damage resulting from the use of any information, apparatus, method or process disclosed in this document.

PERSONNEL IN CONFIDENCE/NOT FOR PUBLICATION

All property rights and copyrights are reserved. Any communication or reproduction of this document and any communication or use of its content without explicit authorisation of the ARIANE programme committee is prohibited. Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting of a patent or registration in the field of intellectual property.

TABLE OF CONTENTS

	Pages :
DISTRIBUTION LIST	**5**
PREAMBLE	**6**
PART I : PWR – MOX Samples	
BEZNAU PWR Samples BM5 and BM6	8
Introduction	8
Fuel assembly description and fabrication data	9
Irradiation follow-up	9
Tables 1 to 5	10 - 14
Figures 1 to 4	15 - 18
PART II : PWR – UO2 Samples	
GÔSGEN PWR Samples GU3 and GU4	20
Tables 1 to 3	22 - 24
Figures 1 to 4	25 - 28

DISTRIBUTION LIST

SIEMENS (D)	Dr. G. Schlosser	2 copies
SCK-CEN (BE)	Mr. P. D'hondt	5 copies
GNB (D)	Dr. R. Hüggenberg	2 copies
MHI (JP)	Mr. S. Abeta	2 copies
BNFL (UK)	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	Mr. Y. Nakajima	2 copies
HITACHI (JP)	Mr. T. Mochida	2 copies
ORNL (USA)	Mr. R. T. Primm III	2 copies
NEL (JP)	Mr. H. Naito	2 copies
JRI (JP)	Mr. T. Kaneko	2 copies
NOK (CH)	Mr. G. Devillaz	2 copies
GKN (NL)	Mr. W.R. Van Engen	2 copies
PSI (CH)	Mr. G. Lederberger	2 copies
TRACTEBEL (BE)	Mr. R. de Wouters	2 copies

PREAMBLE

This report has been prepared by BELGONUCLEAIRE as a theoretical support to the ARIANE experimental programme.

It includes mainly the detailed power and burnup histories of samples BM5, BM6, GU3 and GU4 selected for radiochemical analyses. The powers $P_{rod,i}$ given in this report are calculated "core normalised", i.e. $\sum_i P_{rod,i} = P_{core}$, including all heating contributions.

The necessary core data and neutronic information have been provided respectively by :

- NOK for what concerns the BEZNAU-1 MOX samples BM5 and BM6
- SIEMENS for what concerns the GÖSGEN UO_2 samples GU3 and GU4

Are also included in this report:

- The (as build) fuel characteristics,
- Fuel temperature evolution calculations (with BN COMETHE 4D code for BM samples and given by SIEMENS for GU samples).

The irradiation history tables are provided also on floppy disk media, in order to facilitate further data processing.

Part I :

PWR - MOX Samples.

BEZNAU PWR

Samples BM5 and BM6

Introduction.

Two MOX samples (BM5, BM6) coming from the M308 assembly irradiated in the BEZNAU-1 PWR reactor are analysed radiochemically in the ARIANE programme.

The M308 assembly has been irradiated during 6 consecutive cycles:

- cycle 20 from july 2, 1990 till may 9, 1991,
  fraction of MOX assemblies in the core : 26 %.
- cycle 21 from june 29, 1991, till july 2, 1992,
  fraction of MOX assemblies in the core : 30 %.
- cycle 22 from september 2, 1992, till april 1,1993,
  fraction of MOX assemblies in the core : 34 %.
- cycle 23 from july 9, 1993, till june 17, 1994,
  fraction of MOX assemblies in the core : 43 %.
- cycle 24 from august 1, 1994, till june 30,1995,
  fraction of MOX assemblies in the core : 33 %.
- cycle 25 from july 30, 1995, till june 28,1996,
  fraction of MOX assemblies in the core : 31 %.

The cross section of the core with the location of the M308 fuel assembly inside the core during its irradiation is shown on figure 1.

Main core data are given on table 1.

Fuel assembly description and fabrication data

The fuel assembly is a 14 x 14 - PWR type with 179 fuel rods and three Pu-content zones. The fuel assembly data are gathered on table 2, including grids data and guide thimbles data. Figure 2 shows the cross-section of the MOX assembly and the location of the segmented rod (position K7) from which the samples BM5 and BM6 are taken.

Table 3 gives the MOX fresh fuel characteristics for the samples.

A drawing of a MOX fuel rod, showing the cutting plane of the samples is given on figure 3. The position of the BM5 sample represents actually the position of the adjacent samples BM5 and BM5', irradiated in the same segment SB02. The sample BM6 comes from the segment SB03 (close to rod bottom).

Irradiation follow-up.

For the samples BM5 and BM6 and for each time step, the table 4 and 5 give:

- the elapsed time (days) and the core burn-up (MWd/tM),
- the core load factor (% nominal power),
- the M308 fuel assembly average burn-up (MWd/tM),
- the boron concentration (ppm) and the local density of the coolant (g/cc) (averaged during the time step),
- the sample linear power (W/cm) and accumulated burn-up (MWd/tM),
- the central and surface temperature (°C) of the pellet at the sample level.

Whole core 3D nodal calculations with fine power reconstruction are performed using the MICROLUX code. In the nodal modelisation of the core, each fuel assembly is represented by 4 radial nodes and 24 axial nodes. Fine power reconstruction is performed by diffusion calculation on selected nodes.

The power evolutions are illustrated on figure 4.

BEZNAU - UNIT 1 MAIN CORE DATA

Type of reactor :	PWR
Nominal thermal power :	1130 MW
Pressure primary system :	158.2 kg/cm²
Feedwater :	6197 kg/sec
Coolant inlet temperature :	283.8 °C
average temperature :	300.9 °C
outlet temperature :	316.9 °C
Fuel :	UO2 + MOX
Oxide density :	10.3 gr/cm³
Number of assemblies :	121
Number of rods per assembly :	179
Lattice type :	14 x 14
Lattice pitch :	1.412 cm
Cladding :	Zr-4
Number of guide tubes per assembly :	16
Number of instrum. tubes per assembly :	1
Active fuel length :	3048 mm (UO2) 3023 mm (MOX)

TABLE 1.

MOX Fuel Assembly Design Data

Fuel Assembly Data	Assembly pitch (cm) : . cold	19.82
	Array type :	14 x 14
	Lattice pitch (mm) : . cold	14.12
	Number of fuel rods per assembly	179
Grids Data	Number of Zircaloy grids in active fuel length	5
	Number of Inconel-718 grids in active fuel length	1
	Volume of bottom Inconel-718 grid (cm^3)	68.76
	Volume of bottom grid SS-304 inserts in active fuel length (cm^3)	24.02
	Volume of one Zircaloy-4 grid including Zircaloy sleeves (cm^3)	200.04
Guide Thimbles Data	Number	16
	Material	Zr-4
	Outer diameter (mm)	13.36
	Inner diameter (mm)	12.50
Instrumentation Tube Data	Number	1
	Material	Zr-4
	Outer diameter (mm)	10.72
	Inner diameter (mm)	9.48

TABLE 2.

Segment Characteristics

Characteristics	SB02 (BM5) – SB03 (BM6)
Pellet:	
Material	UO_2-PuO_2
Density (%TD)	94.665
Diameter (mm)	9.29
$(U+Pu+Am^{241})$/oxide (w/o)	88.164
Pu/Pu+U (w/o)	5.5
Isotopic composition	
U^{234}/U (w/o)	0.002
U^{235}/U (w/o)	0.231
U^{236}/U (w/o)	0.000
U^{238}/U (w/o)	99.767
$Pu^{238}/(Pu+Am^{241})$ (w/o)	0.603
$Pu^{239}/(Pu+Am^{241})$ (w/o)	66.086
$Pu^{240}/(Pu+Am^{241})$ (w/o)	23.198
$Pu^{241}/(Pu+Am^{241})$ (w/o)	6.554
$Pu^{242}/(Pu+Am^{241})$ (w/o)	2.643
$Pu^{241}/(Pu+Am^{241})$ (w/o)	0.916
Measuring date	03/90
Impurities (equivalent. Boron ppm/(U+Pu+Am)	1.153
Linear weight (g/cm)	6.944
Cladding :	
Material	Zr-4
Inner diameter (mm)	9.48
Outer diameter (mm)	10.72
Segment :	
Active length (cm)	42.2

TABLE 3.

ARIANE - Sample BM5

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M308 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (g/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 20		Begin : 02.07.90	End : 09.06.91							
1	7	24.3	7	1099	44	0.7546	286	7	429	336
1.5	27	48.7	30	944	92	0.7499	288	30	525	379
2	67	72.6	76	822	145	0.7445	291	77	722	437
1	94	96.5	106	712	203	0.7383	294	110	848	490
1	108	48.7	121	933	96	0.7494	288	126	533	373
110	3056	96.5	3446	560	198	0.7385	294	3685	845	487
0.5	3066	72.6	3458	492	144	0.7437	291	3697	717	432
76	5119	97.3	5750	286	197	0.7376	294	6143	843	480
0.5	5126	48.7	5758	415	89	0.7495	288	6150	519	369
23	5751	97.8	6451	147	191	0.7380	294	6869	830	473
0.2	5753	48.7	6454	356	89	0.7495	288	6872	519	369
3.5	5848	97.8	6560	111	191	0.7380	294	6981	830	472
0.5	5858	71.7	6571	225	138	0.7440	291	6993	691	413
69.5	7746	97.8	8659	24	193	0.7375	295	9184	832	468
17.6	8210	94	9170	90	186	0.7385	294	9719	811	457
Cycle 21		Begin : 29.06.91	End : 02.07.92							
0.5	3	24.3	9173	1400	38	0.7561	285	9722	399	327
2	30	48.7	9196	1244	78	0.7528	287	9748	506	365
1.5	61	74.3	9221	1114	125	0.7490	289	9778	628	383
1	86	89.4	9242	1044	156	0.7464	290	9804	741	435
1	112	94.2	9264	1020	167	0.7454	290	9831	758	442
2.5	178	94.2	9319	1015	167	0.7453	291	9899	758	442
0.5	188	71.3	9337	1111	133	0.7491	290	9909	616	379
12	506	95.6	9594	986	168	0.7453	291	10239	760	441
0.5	516	71.3	9602	1072	122	0.7491	289	10249	615	379
51.5	1888	96	10752	889	168	0.7451	291	11665	762	434
1	1908	71.3	10768	915	121	0.7489	289	11685	609	375
138	5604	96.5	13862	617	187	0.7447	291	15448	766	413
0.2	5605	75.2	13866	506	126	0.7480	289	15452	627	377
83	7837	96.7	15734	306	166	0.7442	291	17699	768	400
1	7850	48.7	15745	435	76	0.7523	287	17712	499	359
66	9669	99.3	17278	102	167	0.7439	291	19515	770	395
Cycle 22		Begin : 02.09.92	End : 01.04.93							
0.5	3	24.3	17281	1071	42	0.7550	285	19519	430	334
2	30	48.7	17303	916	87	0.7507	288	19547	524	360
2	72	74.3	17338	784	140	0.7464	290	19593	689	390
2	122	89.4	17380	711	176	0.7416	292	19650	783	404
35	1057	96	18170	622	193	0.7397	293	20756	826	421
38	2088	95.6	19025	508	191	0.7396	293	21945	824	414
1	2082	48.7	19036	677	88	0.7503	288	21960	531	357
129.2	5511	95.4	21957	258	183	0.7401	293	25834	814	389
Cycle 23		Begin : 09.07.93	End : 17.05.94							
8	111	50	22096	1211	118	0.7486	289	25988	597	357
68.9	2029	100	24436	850	245	0.7362	295	28747	906	405
2.5	2066	53.1	24482	947	125	0.7475	289	28798	630	364
4	2177	100	24617	718	241	0.7358	295	28956	920	393
5	2316	100	24785	702	246	0.7351	296	29157	905	408
2	2345	53.1	24821	914	124	0.7475	289	29196	627	363
59.9	4013	100	26838	594	239	0.7356	296	31537	930	383
59.9	5681	100	28838	402	240	0.7347	296	33886	929	387
59.9	7348	100	30820	224	234	0.7348	296	36179	961	376
49.9	9796	100	32460	66	225	0.7349	296	38051	1004	364
20	9205	84.1	33014	50	186	0.7396	293	38658	886	344
Cycle 24		Begin : 01.08.94	End : 30.06.95							
6	78	46.8	33101	1203	91	0.7506	288	38747	563	321
2	118	72.1	33146	1063	145	0.7454	290	38794	746	340
1	139	75.3	33170	1044	154	0.7444	291	38819	757	342
86.7	2535	99.3	35838	784	210	0.7383	294	41793	940	354
86.6	4930	99.3	38494	495	211	0.7371	295	44779	911	363
85.7	7326	99.3	41143	229	207	0.7368	295	47713	892	364
1	7340	48.8	41159	366	90	0.7498	288	47728	565	332
44.8	8583	99.7	42532	38	197	0.7377	294	49175	880	358
1.1	8610	99	42565	3	203	0.7367	295	49211	886	362
16.8	9050	94	43052	3	192	0.7379	294	49740	875	356
1.6	9070	46	43074	3	85	0.7500	288	49762	559	335
Cycle 25		Begin : 30.07.95	End : 28.08.96							
7.8	109	50	43172	1160	77	0.7511	287	49861	541	334
60.6	1789	99.7	44685	827	165	0.7416	292	51491	799	359
1	1802	49.6	44697	951	81	0.7505	288	51504	553	336
57.6	3401	99.7	46157	627	170	0.7405	293	53110	815	360
57.6	5000	99.7	47637	442	179	0.7390	294	54796	840	361
1	5021	75.7	47656	462	132	0.7444	291	54817	700	356
53.7	6513	99.8	49047	272	176	0.7391	294	56367	828	362
1	6527	50.4	49060	434	84	0.7498	288	56380	570	339
65.4	8344	99.8	50774	102	175	0.7392	294	58257	821	363
1	8371	99.1	50800	8	182	0.7381	294	58286	845	363
20.5	8889	90.8	51294	20	166	0.7400	293	58842	794	360
1	8901	42.8	51306	246	71	0.7512	287	58854	542	340

TABLE 4.

ARIANE - Sample BM6

Elapsed Time (Day)	Core Burn-up (MWd/t)	Core Load Fact. (%)	M308 Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Water Density (g/cc)	Water Temp. (°C)	Sample Burn-up (MWd/t)	Center Temp. (°C)	Surface Temp. (°C)
Cycle 20		Begin : 02.07.90		End : 09.05.91						
1	7	24.3	7	1088	21	0.7561	284	3	350	311
1.5	27	48.7	30	944	46	0.7572	284	15	434	337
2	67	72.6	76	822	77	0.7561	285	40	500	363
1	94	96.5	106	712	114	0.7550	285	59	588	377
1	108	48.7	121	933	49	0.7571	284	67	443	340
110	3056	96.5	3446	560	117	0.7549	285	2169	598	379
0.5	3066	72.6	3458	492	90	0.7559	285	2177	518	373
76	5119	97.3	5750	286	130	0.7547	286	3797	654	397
0.5	5126	48.7	5758	415	56	0.7570	284	3802	458	347
23	5751	97.8	6451	147	129	0.7547	286	4287	649	394
0.2	5753	48.7	6454	356	56	0.7570	284	4289	458	347
3.5	5848	97.8	6560	111	130	0.7547	286	4364	654	396
0.5	5858	71.7	6571	225	92	0.7559	285	4371	520	367
69.5	7746	97.8	8659	24	135	0.7546	286	5910	674	404
17.6	8210	94.0	9170	90	130	0.7548	285	6285	651	393
Cycle 21		Begin : 29.06.91		End : 02.07.92						
0.5	3	24.3	9173	1400	18	0.7583	284	6287	338	304
2	30	48.7	9195	1244	38	0.7574	284	6299	403	328
1.5	61	74.3	9221	1114	64	0.7565	285	6314	465	351
1	86	89.4	9242	1044	82	0.7559	285	6328	509	364
1	112	94.2	9264	1020	89	0.7557	285	6343	516	365
2.5	178	94.2	9319	1015	90	0.7557	285	6379	517	365
0.5	188	71.3	9327	1111	63	0.7566	285	6384	464	350
13	506	96.6	9594	990	91	0.7557	285	6563	516	365
0.5	516	71.3	9602	1072	64	0.7566	285	6568	465	350
51.5	1888	96.0	10752	889	94	0.7556	285	7359	523	365
1	1908	71.3	10768	915	67	0.7565	285	7370	470	352
138	5604	96.5	13862	617	102	0.7555	285	9668	543	363
0.2	5609	75.2	13866	506	80	0.7563	285	9670	512	365
65	7637	96.7	15734	306	111	0.7554	285	11178	571	363
1	7850	48.7	15745	435	48	0.7573	284	11186	443	341
66	9669	99.3	17278	102	115	0.7552	285	12426	583	364
Cycle 22		Begin : 02.09.92		End : 01.04.93						
0.5	3	24.3	17281	1071	22	0.7582	284	12427	353	311
2	30	48.7	17303	916	47	0.7572	284	12443	440	340
2	72	74.3	17338	784	80	0.7561	285	12469	512	365
2	122	89.4	17380	711	105	0.7554	285	12503	555	359
35	1057	96.0	18170	622	118	0.755	285	13181	594	366
38	2088	95.6	19025	508	121	0.755	285	13934	604	368
1	2082	48.7	19036	677	52	0.7571	284	13943	453	345
129.2	5511	95.4	21957	258	121	0.7560	285	16497	603	364
Cycle 23		Begin : 09.07.93		End : 17.06.94						
8	111	50.0	22096	1211	65	0.7570	284	16582	468	350
58.9	2029	100.0	24436	850	149	0.7545	286	18256	718	397
2.5	2066	53.1	24482	947	75	0.7567	284	18287	494	355
4	2177	100.0	24617	718	155	0.7544	286	18388	737	400
5	2316	100.0	24785	702	162	0.7543	286	18520	755	397
2	2345	53.1	24821	914	75	0.7567	284	18544	495	355
59.9	4013	100.0	26838	594	158	0.7544	286	20095	746	395
59.9	5681	100.0	28838	402	169	0.7542	286	21753	767	384
59.9	7348	100.0	30820	224	171	0.7541	286	23426	772	381
49.9	8738	100.0	32460	66	171	0.7541	286	24825	771	372
20	9205	64.1	33014	50	137	0.7550	285	25271	675	372
Cycle 24		Begin : 01.08.94		End : 30.06.95						
6	78	46.8	33101	1203	48	0.7572	284	25318	450	336
2	118	72.1	33146	1063	78	0.7562	285	25343	510	350
1	139	75.3	33170	1044	85	0.7560	285	25357	526	351
86.7	2535	99.3	35838	784	126	0.7548	285	27147	627	361
86.6	4930	99.3	38494	495	142	0.7545	286	29158	702	368
86.7	7326	99.3	41143	229	150	0.7544	286	31277	735	362
1	7340	48.8	41159	366	60	0.7570	284	31287	482	339
44.8	8583	99.7	42532	38	145	0.7544	286	32352	721	359
1.1	8610	99.0	42565	3	155	0.7543	286	32380	750	360
16.8	9050	94.0	43052	3	146	0.7545	286	32783	725	358
1.6	9070	46.0	43074	3	60	0.7570	284	32798	484	338
Cycle 25		Begin : 30.07.95		End : 28.06.96						
7.8	109	50	43172	1160	47	0.7571	284	32858	451	331
60.6	1789	99.7	44685	827	108	0.7550	285	33932	582	347
1	1802	49.6	44697	951	53	0.7570	284	33940	468	334
57.6	3401	99.7	46157	627	121	0.7548	285	35077	624	355
57.6	5000	99.7	47637	442	135	0.7545	286	36352	692	355
1	5021	75.7	47656	462	98	0.7557	285	36368	565	331
53.7	6513	99.8	49047	272	138	0.7545	286	37577	709	350
1	6527	50.4	49060	434	62	0.7569	284	37587	495	333
65.4	8344	99.8	50774	102	139	0.7545	286	39076	718	347
1	8371	99.1	50800	8	150	0.7543	286	39100	748	329
20.5	8889	90.8	51294	20	136	0.7547	286	39557	704	350
1	8901	42.8	51306	246	54	0.7572	284	39566	476	332

TABLE 5.

BEZNAU - Unit 1

Irradiation of M308 MOX fuel assembly

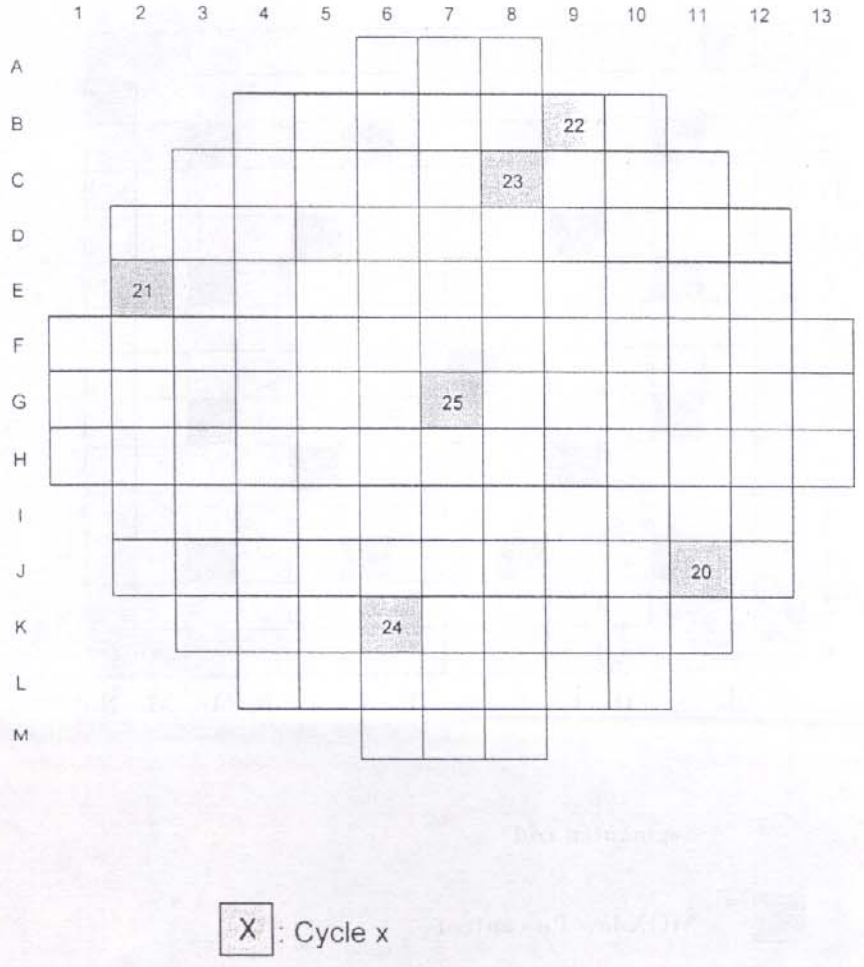
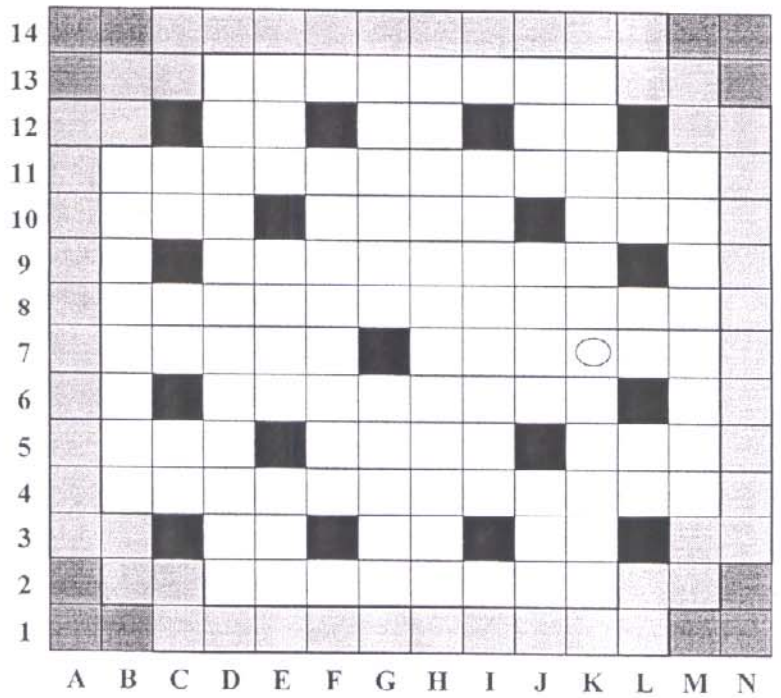


FIGURE 1.

M308 FUEL ASSEMBLY
(Top View)

LOCATION OF RODS



Segmented rod

MOX low Pu content

MOX intermediate Pu content

MOX high Pu content

Guide or intrumentation tube

FIGURE 2.

Position of the samples in segmented rod K7
(from bottom of the rod)

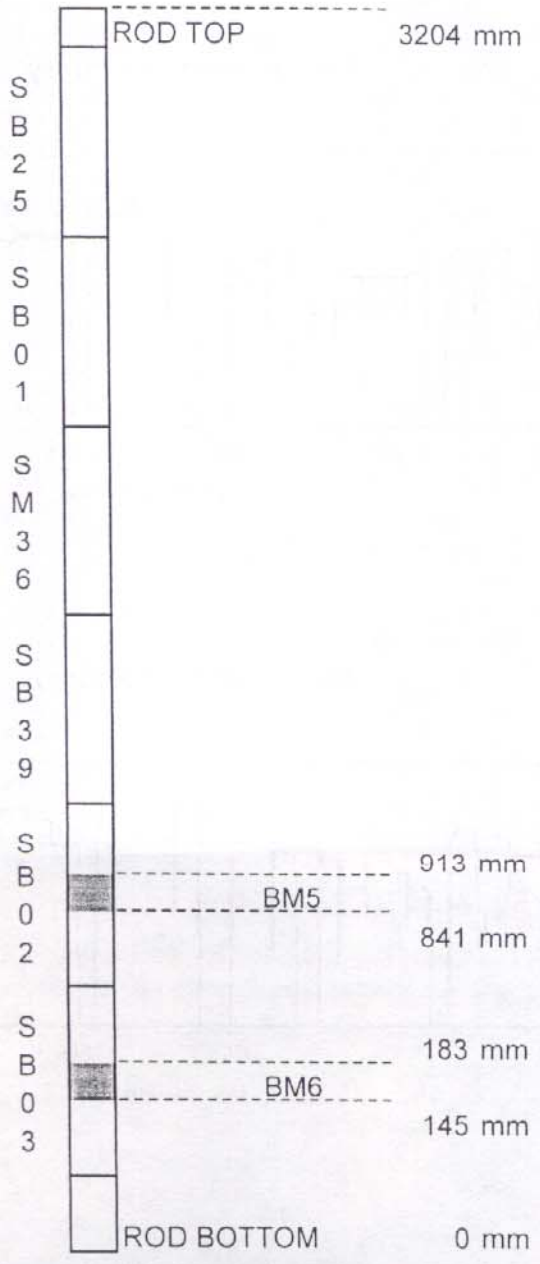
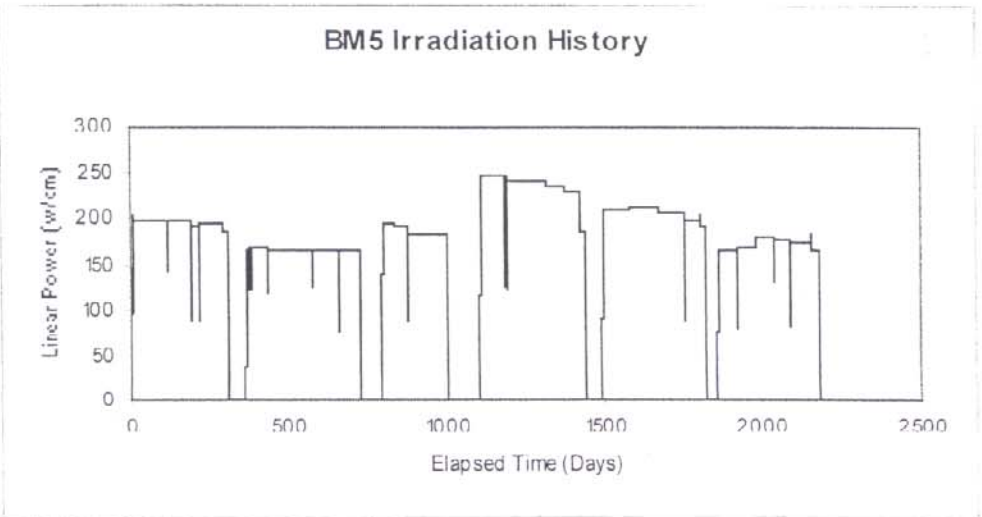


FIGURE 3.


BM5 Irradiation History
Linear Power (w/cm)
300
250
200
150
100
50
0
0
500
1000
1500
2000
2500
Elapsed Time (Days)

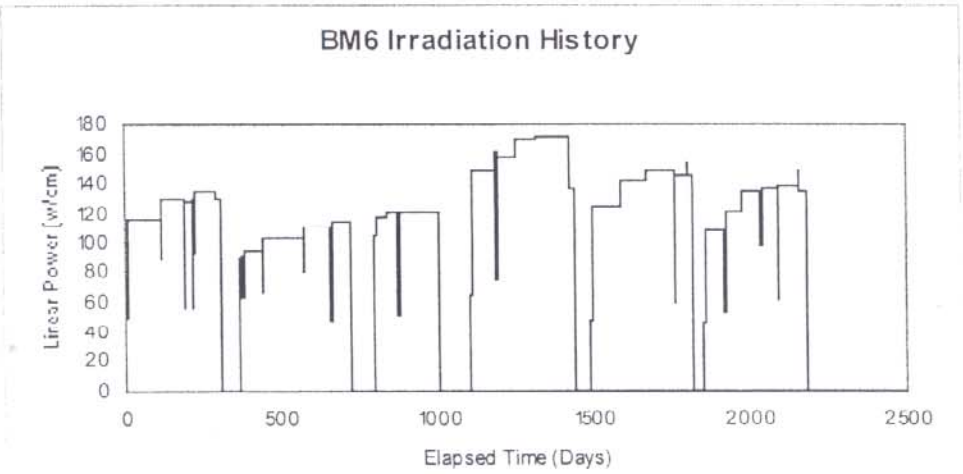

BM6 Irradiation History
Linear Power (w/cm)
180
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
2500
Elapsed Time (Days)

FIGURE 4.

Part II :

PWR - UO2 Samples.

GÖSGEN PWR
samples GU3 and GU4

The two UO_2 samples GU3 and GU4 have been irradiated in the GÖSGEN reactor during 3 cycles in the fuel assembly N° 1601 (cycles 16 and 17) and assembly N° 1701 (cycle 18) after fuel rod changing.

Main core and fuel assembly data are given on table 1.

The assembly 1601 has been irradiated during 2 cycles :

- cycle 16 from june 29, 1994 till june 10,1995
- cycle 17 from july 5, 1995 till june 8, 1996

The assembly 1701 has been irradiated during the cycle :

- cycle 18 from june 30, 1996 till june 7, 1997

The location of these fuel assemblies inside the core during the irradiation is shown on figure 1.

The position of the samples GU3 and GU4 inside the fuel assemblies 1601 and 1701 is shown on figure 2.

Figure 3 shows the segmented rod. The position of the sample GU3 represents actually samples GU3 and GU3'. The fuel rod data are given on table 2.

Figure 4 shows the irradiation history of the two samples GU3 and GU4.

Table 3 gives the complete irradiation history for the ARIANE samples including :

- the core burn-up (MWd/tM), load factor (% nominal power) and boron concentration in the coolant (ppm),
- the fuel assembly average burn-up (MWd/tM),
- the sample linear power (W/cm) and effective temperature (°C),
- the sample burn-up (MWd/tM),
- the water density (g/cc) and temperature (°C).

For the Gösgen samples, the values given in table 4 are pointwise values (not time-step averaged), as provided by SIEMENS.

As it can be shown on the table, after the natural end of cycle (time when the critical boron at 100 % power becomes close to 0.), the power of the core is reduced and the cycle is prolonged a few weeks.

GÖSGEN MAIN CORE DATA

Type of reactor :	PWR
Nominal thermal power :	3002 MW
Pressure primary system :	153 kg/cm²
Coolant inlet temperature :	292.0 °C
average temperature :	309.0 °C
outlet temperature :	326.0 °C
Fuel :	UO2
Oxyde density :	10.4 gr/cm³
Number of assemblies :	177
Number of rods per assembly :	205
Lattice type :	15 x 15
Lattice pitch :	1.43 cm
Assembly pitch :	21.56 cm
Cladding :	Zr-4
Number of guide tubes :	20
Active fuel length :	3550 mm
Guide tube :	
Material :	Zr-4
Inner diameter :	12.4 mm
Outer diameter :	13.8 mm

TABLE 1.

ROD DATA

Pellet :		
Material		UO2
Density	(gr/cm)	10.4
Diameter	(mm)	9.11
U/oxide	(w/o)	88.14
Isotopic composition :		
U234/U	(w/o)	0.042
U235/U	(w/o)	4.1
U238/U	(w/o)	95.858
Linear weight (g/cm)		6.7
Cladding :		
Material		Zr-4
Outer diameter	(mm)	10.75
Inner diameter	(mm)	9.3

TABLE 2.

ARIANE - Sample GU3
(SIEMENS DATA)

Elapsed time (Cumulative Full Power Days)	Core Burn-up (MWd/t)	Core Load Fact. (%)	Assembly Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Sample Temp. (K)	Core average values: Water Density (g/cc)	Core average values: Water Temp. (°C)	Sample Burn-up (MWd/t)
Cycle 16		Begin : 29.06.94		End : 10.06.95					
0	0	100.0	0	1705	376.3	1203.1	0.7046	308.7	0
6	236	100.0		1347	398.5	1244.1	0.7036	308.7	403
150	5902	100.0		690	369.2	1194.6	0.7038	308.7	10171
320	12592 (*)	100.0		5	346.4	1154.1	0.7033	308.7	20796
336.8	13250	92.0	19400	5	298.1	1065.2	0.7249	300.2	21771
Cycle 17		Begin : 05.07.95		End : 08.06.96					
0	0	100.0	19400	1601	300.2	1052.5	0.7045	308.7	21771
6	236	100.0		1247	314.3	1068.5	0.7034	308.7	22096
150	5910	100.0		602	295.5	1005.0	0.7038	308.7	29872
299.5	11802 (*)	100.0		9	287.4	978.7	0.7038	308.4	37461
328.7	12949	89.6	35000	9	234.5	865.4	0.7318	297.1	38866
Cycle 18		Begin : 30.06.96		End : 07.06.07					
0	0	100.0	17700	1675	280.8	944.7	0.7037	308.7	38866
6	237	100.0		1300	273.6	933.6	0.7030	308.7	39149
150	5926	100.0		631	236.7	866.6	0.7037	308.7	45417
301.2	11900 (*)	100.0		17	230.8	858	0.7039	308.4	51400
331.6	13099	89.3	33100	17	193.2	794.9	0.7316	297.2	52504

ARIANE - Sample GU4
(SIEMENS DATA)

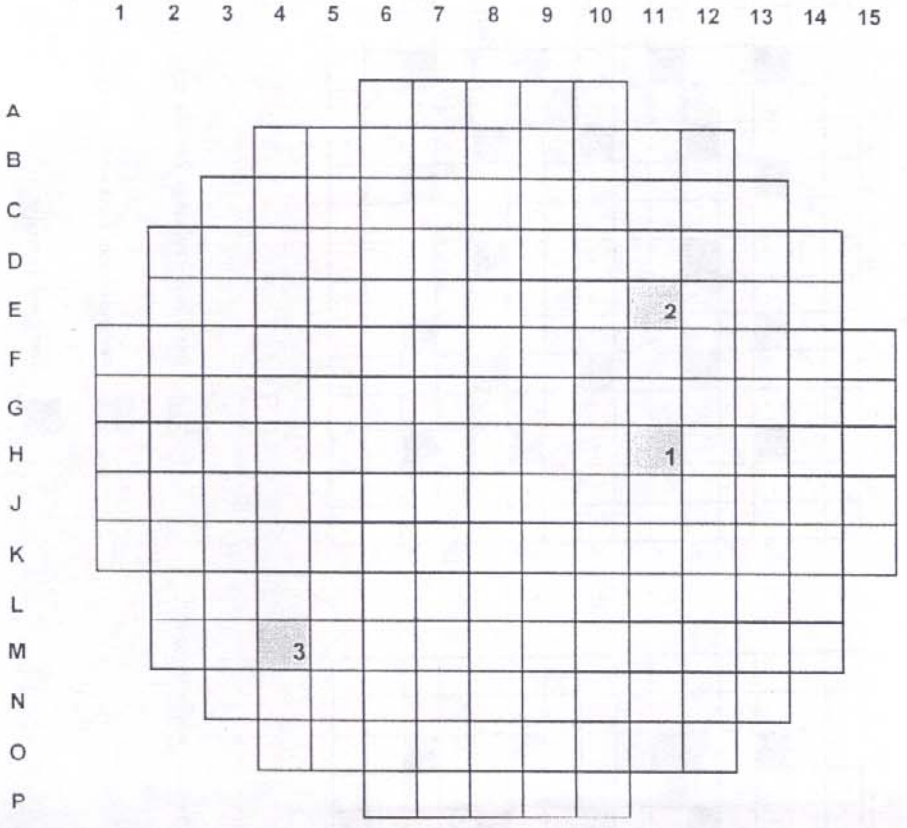
Elapsed time (Cumulative Full Power Days)	Core Burn-up (MWd/t)	Core Load Fact. (%)	Assembly Burn-up (MWd/t)	Boron Conc. (ppm)	Sample Power (W/cm)	Sample Temp. (K)	Core average values: Water Density (g/cc)	Core average values: Water Temp. (°C)	Sample Burn-up (MWd/t)
Cycle 16		Begin : 29.06.94		End : 10.06.95					
0	0	100.0	0	1705	92.5	731.1	0.7046	308.7	0
6	236	100.0		1347	124.2	782.0	0.7036	308.7	111
150	5902	100.0		690	191.8	901.1	0.7038	308.7	4001
320	12592 (*)	100.0		5	261.1	1008.5	0.7033	308.7	10530
336.8	13250	92.0	19400	5	212.8	919.9	0.7249	300.2	11248
Cycle 17		Begin : 05.07.95		End : 08.06.96					
0	0	100.0	19400	1601	98.0	744.8	0.7045	308.7	11246
6	236	100.0		1247	125.7	786.9	0.7034	308.7	11372
150	5910	100.0		602	183.2	865.5	0.7038	308.7	15250
299.5	11802 (*)	100.0		9	242.3	949.8	0.7038	308.4	20608
328.7	12949	89.6	35000	9	185.5	851.2	0.7318	297.1	21762
Cycle 18		Begin : 30.06.96		End : 07.06.97					
0	0	100.0	17700	1675	75.0	687	0.7037	308.7	21762
6	237	100.0		1300	90.5	709.1	0.7030	308.7	21858
150	5926	100.0		631	125.4	756.8	0.7037	308.7	24564
301.2	11900 (*)	100.0		17	167.2	805.6	0.7039	308.4	28298
331.6	13099	89.3	33100	17	130.6	744.6	0.7316	297.2	29067

(*) : Natural End of Cycle

TABLE 3.

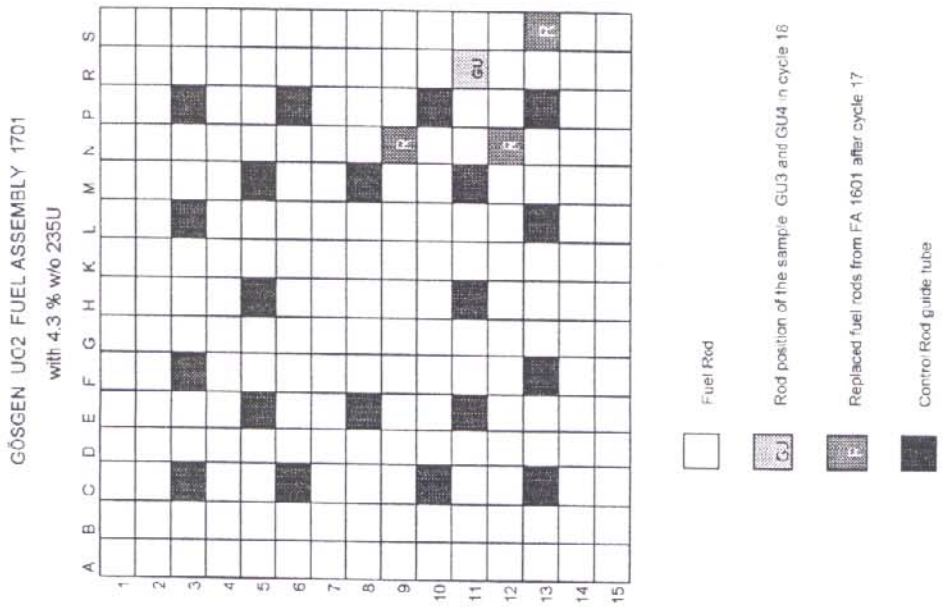
CROSS SECTION OF GÖSGEN NPP

Irradiation of UO2 assembly FA-No. 1601 and 1701



Assembly FA-No. 1601	H 11	Irradiation cycle 16 (1)
	E 11	Irradiation cycle 17 (2)
Assembly FA-No. 1701	M 4	Irradiation cycle 18 (3)

FIGURE 1.


GÖSGEN UO2 FUEL ASSEMBLY 1701
with 4.3 % w/o 235U
A B C D E F G H K L M N P R S
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
GU
R
Fuel Rod
Rod position of the sample GU3 and GU4 in cycle 16
Replaced fuel rods from FA 1601 after cycle 17
Control Rod guide tube

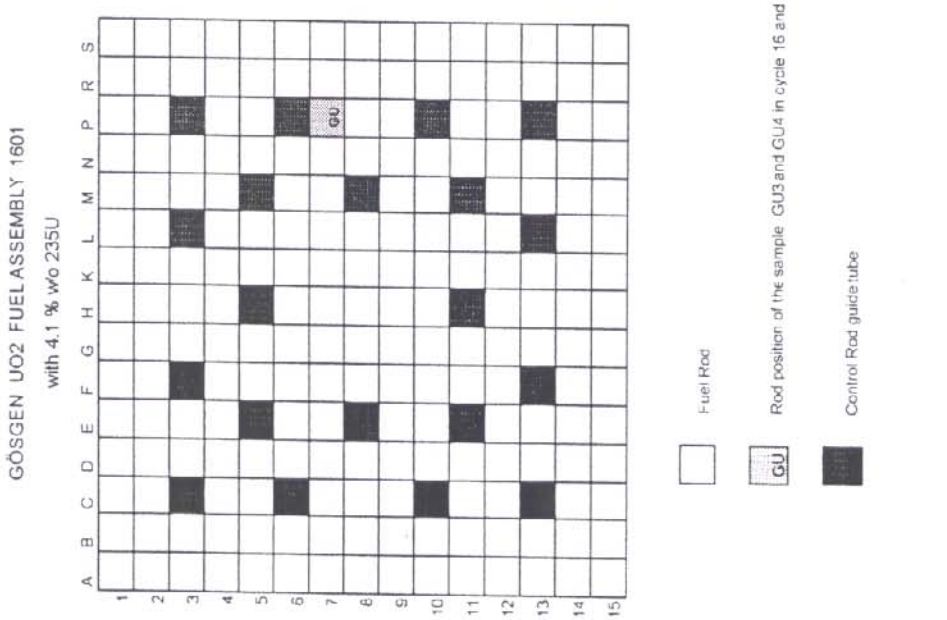

GÖSGEN UO2 FUEL ASSEMBLY 1601
with 4.1 % w/o 235U
A B C D E F G H K L M N P R S
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
GU
Fuel Rod
Rod position of the sample GU3 and GU4 in cycle 16 and 17
Control Rod guide tube

FIGURE 2.

Position of the samples
(from bottom of active fuel column)

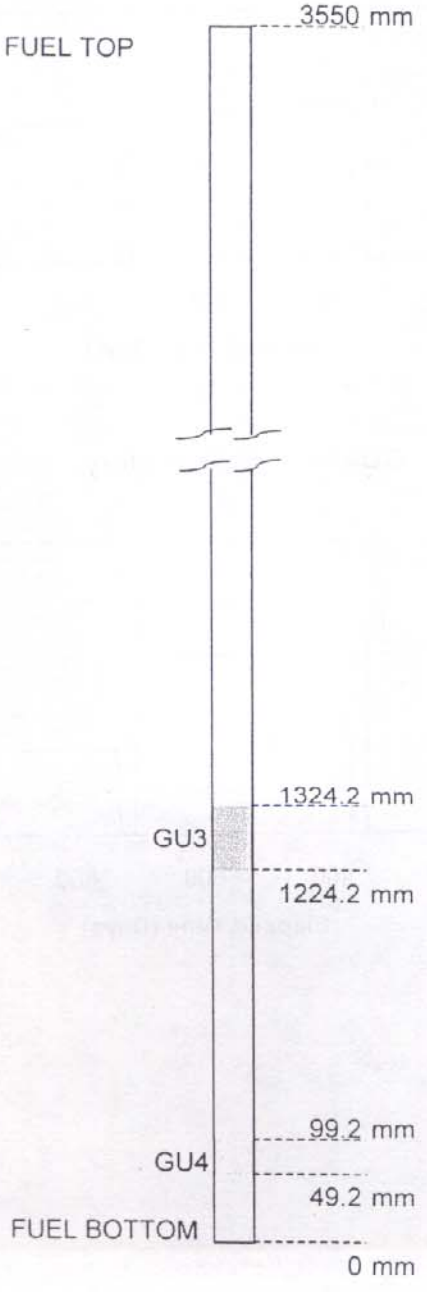
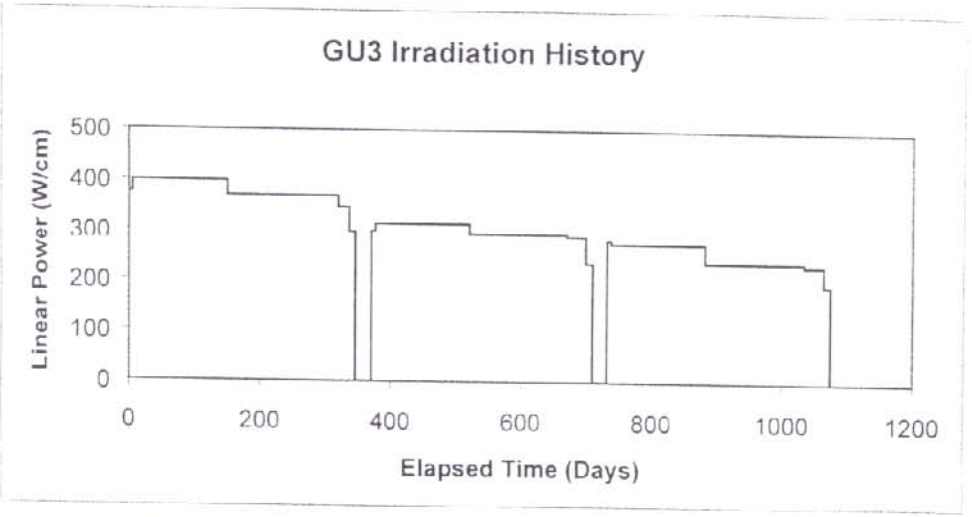


FIGURE 3.


GU3 Irradiation History
Linear Power (W/cm)
500
400
300
200
100
0
0
200
400
600
800
1000
1200
Elapsed Time (Days)

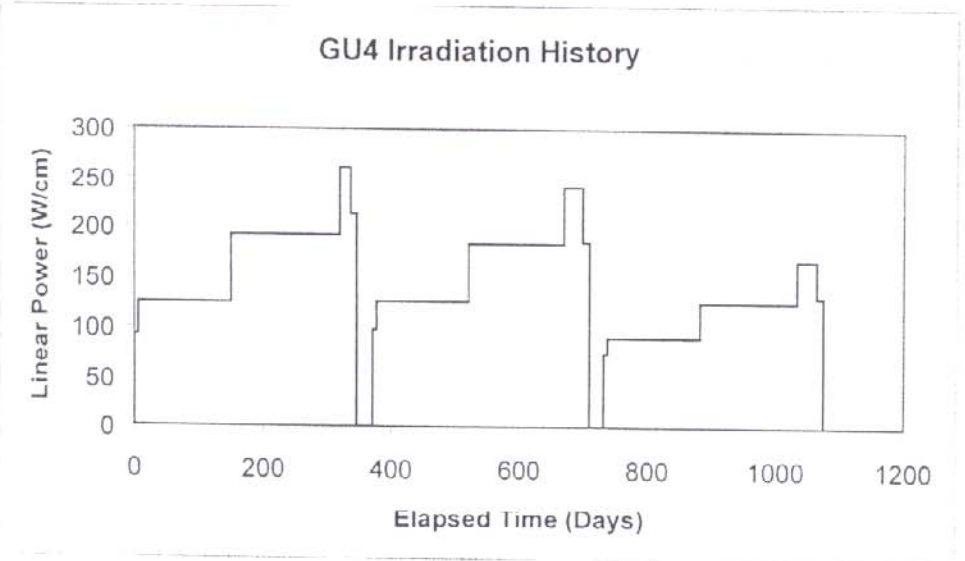

GU4 Irradiation History
Linear Power (W/cm)
300
250
200
150
100
50
0
0
200
400
600
800
1000
1200
Elapsed Time (Days)

FIGURE 4.

AR 2001/20
BN Ref. 0100823/221

ARIANE
International Programme

Irradiation Data Report
Part 3

Issued February, 2001

BELGONUCLEAIRE
Avenue Ariane, 4 - 1200 Brussels.

	Type of document : REPORT	BN reference N° / File - « Rev. » - Page 0100823 / 221 - « - » 1
		Other reference : AR 2001/20
Client : ARIANE Participants		Author(s) : B. Lance & H. Gabaïeff
Project: ARIANE International Programme		
Subject:		

ARIANE PROGRAMME

IRRADIATION DATA REPORT
PART 3

With the contribution of SIEMENS

C															
B															
A															
–	Feb. 2001	0100823	FIN	TA	BLA	BL	BD		ML				HBe		21
Rev.	Date	Chrono Filing n°	Status	Typist's Initials	Initials	Visa N°1	Initials	Visa N°2	Initials	Visa N°3	Initials	Visa N°4	Initials	Visa N°5	Number of Pages
					Author		Verified by		Approved by		Q.A.		Issued by		

Distribution :

ARIANE Programme Participants

BN : Mrs. Boulanger

MM. Vanderborck, Lippens, Mertens, Renard, Lance, Basselier

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use of exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, withjout prejudice to any other right.

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 - 1200 Bruxelles

TVA : BE 403.126.258
RCB : 271.300

TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

LIST OF MODIFICATIONS

DATE	REVISION	OBJECT
Feb. 2001	-	Final issue

NOTICE

LIABILITY

This document was prepared by BELGONUCLEAIRE (BN), with the contribution of SIEMENS. Neither BN or any person acting on behalf of BN:

(a) gives any warranty, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this document, or that the use of any information, apparatus, method or process disclosed in this document may not infringe third party, or

(b) assumes any liabilities with respect to the use of, or for damage resulting from the use of any information, apparatus, method or process disclosed in this document.

PERSONNEL IN CONFIDENCE/NOT FOR PUBLICATION

All property rights and copyrights are reserved. Any communication or reproduction of this document and any communication or use of its content without explicit authorisation of the ARIANE programme committee is prohibited. Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting of a patent or registration in the field of intellectual property.

TABLE OF CONTENTS

	Pages :
DISTRIBUTION LIST	5
INTRODUCTION	6
POSITION OF THE SAMPLES	6
METHODS AND RESULTS	6
REFERENCES	7

DISTRIBUTION LIST

SIEMENS (D)	Dr. G. Stach	2 copies
SCK-CEN (BE)	Mr. P. D'hondt	5 copies
GNB (D)	Dr. R. Hüggenberg	2 copies
MHI (JP)	Mr. S. Abeta	2 copies
BNFL (UK)	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	Mr. Y. Nakajima	2 copies
HITACHI (JP)	Mr. T. Mochida	2 copies
ORNL (USA)	Mr. R. T. Primm III	2 copies
NEL (JP)	Mr. H. Naito	2 copies
JRI (JP)	Mr. T. Kaneko	2 copies
NOK (CH)	Mr. G. Devillaz	2 copies
GKN (NL)	Mr. W.R. Van Engen	2 copies
PSI (CH)	Mr. C. Hellwig	2 copies
TRACTEBEL (BE)	Mr. R. de Wouters	2 copies

1 INTRODUCTION

This report has been compiled in the framework of the ARIANE international programme, as a complement to the Refs. 1 and 2. It describes the power history of the PWR fuel assemblies (FA) at the axial levels of the ARIANE samples. The calculations concerning the MOX samples irradiated in Beznau have been perfomed by BELGONUCLEAIRE. The results for the Gösgen UO_2 samples have been provided by SIEMENS. No calculation can be performed for the BWR samples as the Dodewaard calculation team does no more exist, further to the reactor definitive shut down in 1992.

2 POSITION OF THE SAMPLES

2.1 PWR MOX samples

The samples BM5 and BM6 belong respectively to the segments SB02 and SB03 (see Figure 1) of the rod located at assembly position K7. The latter rod has been irradiated in the assembly M308.
The samples BM1 and BM2-D (Figure 2) belong to the rod located at position D3, and the samples BM3 and BM4-D to the rod situated at position B6. All these rods belong to the M109 assembly.

2.2 PWR UO2 samples

The sample GU1 (Figure 3) belong to the rod 14H13, located in the FA 12-40. The samples GU3 and GU4 (Figure 4) belong to the rod 16B05, irradiated in the FA 16-01 during the cycles 16 and 17, and in the FA 17-01 for the cycle 18.

The Table 1 gives the axial position of all the samples, for which the FA linear power and the FA averaged burnup have been determined. The values take the base of the bottom stop as the origin.

3 METHODS AND RESULTS

All reported values of linear power, given in the Tables 2 and 3, are the averaged FA linear power, reduced to one single rod, i.e. taking into account the number of 172 rods per assembly for the PWR MOX case, and 205 rods per assembly for the PWR UO_2 case.

3.1 PWR MOX samples

The core calculations (nodal calculations) which have been realized (Refs. 1 & 2) give 24 values of linear power, equally distributed along the active height (3023 mm) of the MOX assemblies. So we had to compare a normal MOX rod with the concerned rods K7, D3 and B6 to determine the two nearest nodes from which a linear interpolation could be performed.

As the heights of the samples BM2-D / BM4-D, and BM1 / BM3 are the same, the results for the PWR MOX samples consist only in 2 tables (all burnups in GWd/tM) : the Table 2.a concerns the M308 assembly and the Table 2.b the M109 one.

The core calculation does not take into account the presence of the grids. Thus, a correction factor of 1.5% is applied to all reported power and burnup values. It is in fact well known that the grids create a localized (in the axial direction) flux depletion which is approximately compensated between them by a mean factor of 1.5%.

3.2 PWR UO2 samples

The results for the PWR UO2 samples have been provided by SIEMENS. These are given in the Table 3.a for the sample GU1, and in the Table 3.b for the samples GU3 and GU4, in the same form as for the PWR MOX samples.

4 REFERENCES

1. Ariane International Programme, "Irradiation Data Report - Part 1", AR 96/05, March 1999.
2. Ariane International Programme, " Irradiation Data Report - Part 2", AR 99/13, July 1999.

Table 1.
Axial position of the samples

Sample	Rod	Assembly	Axial position (mm)	Comment
PWR MOX samples irradiated in Beznau				
BM5	K7	M308	893	Contact point between BM5-PSI and BM5-SCK
BM6	K7	M308	164	Centre of the sample
BM1	D3	M109	954	Centre of the sample
BM2-D	D3	M109	257.5	Centre of the sample
BM3	B6	M109	954	Centre of the sample
BM4-D	B6	M109	257.5	Centre of the sample
PWR UO2 samples irradiated in Gösgen				
GU1	14H13	12-40	960.5 - 993.5	
GU3	16B05	16-01 → 17-01	1224.2 - 1324.2	
GU4	16B05	16-01 → 17-01	49.2 - 99.2	

Table 2.a.
History of the fuel assemblies at the axial levels of samples BM5 and BM6

Cycle 20 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	1.0	48.8	0.01	23.3	0.00
2	1.5	101.5	0.03	50.8	0.02
3	2.0	159.9	0.09	84.8	0.04
4	1.0	224.6	0.12	125.8	0.06
5	1.0	105.2	0.14	54.3	0.07
6	110.0	218.1	4.06	128.8	2.39
7	0.5	157.9	4.07	98.5	2.40
8	76.0	215.8	6.76	143.3	4.18
9	0.5	97.3	6.76	60.6	4.18
10	23.0	209.3	7.55	141.8	4.72
11	0.2	97.1	7.56	61.3	4.72
12	3.5	209.0	7.67	143.0	4.80
13	0.5	150.7	7.69	100.2	4.81
14	69.5	210.8	10.08	148.5	6.50
15	17.6	201.7	10.66	142.1	6.91

Cycle 21 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	0.5	36.6	10.67	17.1	6.91
2	2.0	75.4	10.69	36.7	6.92
3	1.5	120.3	10.72	61.9	6.93
4	1.0	150.1	10.75	80.1	6.95
5	1.0	160.7	10.77	87.1	6.96
6	2.5	161.0	10.84	87.5	7.00
7	0.5	117.7	10.85	61.8	7.00
8	12.0	162.1	11.17	88.5	7.18
9	0.5	117.3	11.18	62.4	7.18
10	51.5	161.8	12.54	91.4	7.95
11	1.0	115.7	12.56	65.5	7.96
12	138.0	159.6	16.16	98.7	10.19
13	0.2	119.7	16.16	77.4	10.19
14	83.0	157.8	18.30	107.5	11.65
15	1.0	72.4	18.32	46.2	11.66
16	66.0	159.3	20.04	111.1	12.86

Table 2.a. (cont'd)

Cycle 22 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	0.5	35.3	20.04	18.2	12.86
2	2.0	72.6	20.06	38.9	12.87
3	2.0	117.2	20.10	66.3	12.89
4	2.0	147.7	20.15	87.0	12.92
5	35.0	162.2	21.08	98.6	13.49
6	38.0	161.2	22.08	101.2	14.12
7	1.0	73.9	22.09	43.2	14.12
8	129.2	155.2	25.37	101.2	16.26

Cycle 23 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	8.0	120.8	25.53	64.1	16.34
2	68.9	248.3	28.32	147.1	18.00
3	2.5	126.1	28.38	73.9	18.03
4	4.0	243.8	28.54	153.5	18.13
5	5.0	248.3	28.74	159.5	18.26
6	2.0	125.3	28.78	74.1	18.29
7	59.9	240.8	31.14	156.1	19.82
8	59.9	240.3	33.49	166.4	21.45
9	59.9	234.2	35.79	167.6	23.09
10	49.9	228.8	37.66	168.0	24.46
11	20.0	185.7	38.26	133.9	24.90

Cycle 24 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	6.0	93.8	38.35	49.5	24.95
2	2.0	148.5	38.40	81.4	24.97
3	1.0	158.3	38.43	88.4	24.99
4	86.7	214.8	41.47	130.8	26.84
5	86.6	215.5	44.52	146.4	28.92
6	86.7	211.5	47.52	153.9	31.10
7	1.0	91.9	47.54	62.0	31.11
8	44.8	201.8	49.02	149.3	32.20
9	1.1	207.8	49.05	159.6	32.23
10	16.8	196.6	49.59	150.5	32.64
11	1.6	87.2	49.62	61.7	32.66

Table 2.a. (cont'd)

Cycle 25 – Assembly M308

Time Step Nr.	Elapsed Time *(days)*	Level of sample BM5		Level of sample BM6	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	7.8	74.4	49.71	44.9	32.72
2	60.6	158.5	51.28	103.9	33.75
3	1.0	78.0	51.29	51.1	33.75
4	57.6	164.0	52.84	115.7	34.84
5	57.6	172.0	54.46	129.8	36.07
6	1.0	126.6	54.48	94.2	36.08
7	53.7	169.7	55.97	132.0	37.24
8	1.0	80.9	55.98	59.4	37.25
9	65.4	168.8	57.79	133.6	38.68
10	1.0	174.9	57.82	144.6	38.71
11	20.5	159.6	58.35	131.0	39.15
12	1.0	68.1	58.36	51.5	39.15

Table 2.b.
History of the fuel assemblies at the axial levels of samples BM2-D, BM4-D, BM1 and BM3

Cycle 18 – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	1.5	39.6	0.01	65.3	0.02
2	2.5	86.6	0.05	136.0	0.07
3	2.5	108.1	0.09	164.1	0.14
4	29.5	129.0	0.71	188.9	1.05
5	52.0	134.0	1.85	187.5	2.64
6	2.0	99.3	1.88	139.3	2.69
7	104.5	137.9	4.24	181.2	5.79
8	104.5	147.3	6.76	179.0	8.84

Cycle 19 – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	1.0	23.6	6.76	40.9	8.85
2	2.5	53.0	6.78	87.5	8.89
3	2.0	64.6	6.80	103.0	8.92
4	2.0	75.9	6.83	118.4	8.96

Cycle 19B – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	1.0	23.7	6.83	40.2	8.97
2	1.5	53.4	6.85	86.1	8.99
3	1.0	65.8	6.86	102.6	9.00
4	2.5	78.3	6.89	119.0	9.05
5	0.1	30.0	6.89	49.8	9.05
6	22.0	76.9	7.17	117.6	9.48
7	169.0	86.2	9.55	117.7	12.73
8	0.2	37.8	9.55	50.9	12.73
9	45.0	87.3	10.19	109.3	13.53
10	1.0	39.4	10.20	51.7	13.54
11	30.0	90.6	10.64	110.6	14.08
12	10.0	91.3	10.79	108.7	14.26

Table 2.b. (cont'd)

Cycle 20 – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	1.0	33.9	10.80	50.6	14.27
2	1.5	72.1	10.82	104.3	14.30
3	2.0	118.7	10.85	163.1	14.35
4	1.0	173.9	10.88	228.0	14.39
5	1.0	77.3	10.89	108.3	14.40
6	110.0	178.3	14.10	225.5	18.46
7	0.5	138.2	14.11	166.5	18.47
8	76.0	198.5	16.58	228.0	21.31
9	0.5	86.4	16.59	105.3	21.32
10	23.0	196.9	17.33	224.1	22.16
11	0.2	87.3	17.33	105.3	22.16
12	3.5	198.6	17.45	224.4	22.29
13	0.5	140.8	17.46	162.5	22.31
14	69.5	205.8	19.80	227.1	24.89
15	17.6	198.7	20.37	220.1	25.52

Cycle 21 – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	0.5	33.4	20.37	52.4	25.52
2	2.0	70.1	20.39	106.2	25.56
3	1.5	116.7	20.42	168.1	25.60
4	1.0	150.3	20.45	209.0	25.63
5	1.0	163.3	20.47	223.8	25.67
6	2.5	164.2	20.54	224.4	25.76
7	0.5	117.1	20.55	165.3	25.78
8	12.0	165.4	20.87	225.4	26.22
9	0.5	118.2	20.88	164.7	26.23
10	51.5	169.9	22.32	225.1	28.13
11	1.0	123.1	22.34	163.0	28.15
12	138.0	180.8	26.42	222.5	33.18
13	0.2	142.1	26.42	168.5	33.18
14	83.0	193.3	29.04	219.4	36.16
15	1.0	84.8	29.06	102.7	36.18
16	66.0	197.0	31.18	220.6	38.56

Table 2.b. (cont'd)

Cycle 22 – M109

Time Step Nr.	Elapsed Time *(days)*	Level of samples BM2-D & BM4-D		Level of samples BM1 & BM3	
		FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(GWd/tM)*
1	0.5	31.8	31.19	44.2	38.56
2	2.0	65.7	31.21	88.6	38.59
3	2.0	109.7	31.24	141.3	38.64
4	2.0	141.8	31.29	176.3	38.69
5	35.0	160.4	32.21	194.5	39.81
6	38.0	164.4	33.23	194.8	41.02
7	1.0	73.3	33.24	92.6	41.03
8	129.2	162.3	36.67	188.5	45.01

Table 3.a.
History of the fuel assemblies at the axial levels of the sample GU1

Cycle 12 - Assembly FA 12-40

elapsed time *(efpd)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	327.8	0.00
6.0	340.2	0.35
150.0	321.1	8.90
294.2 (EOC_{nat})	311.1	16.96
317.0 ($EOC_{stretch}$)	291.0	18.13

Cycle 13 - Assembly FA 12-40

elapsed time *(efpd)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	204.8	18.13
6.0	235.9	18.36
150.0	254.0	24.61
292.3 (EOC_{nat})	262.3	31.05
321.3 ($EOC_{stretch}$)	235.9	32.35

Cycle 14 - Assembly FA 12-40

elapsed time *(efpd)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	221.9	32.35
6.0	229.3	32.61
150.0	214.7	38.84
290.1 (EOC_{nat})	212.4	44.57
331.3 ($EOC_{stretch}$)	188.7	46.14

Cycle 15 - Assembly FA 12-40

elapsed time *(efpd)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	194.4	46.14
6.0	212.1	46.35
150.0	202.7	51.59
301.9 (EOC_{nat})	201.9	56.98
326.7 ($EOC_{stretch}$)	182.5	57.80

Table 3.b.
History of the fuel assemblies at the axial levels of the samples GU3 and GU4

Cycle 16 - Assembly FA 16-01

elapsed time *(efpd)*	Level of sample GU3		Level of sample GU4	
	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	359.4	0.00	89.3	0.00
6.0	380.9	0.39	119.7	0.11
20.0	379.3	1.32	127.2	0.40
40.0	377.0	2.64	136.1	0.84
60.0	375.5	3.95	146.8	1.32
90.0	373.9	5.92	164.0	2.09
120.0	371.5	7.88	179.4	2.94
150.0	357.7	9.82	185.6	3.88
180.0	358.9	11.69	202.2	4.85
210.0	349.8	13.57	209.0	5.91
240.0	347.2	15.40	221.4	7.00
270.0	345.2	17.21	234.2	8.16
300.0	342.0	19.21	246.2	9.38
320.0 (EOC_{nat})	339.6	20.22	254.3	10.25
330.0	316.4	20.81	223.7	10.69
334.6	316.9	21.06	224.1	10.87
336.8 ($EOC_{stretch}$)	317.7	21.18	225.4	10.95

Cycle 17 - Assembly FA 16-01

elapsed time *(efpd)*	Level of sample GU3		Level of sample GU4	
	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	292.6	21.18	95.1	10.95
6.0	303.7	21.49	120.6	11.07
20.0	303.3	22.23	129.0	11.37
40.0	301.3	23.29	136.8	11.82
60.0	299.6	24.34	145.5	12.29
90.0	297.9	25.90	159.0	13.05
120.0	296.3	27.46	171.3	13.88
150.0	285.7	29.00	174.9	14.78
180.0	287.6	30.49	189.5	15.69
210.0	281.2	32.00	194.9	16.68
240.0	280.0	33.47	206.2	17.70
270.0	279.4	34.93	218.3	18.77
299.5 (EOC_{nat})	277.7	36.36	229.9	19.90
309.6	269.0	36.85	230.8	20.30
319.3	261.9	37.31	216.8	20.67
326.7 ($EOC_{stretch}$)	255.7	37.73	199.4	21.00

Table 3.b. (cont'd)

Cycle 18 - Assembly FA 17-01

elapsed time *(efpd)*	Level of sample GU3		Level of sample GU4	
	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*	FA averaged linear power *(W/cm)*	FA averaged burnup *(MWd/kgM)*
0.0	329.5	20.00	90.9	9.71
6.0	323.8	20.34	110.3	9.83
20.0	319.5	21.14	115.5	10.10
40.0	314.0	22.25	121.8	10.50
60.0	307.8	23.35	129.2	10.93
90.0	300.7	24.97	140.9	11.60
120.0	295.4	26.54	151.5	12.34
150.0	282.7	28.09	154.8	13.13
180.0	282.9	29.58	167.6	13.95
210.0	275.8	31.06	172.8	14.83
240.0	274.0	32.51	183.1	15.74
270.0	273.2	33.94	194.5	16.70
300.0	271.5	35.38	205.7	17.72
301.2 (EOC_{nat})	271.4	35.44	206.2	17.76
311.3	265.0	35.91	196.0	18.13
321.0	259.7	36.36	188.2	18.46
330.4	255.3	36.79	182.5	18.77
331.6 ($EOC_{stretch}$)	254.6	36.84	181.7	18.81

Figure 1

Position of the samples BM5 and BM6 in the segmented rod K7 (from bottom of the rod)

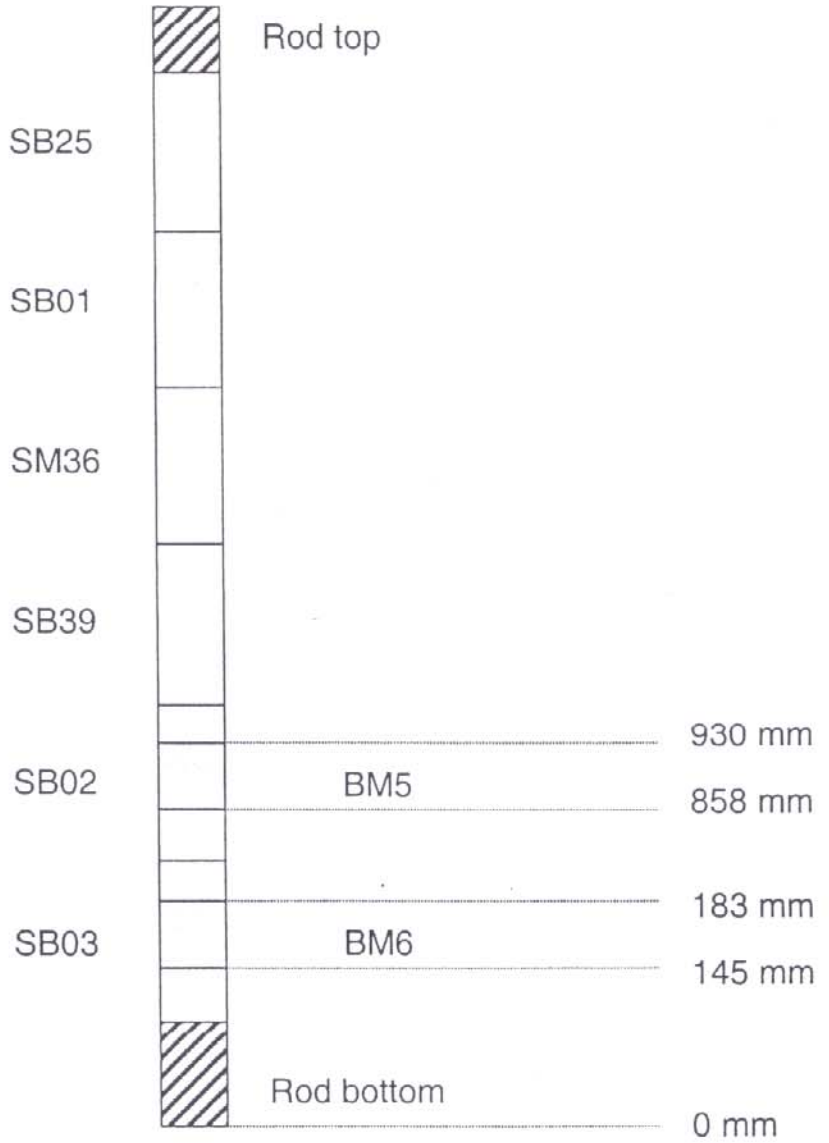


Figure 2

Position of the samples BM1, BM2-D, BM3 and BM4-D in the rods B6 and D3 (from bottom of the rod)

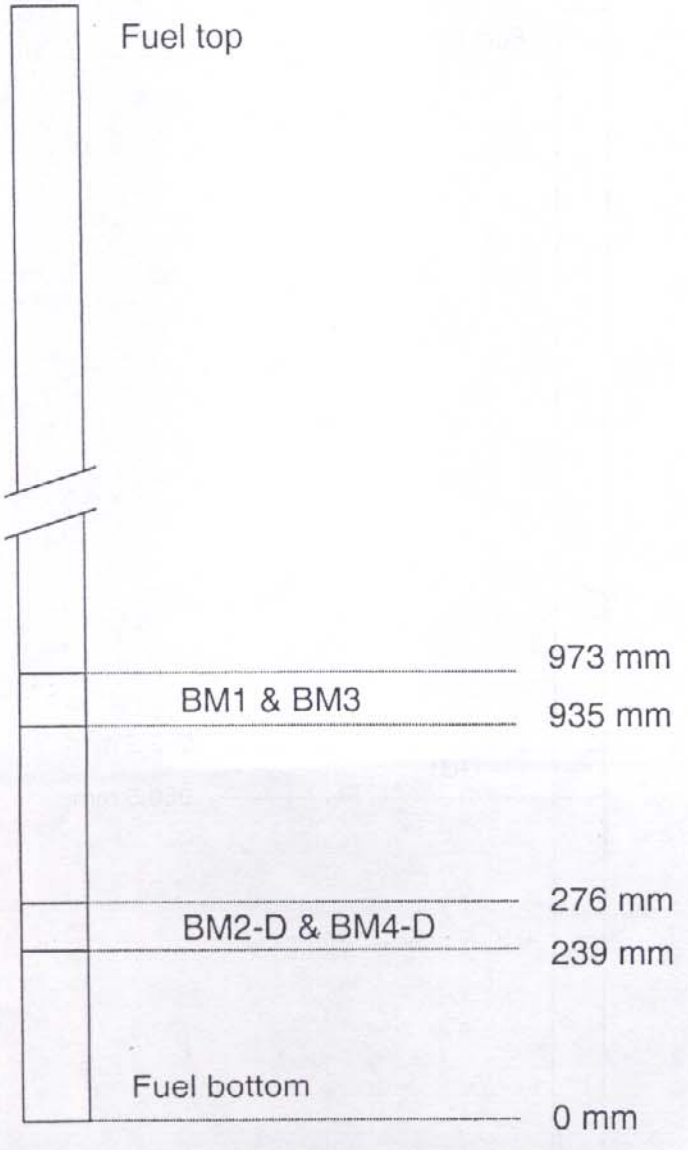


Figure 3

Position of the sample GU1 in the rod 14H13
(from bottom of the rod)

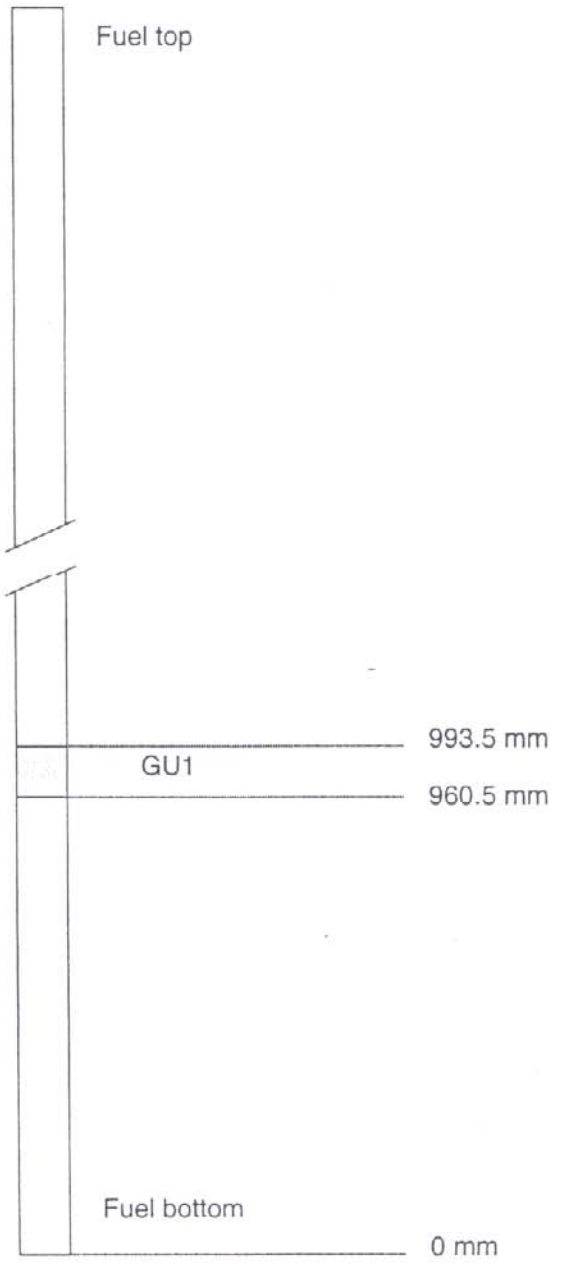
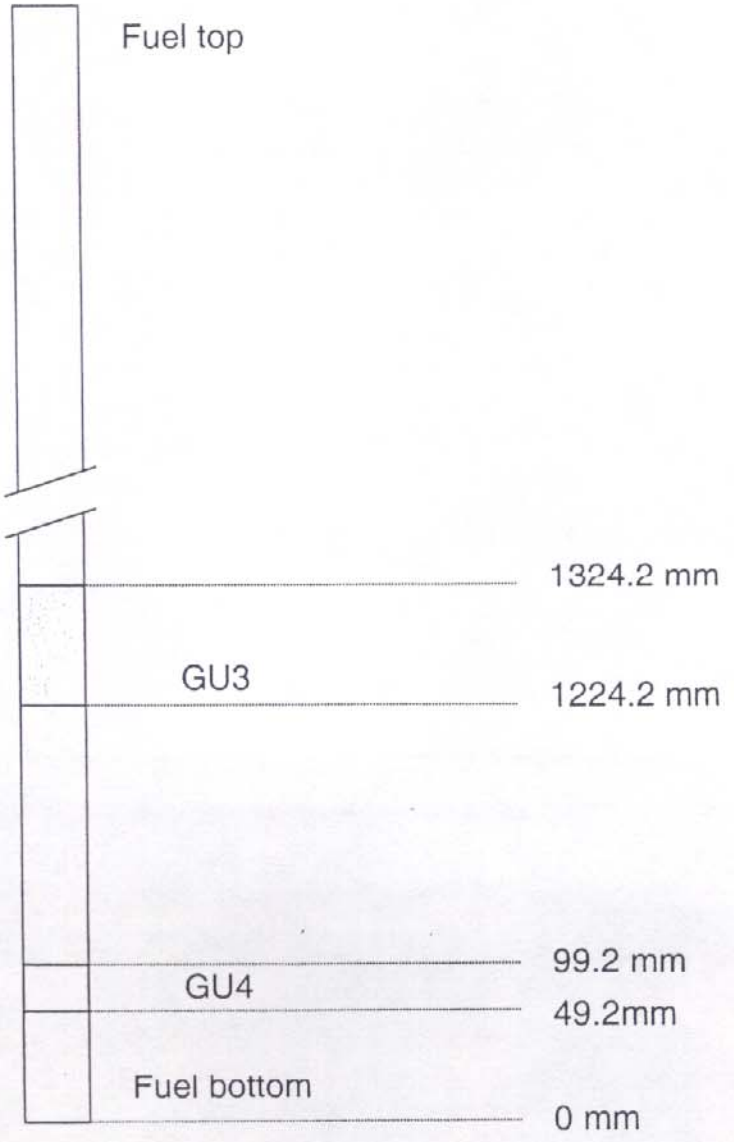


Figure 4

Position of the samples GU3 and GU4 in the rod 16B05 (from bottom of the rod)



	Type of document : Technical Note	BN reference N° / File - « Rev. » - Page 9904108/221 - "A" - 1 Other reference :
Client : ARIANE participants		Author(s) : D. BOULANGER M. LIPPENS
Project: ARIANE		
Subject:		

REASSESSMENT OF THE IDENTITY OF RODS IRRADIATED IN ASSEMBLY M109 AND USED IN THE FRAMEWORK OF THE PROGRAMMES M109, ARIANE AND FIGARO

Rev.	Date	Chrono Filing n°	Status	Typist's Initials	Initials	Visa N°1	Initials	Visa N°2	Initials	Visa N°3	Initials	Visa N°4	Initials	Visa N°5	Number of Pages
					Author		Verified by		Approved by		Q.A.		Issued by		
C															
B															
A	14.12.99	9908373	FIN	JS	BD		ML						JS		28
	03.06.99	9904108	FIN	JS	BD		ML				-	-	HBe		25

Distribution : . ARIANE participants
. BN : Mrs. Boulanger, Messrs Vanderborck (1st page), Basselier (1st page), Lippens

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use of exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, without prejudice to any other right.

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 – 1200 Bruxelles
TVA : BE 403.126.258
RCB : 271.300
TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

LIST OF MODIFICATIONS

DATE	REVISION	OBJECT
June 1999	"-"	Final edition
December 1999	A	Update to demonstrate impossibility of alternative "cask rotation" loading leading to erroneous rod name attribution

TABLE OF CONTENTS

* * *

1. DISTRIBUTION LIST ARIANE page 4

2. INTRODUCTION page 5

2. ROD HANDLING page 6

3. PIE RESULTS page 9

4. CONCLUSIONS page 13

REFERENCES page 14

TABLES

FIGURES

* * *

ARIANE INTERNATIONAL PROGRAMME

* * *

DISTRIBUTION LIST

* * *

SIEMENS (D)	:	Dr. G. Schlosser	2 copies
SCK•CEN	:	Mr. P. D'hondt	5 copies
GNB (D)	:	Dr. R. Hüggenberg	2 copies
MHI (JP)	:	Mr. S. Abeta	2 copies
BNFL (UK)	:	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	:	Mr. Nakajima	2 copies
HITACHI (JP)	:	Mr. T. Mochida	2 copies
ORNL (USA)	:	Mr. T.T. Primm III	2 copies
NEL (JP)	:	Mr. H. Naito	2 copies
JRI (JP)	:	Mr. T. Kaneko	2 copies
NOK (CH)	:	Mr. G. Devillaz	2 copies
GKN (NL)	:	Mr. W.R. Van Engen	2 copies
PSI (CH)	:	Mr. G. Ledergerber	2 copies
TRACTEBEL (B)	:	Mr. R. de Wouters	2 copies

* * *

1. INTRODUCTION

The MOX fuel assembly M109 was base irradiated in the BEZNAU1-PWR from July 1988 till March 1993.

From the assembly, ten (10) rods were extracted (November 1993) and transported to PSI (November 1994) with a view to perform experimental work within the framework of the programmes M109 (8 rods), ARIANE (samples from 2 rods selected amongst the previous group of 8) and FIGARO (2 rods).

Progressively, during the carrying out of these programmes, different experimental results showed an increasing number of discrepancies with expectations. Mainly, one noticed:

- the fission gas release data were not in agreement with power history (excessive FGR for low rated rod G5) ;
- the radiochemistry results for rods E11 and G5 were too close to each other compared to reliable calculated burnup difference ;
- the large grain size (15 µm) of rod I2 expected from fabrication data was not found during PIE.

These results raised the assumption of possible mixing in identity of rods used for the different programmes.

Today, numerous PIE results foreseen in the programmes as well as complementary experimental investigations made by PSI demonstrate that the identity of the rods used during hot cell work do not correspond to the name they received originally (the rods are not marked at fabrication, but are named by their position in assembly). Such discrepancy results from the erroneous information on position of reference mark on cask used for rod transport between BEZNAU site and PSI. The drawing of cask does not reproduce correctly the mark position actually made on cask at fabrication. The consequence of this is the incorrect traceability of the rod identity, all individual names of rods having been attributed to rods in adjacent cells, leading to a general rotation of 1/5 of full-turn of rod names in cask.

The present note aims to demonstrate the validity of the assumption of «cask rotation» and the need of rod renaming. It describes successively:

- the scenario of rod extraction from M109 assembly, insertion in cask on BEZNAU site, and extraction and marking at PSI.

- the principal PIE results and their interpretation first in the as-received condition (i.e. without knowing that the rod identity was incorrect) and then assuming cask rotation and reattribution of PIE results after rod renaming.

The PIE results used to support the «cask rotation» assumption are taken from three projects mentioned above. Except when coming from the ARIANE project, the results used here are summarized without giving much detail, to protect the confidentiality of data accumulated in the projects.

2. ROD HANDLING

The cask used to transport the rods between BEZNAU site and PSI hot cells contains a series of tubes to receive the fuel rods. These tubes open on an upper plate hold by a central screw. The screw cannot rotate relatively to the plate, and has a flat part. This mark is used to orientate the cask tubes relatively to a known and fixed azimuthal position. Figure 1 (a), copied from the original cask drawing, illustrates the reference mark position.

For the rod extraction and cask loading operations, PSI provided NOK with a cask drawing according to Figure 1 (a). The sequence of rod unloading from assembly and hence the rod positions in the cask were fixed on site according to the diagram shown on Figure 1 (a) as well.

The actual rod extraction sequence has been carried out following this proposal [1]. Extraction from assembly M 109 was made by means of rod handling tools designed and operated by Westinghouse specialists who also used a grid system allowing unambiguous extraction of the rod from the requested assembly cell.

Photographs of cask top side, taken immediately after cask fabrication, and examined during these last months, showed that the reference mark was oriented according to Figure 1(b/c)) and not to Figure 1(a) [2]. This difference was not recognized or was not noticed as relevant at the time of fabrication.

The first extracted rod was F2 [1]. Since there was no record of any query of the position of the flat part of the screw relative to the holes, it can be assumed (assumption 1) that the Westinghouse team accepted an "approximate" position of the flat and began loading F2 36° anti-clockwise up (position 1 on Figure 1 (b)) from its planned position. After loading of rod F2, the next rods were loaded adjacent to each other in the tubes (in dark on drawing) and following an anti-clockwise rotation. This sequence of rod loading was followed by binocular to control the relative good rod positioning, retaining so all positional relationships. All rods were therefore shifted 36° anti-clockwise from their planned position due to the incorrect hole orientation of - 36°. The loading diagram was then documented as expected and using the given cask drawing, leading to pattern shown on Figure 1 (a). The true loading pattern is - with this assumption 1- given by Figure 1 (b).

Since assumption 1 can not be confirmed by a film recording showing the rod handling operations, all the other possible scenarios have to be considered.

The only reasonable alternative (assumption 2) to the first scenario, would be that the Westinghouse team would have loaded all rods systematically beginning with F2 loaded 36° clockwise down (position 1'. Figure 1 (c)) from the planned position and all subsequent rods accordingly.

Both assumptions (first loading position is 1 or 1') are possible alternatives but give rise to different rod identity errors.

At PSI, the cask was positioned horizontally and parallel to hot cell window, imposing the use of a mirror to observe the cask topside.

It was decided to position the cask to have the flat part of the screw (reference mark) in horizontal position. According to loading diagram (Fig. 1 (a)), rod B6 should have been in the uppermost position, just above the flat mark. At unloading, it was noticed that the cask was built according to Figures 1 (b/c), i.e. flat position rotated 36° clockwise compared to drawing. This is supported by photo evidence.

Both alternatives (assumptions 1 and 2) are compatible with by the observed position of the rods on the PSI hot-cell photo. In neither case would there have been a rod in the planned "B6 position" perpendicular to the flat. In both cases, this twelve o'clock position would have been empty.

It is understood that at PSI the reference point on unloading was the twelve o'clock position relative to the flat in which it was expected to find B6. Due to the "approximate" position of the flat, the cask was rotated to bring a rod at "B6" position, i.e. at the twelve o'clock position.

Assuming that statement 1 is correct, the cask should have been rotated 36° clockwise viewed from top. This would have brought rod B6 to the twelve o'clock position with all other rods correctly positioned and all would have been well. Actually, it is supposed (now confirmed by PIE evidences) that is was rotated 36° anti-clockwise to bring rod F2 to the top.

According to [2], the 36° anti-clockwise rotation bringing rod F2 in the "B6" position is the most likely explanation.

Taking these two compounded "errors" (total 72° rotational error from 36° anti-clockwise rotation at loading and 36° anti-clockwise rotation at unloading), it would be possible to reconstruct the actual position and hence the true identity of all the rods.

Using the alternative loading pattern of assumption 2 (figure 1 (c)), a rotation of the cask 36° anti-clockwise would have brought rod B6 in twelve o'clock position with all other rods correctly positioned and all would have been well. It could also possibly have been rotated 36° clockwise to bring rod G5 to the top. Taking these two compouned "errors" (total 72° rotational error from 36° clockwise cask rotation at loading and 36° clockwise rotation at unloading), it would be possible to reconstruct the actual position and hence the true identity of the rods.

According to [2] and as mentioned herebefore, the cask was the most likely rotated in hot cells 36° anticlockwise, to bring the "B6" position in the twelve o'clock position. In the assumption 1 (36° anti-clockwise rotation at loading), the uppermost position is occupied by rod F2. Following assumption 2 (36° clockwise rotation at loading), the rod B6 occupies that position.

Very detailed analysis of the results of PIE performed on the ten rods extracted from assembly M109 concludes to the incompatibility of PIE results with the assumption 2 (leading to rod B6 first extracted) and the complete compatibility of all PIE results with assumption 1 (leading to rod F2 first extracted).

Should (event not probable according to [2]) PSI have rotated the cask 36° clockwise at unloading, then the twelve o'clock position is occupied by rod B6 following assumption 1 or by rod G5 following assumption 2. In this case, none of the proposed scenario (B6 or G5 as firstly extracted rod) leads to PIE results compatible with given rod names.

In conclusion, there exists a consistant set of parameters which explain the origin of the mismatch between PIE results and rods characteristics. Secondly, amongst all reasonable proposed scenarios for rod erroneous handling, only one is compatible with all PIE results. This scenario leads to have rod F2 firstly extracted and not B6.

Once the rod "B6" is correctly renamed F2, the other extracted rods can be renamed as follows. After extraction of the uppermost rod first, the unloading sequence was from top to bottom with a clockwise rotation (figure 1 (a)), to give the total unloading sequence [3] (name as given at unloading) : B6, D3, L8, F2, M6, K2, I2, G2, E11, G5. Immediately after extraction and before extraction of the next one, each rod was marked at bottom side, and a photograph of the mark taken.

Knowing that the firstly extracted rod was not B6 but F2, the position of which being turned by 1/5 of full-turn, it is easy to rename all the rods using the "1/5 of full-turn" rule.

The «correct» rod names are given in Figure 2. The Figure has to be used as follows : a rod, which has a name given at time of cask unloading (indicated « as expected » or « foreseen ») has actually for name, the one found in the adjacent cell in the same raw, e.g. B6 is renamed (= real name) F2, I2 is E11, and so on.

The rod name given at cask unloading is the one used during all subsequent experimental work and reporting made before recognition of "cask rotation". Table 1 summarizes the rod identifications and attributes the correct rod names to the three programmes M109, ARIANE and FIGARO.

3. PIE RESULTS

3.1. Preamble

The present section deals with the PIE results analysis. The most important of them are briefly presented and discussed, in the "as-received" condition (i.e. the result is associated to rod name given at cask unloading) as well as after rod renaming according to Figure 2.

The rods are characterized at fabrication and during irradiation by some differences between them. These differences, summarized in Table 2, have a direct consequence on their in-reactor behaviour and characteristics after irradiation. One notices mainly :

- fuel density close to 95.2 % TD, except for rod E11 with 94.2 % TD
- fuel grain size of 8-9, 11-12 (rod E11 only) or 15-16 µm. The variability of 1 µm for a given rod is due to the variability of measurement results across ceramographic section or between pellets of a same batch.
- rod burnup (and power) similar for all rods but G5 (~ 10 % lower).

3.2. Gamma-scanning

- Three campaigns of gamma-scanning / spectrometry were performed, one for each programme M109, ARIANE and FIGARO. The relative (rod average) Cs137 activities are shown at Figure 3. For each campaign, the average activity of all rods of the campaign is normalized to 1. The same is made for rod calculated burnups.

The as-expected results (i.e. considering the rod names given at extraction from cask at PSI) show :

- absence of low activity for G5, but well for G2.
- large difference (~ 10 %) of calculated burnup between E11 and G5 not found by spectrometry.

The same results presented after rod renaming (i.e. assuming a "cask rotation") show significant improvement compared to calculations :

- rod G5 has the lowest activity
- differences between calculated burnups and measured Cs137 activities are lower.

3.3. Detailed gamma-spectrometry

Beginning 1998, PSI performed a special gamma-spectrometry campaign on parts of rods E11, G5, I2 and D3 (as foreseen name). The ratio (1.10) between E11 and G5 of Cs137 gamma activity expected from burnup calculations has not been found during this new series of measurements [4]. Rod relative activity, measured close to peak pellet burnup was close to 1.00 (Table 3). Assuming cask rotation and rod renaming (E11 is D3, G5 is B6), one observes a much better agreement with calculation (burnup ratio ~ 0.97).

3.4. Rod and fuel column lengths

Rod length change during irradiation is almost identical for the 4 measured rods. Similarity of initial length (tolerance ± 1.2 mm) and fast fluence for all rods of assembly M109 do not allow to conclude on rod name inversion.

The significant differences of initial fuel column length (up to 10 mm) between rods provide good signatures of rods to study fuel length change during irradiation.

The length changes in the as-received condition are hardly compatible with similarity of fuel properties (same densification / accommodation performances), achieved burnups and expected swelling rate. The same experimental results, interpreted after rod renaming show much lower dispersion in length changes, compatible with previous properties and measurement precision.

3.5. Rod Free Volumes

The results in the "as-received" conditions show clear correlation neither with fuel properties nor with irradiation conditions. After rod renaming the volume changes appear however better correlated to burnups, but still show dispersion. This one most probably comes from measurement precision as shown by the reproducibility values (cfr. PSI report on NDT + puncture results of M109 Programme [5]).

3.6. Fission Gas Release

A too high FGR is noticed for rod G5 in the "as-expected" condition, whereas a low FGR is noticed for one rod (G2). A much better agreement with rod burnup is shown after renaming. The correlation with burnup results from good proportionality between burnup and linear power sustained during cycles 20 and 21 (this last cycle probably controlling most of FGR). Figure 4 shows the rod relative powers during cycles 20, 21 and 22. A better correlation between FGR and power during cycle 21 is obtained when assuming cask rotation.

3.7. Xe and Kr Isotopic Composition

After production, the Xe^{131} and Kr^{83} isotopes are partly consumed due to their rather high neutron absorption cross-section compared to the other isotopes. One expects therefore higher Xe^{131} and Kr^{83} contents for the low burnup rod G5. This is not confirmed when considering the as-expected results but well when assuming cask rotation and rod renaming.

3.8. Fuel Density

At fabrication, the fuels of batches B, C and E have a density of 95.1, 94.2 and 95.2 % TD respectively. The lower density of batch C is due to an increasing fraction of coarse porosity (>5-7μm). During the resisting tests, the three batches show similar and negligible density change (in agreement with the similar and small fraction of pores <5-7μm).

From the similarity of densification/accommodation properties resulting from these characteristics, close dimensional changes of all fuel batches are expected during irradiation.

Density changes observed after irradiation on fuel of rods E11 and G5 show a difference of more than 1 %, not compatible with expected in reactor behaviour. After rod renaming, density changes are similar.

3.9. Fuel Grain Size

Fuel grain sizes were measured after irradiation on rods E11, G5, I2 and D3 (as expected name), with the following observations :

- For rod G5 (as-expected name), the observed grain size of 8 μm agrees with G5 fabrication data but also with B6 (after renaming). The same conclusion is obtained for rod D3 (as expected) or L8 after renaming.

- For E11 (as expected), the grain size is 9 μm after irradiation, instead of 11 μm, as expected. The 9 μm is compatible with D3 after rod renaming.

- Rod I2, with expected grain size of 15 μm, has a grain size of 11-12 μm only. This last value is totally and only compatible with rod E11 when considering cask rotation and renaming.

These results fully support the assumption of cask rotation and lead to conclude that rods E11, G5, I2 and D3, in the as-expected name are actually D3, B6, E11 and L8 after renaming.

3.10. Radiochemistry

Burnup (Nd148 indicator), Pu content and isotopic compositions were determined on fuel samples from rods E11 and G5 in the framework of the ARIANE Programme. Samples BM1 (from E11) and BM3 (from G5) taken at peak pellet burnup position show nearly identical Pu isotopic compositions (Tables 4(a) and (b)) and burnups (Table 5). Such results are not compatible with calculations, giving a burnup difference of about 10 % between these two rods.

Internal audits at PSI conclude that BM1 and BM3 were sampled from E11 and G5 (as-expected name) respectively. The complementary gamma-spectrometry on E11 and G5 (§ 3.3) fully confirmed the experimental similarity of burnups of E11 and G5 (as-expected name), reinforcing the radiochemistry results validity.

In conclusion of that analysis, it has been suggested that E11 and G5 (as-expected names) were most probably D3 and B6 (after renaming), in consequence of cask rotation assumption.

3.11. SIMS

Radial distribution of Nd isotopic composition measured on BM3 sample shows a clear gradient of concentration of Nd 143 accross pellet (figure 5). An opposite gradient is noticed for Nd 144. This result agrees with the conversion of Nd 143 into Nd 144 under thermal neutron flux. The importance of the observed gradient is hardly compatible with the rod G5 irradiated in symmetrical conditions, but is fully supported by the position of rod B6 at periphery of the zone of high Pu content.

3.12. Other Experimental Results

Other experimental results were obtained in the framework of the programmes. Their analysis taking into account the cask rotation assumption leads to the following conclusions:

- Profilometry : the four measured rods E11, G5, I2 and D3 (as received name) show nearly identical cladding free creep-down and PCMI extent. For rod G5, a lower PCMI is expected. The present PIE results suggest that rod G5 is not within the group of four, in agreement with the assumption on rod identity.

- Fuel central temperature in HALDEN : a difference of fuel central temperature of about 3 % was noticed between segment I2/O and D3/L during Phase 1 irradiation of FIGARO Programme. This difference is within accepted limit of precision on power and measured temperature. Assuming that rod I2 is actually E11 and D3 is actually L8 leads to a natural explanation for this difference in term of initial lower fuel density for rod E11. This lower density leads to an estimated increase of temperature of about 3 % for E11 compared to L8, due to thermal conductivity decrease.

- Radiochemistry analysis in FIGARO programme : rods I2 and D3 introduced in the FIGARO programme have a calculated burnup ratio of 1.03. The same ratio is calculated for the rods E11 and L8. The burnup ratio determined experimentally for the same pairs of rods is equal to 1.03 also. As expected names and rod renaming assumption are thus both compatible with experimentally determined burnups.

4. CONCLUSIONS

Analysis of "as-received" PIE results obtained in the framework of programmes M109, ARIANE and FIGARO led to inconsistencies with rod fabrication data and irradiation conditions.

Further analysis of PIE results and rod handling procedures confirm that rod names attributed to rods at unloading of transport cask at PSI were not those attributed to the rods when they were loaded in mother assembly M109.

This erroneous attribution of rod names came from difference in position of orientation mark on drawing of cask used for transport between BEZNAU and PSI, and position of that mark on cask itself. This led to difference of interpretation of cell position in cask.

After rod renaming, based on exact rod names attribution resulting from 1/5 full-turn of rod names initially attributed to rods in cask, a marked improvement of all PIE results is obtained, and contradictions with fabrication data and irradiation conditions disappear.

For the ARIANE programme, the consequences of this cask rotation is the withdrawal of rods E11 and G5 from the programme, and the introduction of rods D3 and B6 respectively (figure 6).

* * *

REFERENCES

[1] J. BASSELIER
FIGARO – Extraction of the Rods
FIG 94/03
BN Ref. 9400938/221, dated 26.01.94

[2] G. LEDERGERBER & al.
NOK M109 Programme. Unloading the Transport Basket at PSI.
PSI Ref. TM-43-98-24, dated 14.04.98

[3] P. SCHLEUNIGER & al.
Annahme der 10 MOX-Brennstäbe für die Programme FIGARO, ARIANE und GEMINI
PSI Ref. AN 43-94-53, dated 19.12.94

[4] G. LEDERGERBER
NOK M109 Programme. Evaluation of Gamma Measurements
PSI Ref. TM-43-98-11, dated 14.04.98

[5] G. LEDERGERBER
Post-Irradiation Examination on eight MOX Fuel Rods of the NOK M109 Programme. Report on NDT, Puncture and Sample Cutting.
Ref. M109 Programme : M109-96/04 (Nov. 1996).

* * *

Table 1.

Fuel rods actually examined

Status	M109								ARIANE		FIGARO	
foreseen	E11	G5	B6	F2	G2	K2	L8	M6	E11	G5	I2	D3
actual*	D3	B6	F2	K2	G5	G2	M6	I2	D3	B6	E11	L8
leaving	E11						L8		E11	G5	I2	D3
entering	D3							I2	D3	B6	E11	L8

* i.e. rename of foreseen rod

Table 2.

Fabrication data

Coord. NOK	Fuel type	Fuel Grain size (µm)	Fuel Density (% TD)	Rod Burnup GWd/tM
F02	B	15-16	95.1	42.6
G02	B	15-16	95.1	41.6
K02	B	15-16	95.1	43.7
G05	E	8-9	95.2	38.7
B06	E	8-9	95.2	43.1
M06	E	8-9	95.2	43.2
L08	E	8-9	95.2	41.4
E11	C	11-12	94.2	42.6
D3	E	8-9	95.2	41.7
I2	B	15-16	95.1	43.1

Table 3.

Cs137 relative ratios from gamma scanning/spectrometry

as expected	E11/G5
M(1)	1.00-1.03
C(2)	1.10

after renaming	D3/B6
M(1)	1.00 -1.03
C(2)	0.97

(1) rod average activity - rod activity close to or at maximum activity level
(2) ratio of maximum calculated burnups

Table 4a

Pu isotopic composition of E11/D3

Sample BM1 (Calculated burnup (at % FIMA) : E11 : 4.90 / D3 : 4.75)

Isotope	Calculated (C) (w%)		Measured (M; w%)								
			CEN	Deviation (C-M)		TUI	Deviation (C-M)		PSI	Deviation (C-M)	
	E11	D3		E11	D3		E11	D3		E11	D3
Pu 239	36.79	36.43	35.50	1.29	0.93	35.14	1.65	1.29	35.72	1.07	0.71
Pu 240	33.41	34.18	35.04	-1.63	-0.86	34.65	-1.24	-0.47	34.88	-1.47	-0.70
Pu 241	18.31	18.00	17.98	0.33	0.02	18.39	-0.08	-0.39	18.20	0.11	-0.20
Pu 242	11.49	11.39	11.48	0.01	-0.09	11.82	-0.33	-0.43	11.19	0.30	0.20

Pu isotopic composition of G5/B6

Table 4b

Sample BM3 (Calculated burnup (at % FIMA) : G5 : 4.43 / B6 : 4.90)

Isotope	Calculated (C) (w%)		Measured (M; w%)								
			CEN	Deviation (C-M)		TUI	Deviation (C-M)		PSI	Deviation (C-M)	
	G5	B6		G5	B6		G5	B6		G5	B6
Pu 239	39.89	35.81	35.50	4.39	0.31	35.59	4.3	0.22	35.44	4.45	0.37
Pu 240	32.79	34.27	34.95	-2.16	-0.68	35.09	-2.3	-0.82	35.26	-2.47	-0.99
Pu 241	17.56	18.17	18.08	-0.52	0.09	17.96	-0.4	0.21	17.87	-0.31	0.30
Pu 242	9.76	11.76	11.48	-1.72	0.28	11.37	-1.61	0.39	11.44	-1.68	0.32

* close to maximum burnup of G5 (as expected)

Table 5.

Results of burnup (GWd/tM) on E11/D3 and G5/B6

	E11*	G5*
M (1)	45.4	45.0
C (2)	48.5	43.8
C/M	1.07	0.97

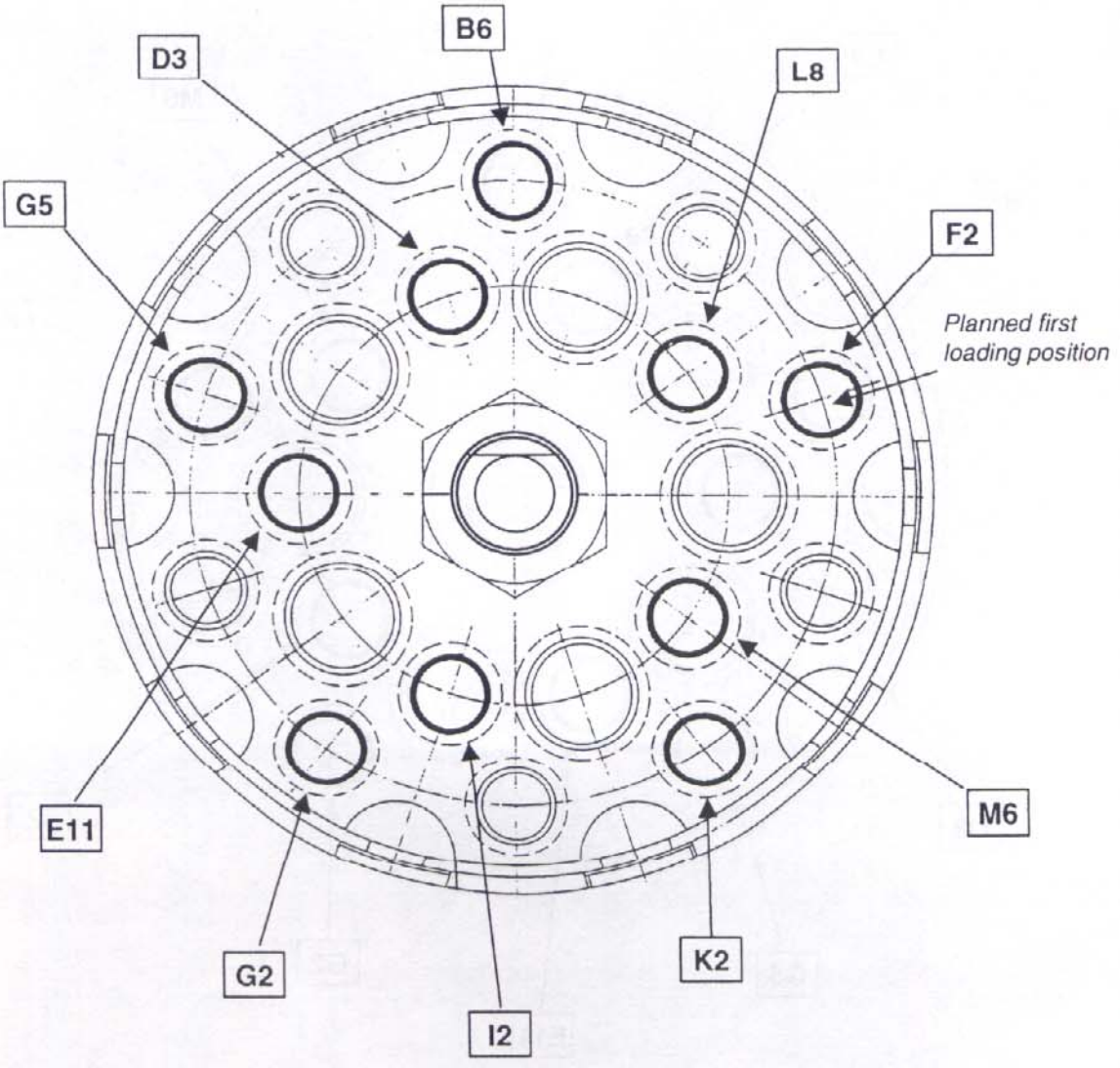
	D3**	B6**
M (1)	45.4	45.0
C (2)	47.0	48.5
C/M	1.04	1.08

* : as expected
** : after renaming

(1) : SCK/CEN measurements using results of BM1 and BM3
Y(Nd148) = 0.0177
1% FIMA = 9.9 GWd/tM

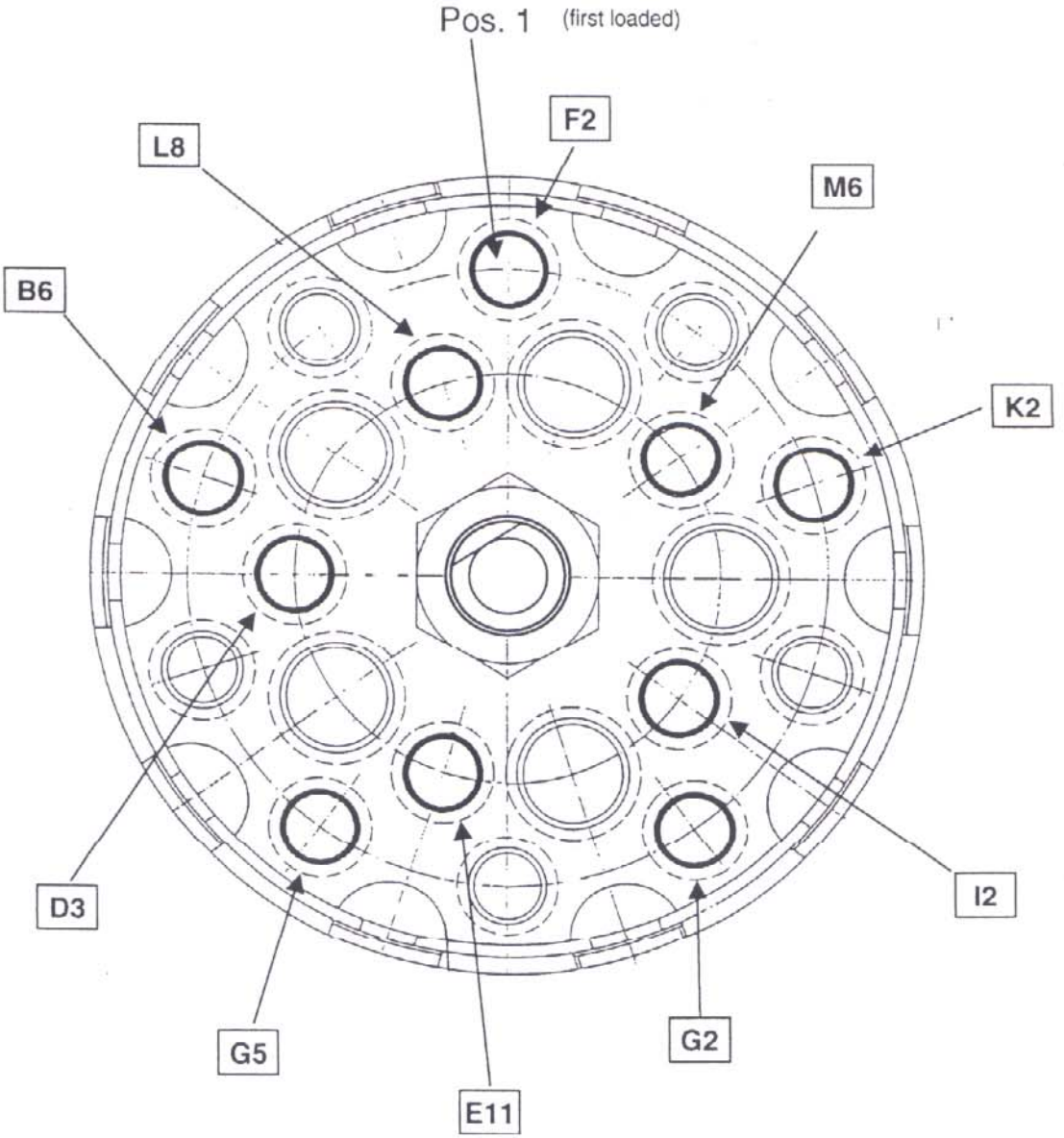
(2) : Calculations

Figure 1. Transport cask



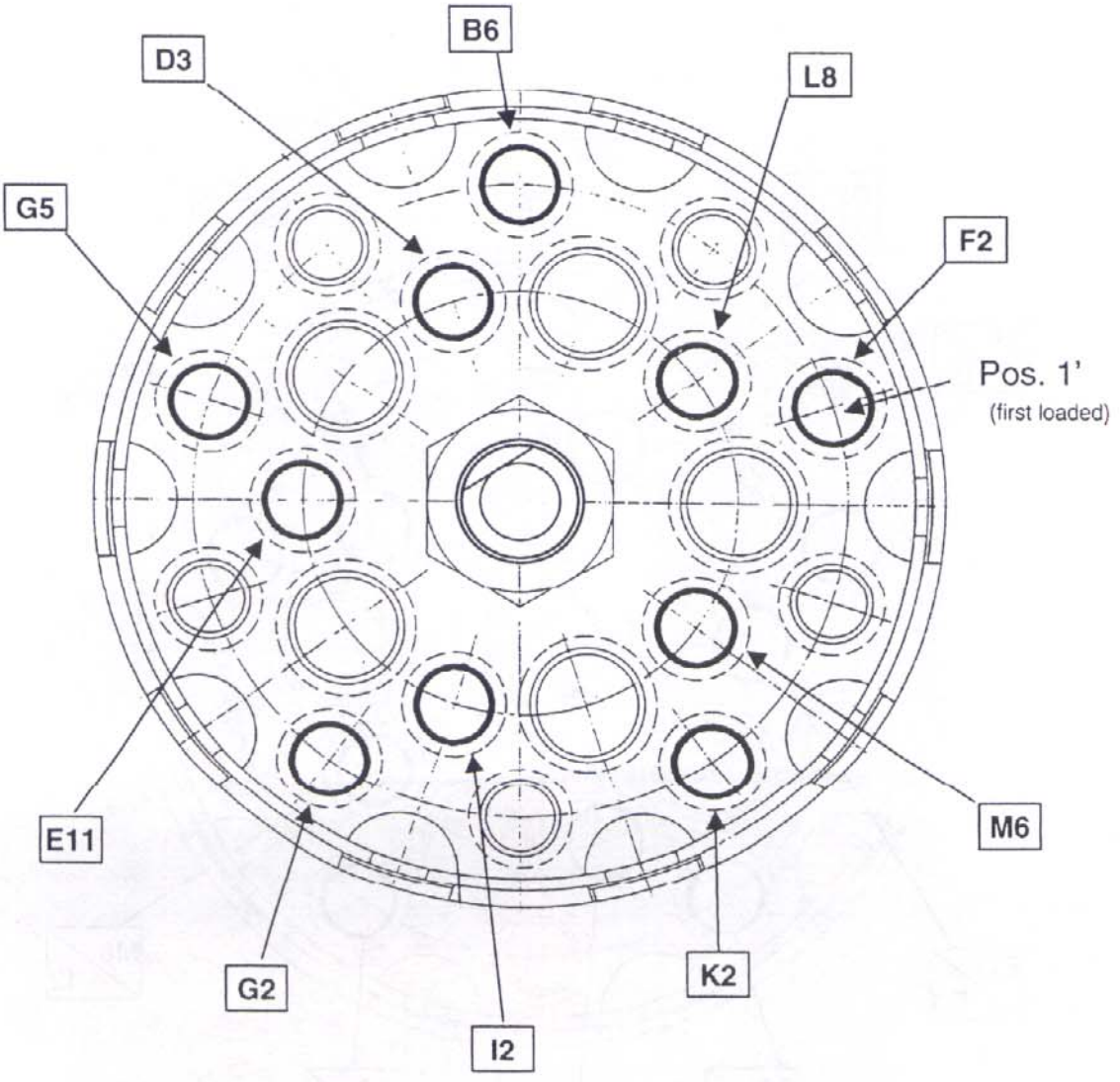
a) Cask drawing and planned loading diagram

Figure 1. Transport cask



b) Cask loading following assumption 1

Figure 1. Transport cask



c) Cask loading following assumption 2

Figure 2. Transport cask

(10 M109 rods - BEZNAU to PSI)

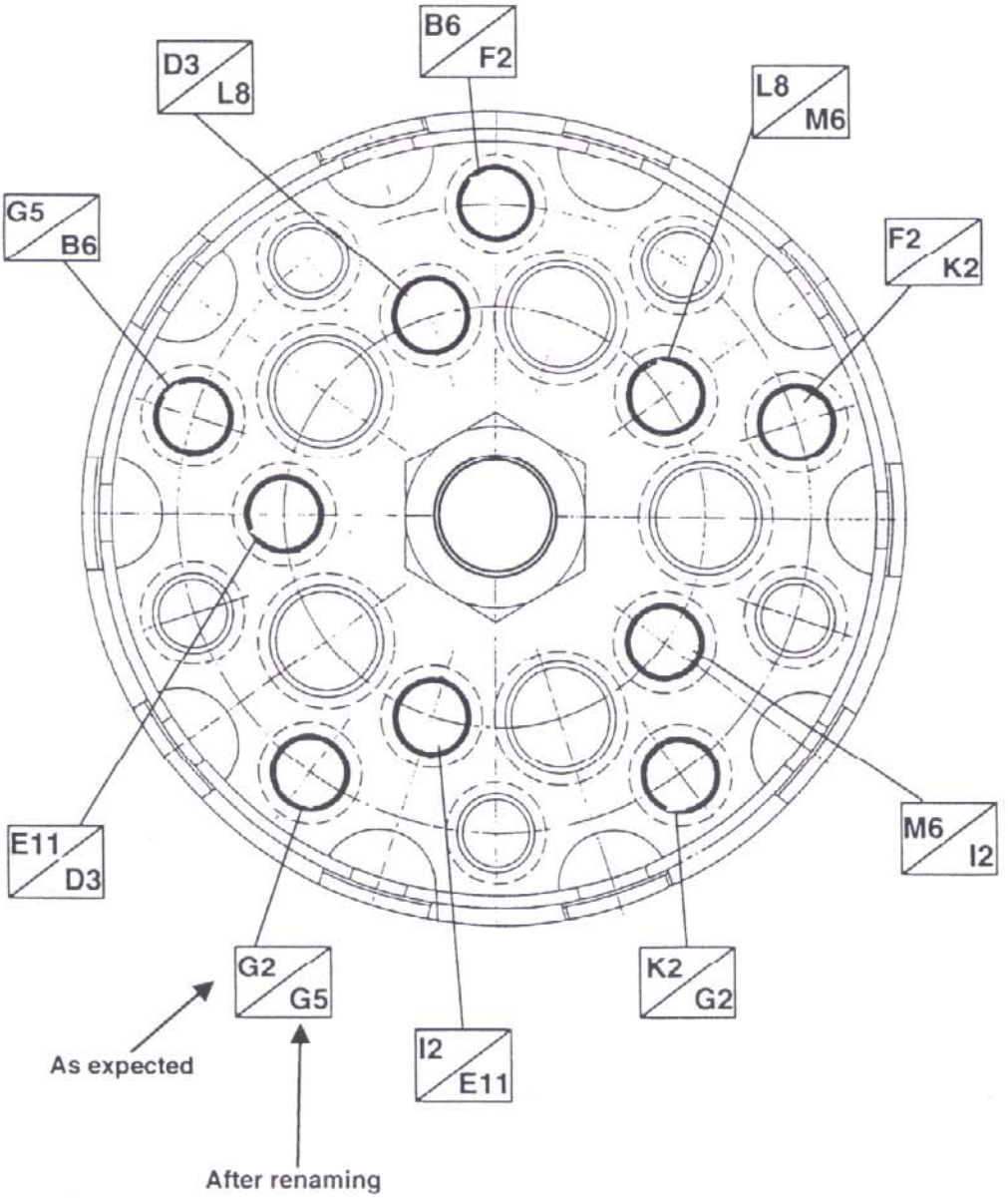
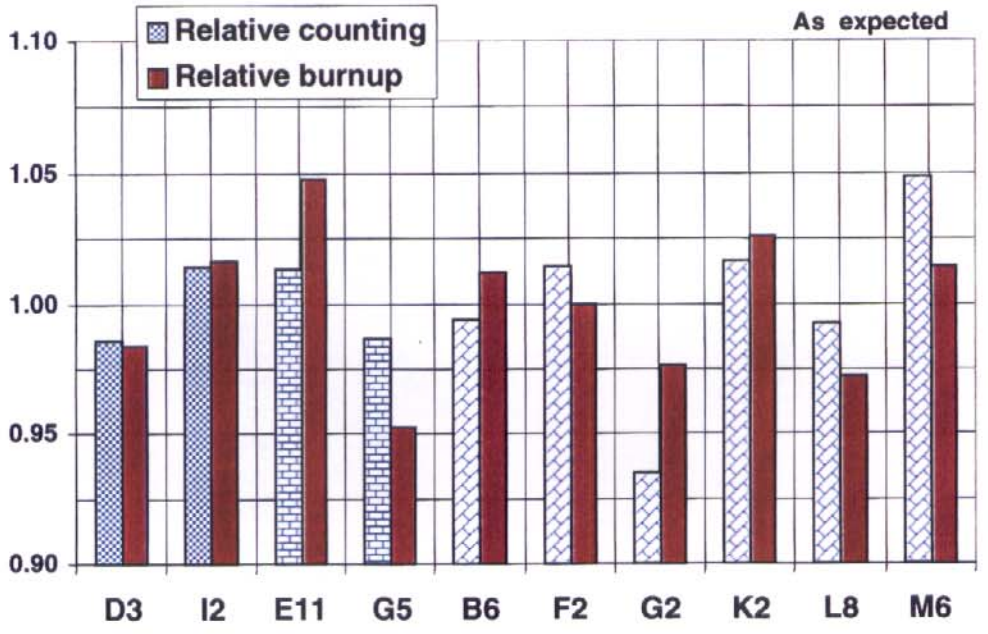


Figure 3

(a)


As expected
Relative counting
Relative burnup
1.10
1.05
1.00
0.95
0.90
D3
I2
E11
G5
B6
F2
G2
K2
L8
M6

(b)

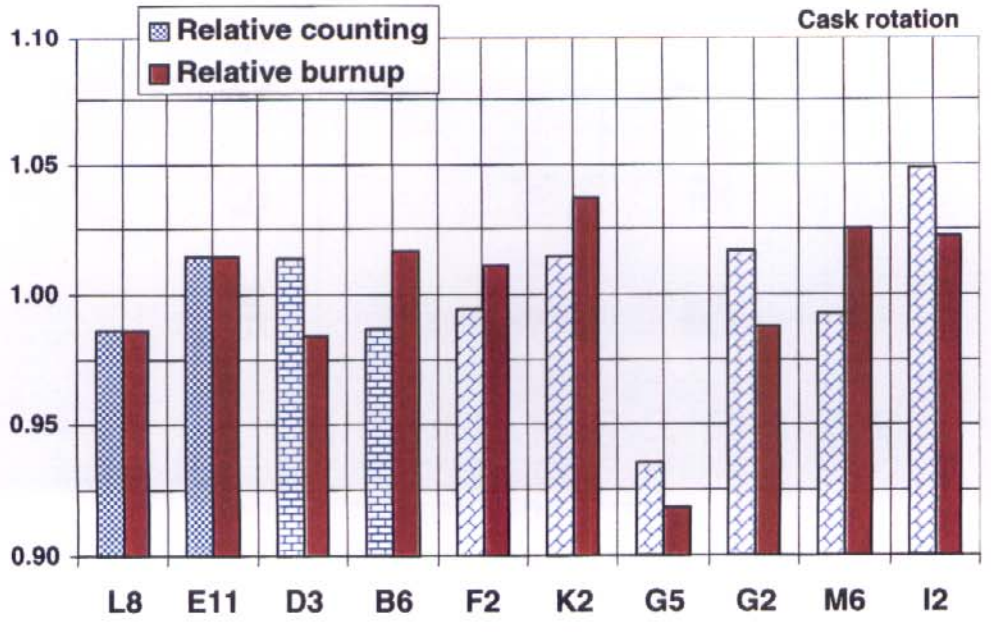

Cask rotation
Relative counting
Relative burnup
1.10
1.05
1.00
0.95
0.90
L8
E11
D3
B6
F2
K2
G5
G2
M6
I2

Figure 4

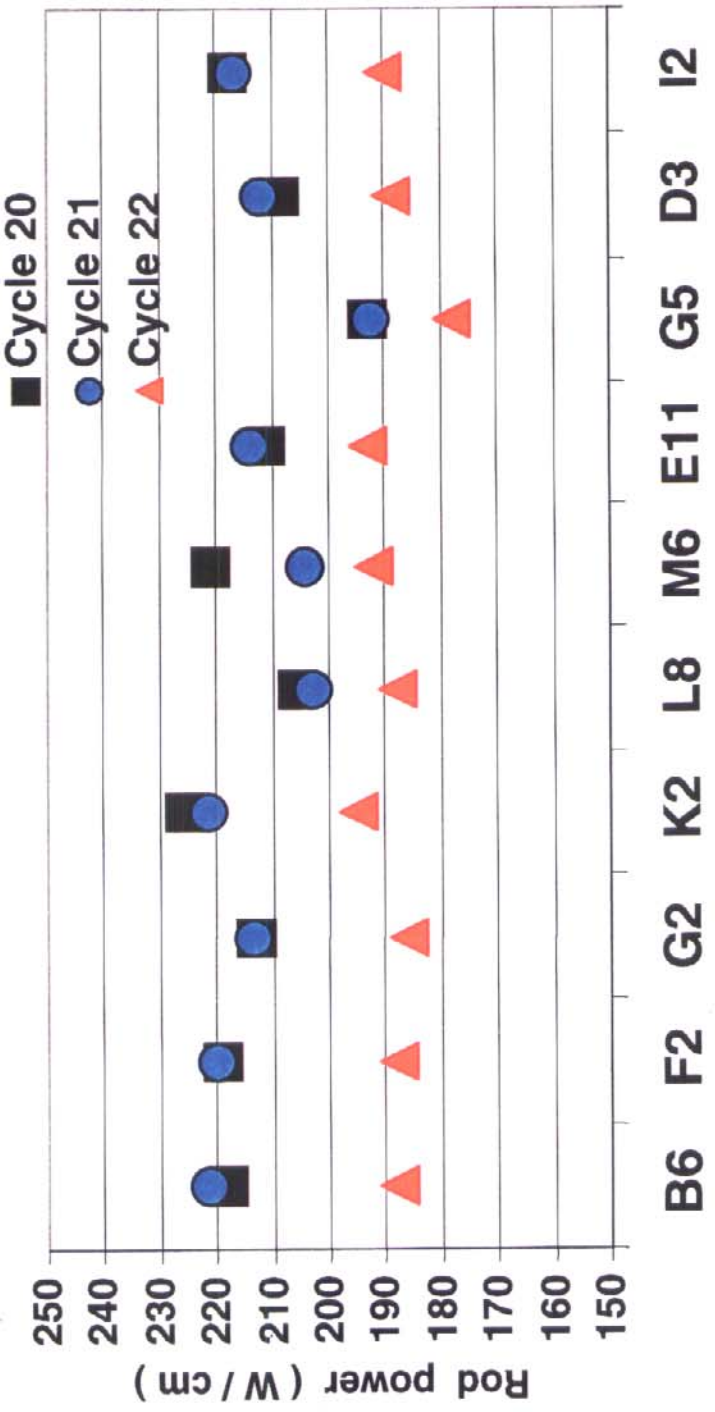
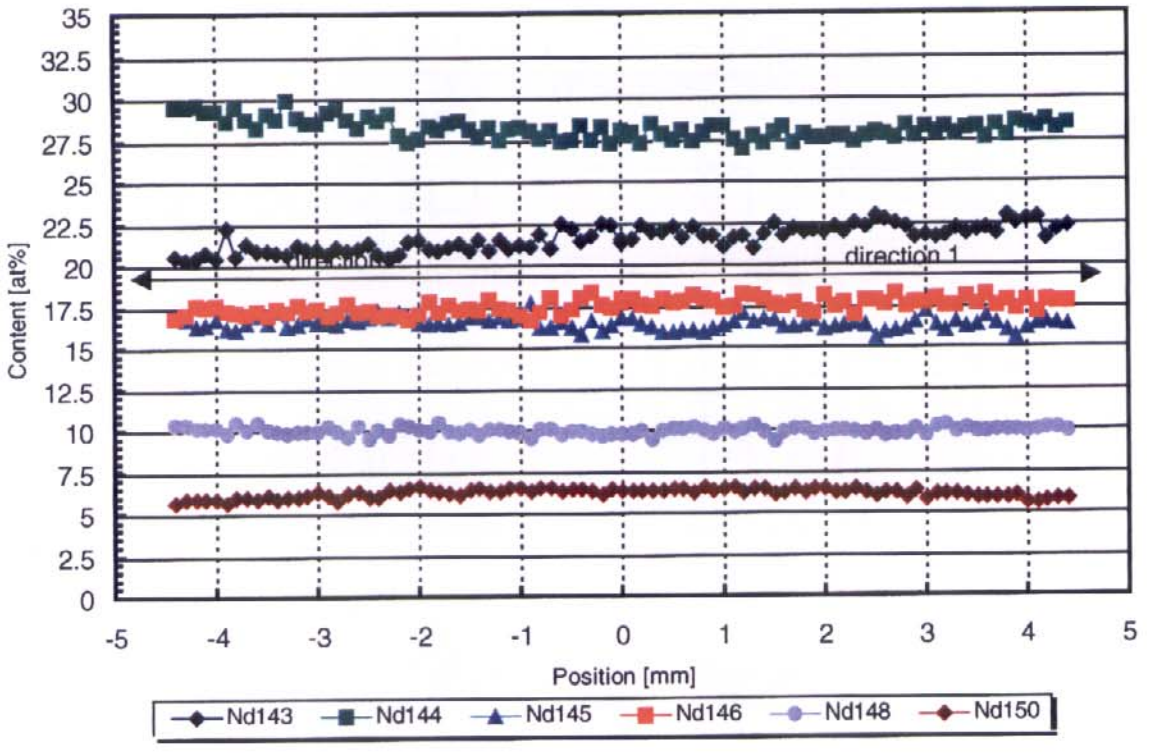

Cycle 20
Cycle 21
Cycle 22
Rod power (W / cm)
250
240
230
220
210
200
190
180
170
160
150
B6
F2
G2
K2
L8
M6
E11
G5
D3
I2

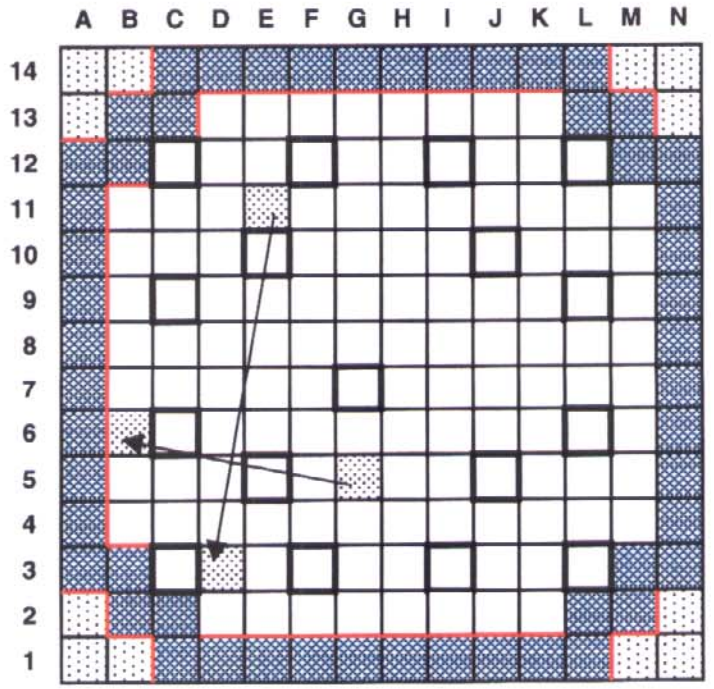
Figure 5



Sample BM3S, local isotopic Nd composition (at%) along directions 1 and 2.

Figure 6.

Modifications of rods introduced in the ARIANE programme



Water hole

High Pu content

Median Pu content

Low Pu content

AR 99/12
BN Ref. 9902146/221

ARIANE
International Programme

SIMS Analysis of three irradiated fuel specimens

Issued March, 1999

BELGONUCLEAIRE
Avenue Ariane, 4 - 1200 Brussels.

LF 300399 (6)AR9912.PPT

	Type of document : **Report**	BN reference N° / File - « Rev. » - Page **9902146 / 221 - « - » 1** Other reference : ***AR 99/12***
Client : ***ARIANE Participants***		Author(s) : ***D. Gavillet (PSI)*** ***E.T. Aerne (PSI)***

Project:
ARIANE INTERNATIONAL PROGRAMME

Subject:

ARIANE INTERNATIONAL PROGRAMME

SIMS ANALYSIS OF THREE IRRADIATED FUEL SPECIMENS

Rev.	Date	Chrono Filing n°	Status	Typist's Initials	Author: Initials	Author: Visa N°1	Verified by: Initials	Verified by: Visa N°2	Approved by: Initials	Approved by: Visa N°3	Q.A.: Initials	Q.A.: Visa N°4	Issued by: Initials	Issued by: Visa N°5	Number Of Pages
C															
B															
A															
-	29.3.1999	9902146	FIN	ND	PSI		ML						HBe		6+54

Distribution :
See distribution list hereafter :
+ BN : Mrs. D. Boulanger
MM. Y. Vanderborck, M. Lippens, Basselier, Th. Maldague, A. Renard

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use of exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, withjout prejudice to any other right.

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 - 1200 Bruxelles
TVA : BE 403.126.258
RCB : 271.300
TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

LIST OF MODIFICATIONS

DATE	REVISION	OBJECT
March 29,1999	-	Final issue

(C:WINDOWS NT\ND\NOTES\ML-ARI-9902146)

NOTICE

PERSONNEL IN CONFIDENCE / NOT FOR PUBLICATION

All property rights and copy rights are reserved. Any communication or reproduction of this document and any communication or use of its content without explicit authorization of the ARIANE Programme Committee is prohibited. Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting of a patent or registration in the field of intellectual property.

LIABILITY

This document was prepared by PAUL SCHERRER INSTITUT (PSI) and reviewed by BELGONUCLEAIRE (BN). Neither PSI, nor BN, nor any person acting on behalf of PSI or BN :

(a) gives any warranty, expressed or implied with respect to the accuracy, completeness or usefulness of the information contained in this document, or that the use of any information, apparatus, method or process disclosed in this document may not infringe third party rights, or

(b) assumes any liabilities with respect to the use of, or for damage resulting from the use of any information, apparatus, method or process disclosed in this document.

TABLE OF CONTENT

	PAGES
Distribution list	***5***
Main body :	***6***
PAUL SCHERRER INSTITUT REPORT :	
ARIANE Programme :	
"SIMS Analysis of three irradiated Fuel Specimens"	

ARIANE INTERNATIONAL PROGRAMME

Distribution List

SIEMENS (D)	:	Dr. Schlosser	2 copies
SCK•CEN (BE)	:	Mr. P. D'hondt	5 copies
GNB (D)	:	Dr. Hüggenberg	2 copies
MHI (JP)	:	Mr. S. Abeta	2 copies
BNFL (UK)	:	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	:	Mr. Nakajima	2 copies
HITACHI (JP)	:	Mr. T. Mochida	2 copies
ORNL (USA)	:	Mr. R.T. Primm III	2 copies
NEL (JP)	:	Mr. H. Naito	2 copies
JRI (JP)	:	Mr. T. Kaneko	2 copies
NOK (CH)	:	Mr. G. Devillaz	2 copies
GKN (NL)	:	Mr. W.R. Van Engen	2 copies
PSI (CH)	:	Mr. G. Ledergerber	2 copies
TRACTEBEL (BE)	:	Mr. R. de Wouters	2 copies

	Type of document :	BN reference N°/ File - « Rev. » - Page
	Report	**9902146 / 221 - " - " - 6**
		Other reference : *AR 99/12*

MAIN BODY

PAUL SCHERRER INSTITUTE REPORT

ARIANE PROGRAMME

SIMS Analysis of the three irradiated fuel specimens

- Date : 29.01.98
- Chrono filing N° at PSI : TM 43-98-10, Rev. 1
- Status : Final
- Number of pages : 54

PAUL SCHERRER INSTITUT	Registrierung **TM-43-98-10**, Rev. 1 Seite 1 von 54 Seiten
Titel: ARIANE Programme SIMS Analysis of three irradiated fuel specimens	Ersetzt **TM-43-98-10**, Rev. 0
Hauptautor/in: D. Gavillet Coautor/innen: E.T. Aerne*	Erstellt 29. Januar 1998 TM-43-98-10-rev1.doc
Klassifizierungsvermerk: VERTRAULICH	

Summary

In the frame of the ARIANE programme, Secondary Ion Mass Spectrometry (SIMS) examinations of three MOX fuel specimens, irradiated in Beznau nuclear power plant have been performed.

The average concentrations determined by radiochemical analysis on neighbour specimens have been used for the quantification of the SIMS data.

Isotope distribution and composition have been obtained across two perpendicular pellet diameters. The nuclide distributions give evidence to the enhanced breeding and fission rate at the periphery of the pellet. Apart from that the diametrical burn-up and isotopic Pu, U and fission products profiles are rather flat over the most part of the pellet cross section. The three specimens exhibit the same global behaviour.

The low conductivity of the specimens associated with variation in the electric extraction field of the instrument made it necessary to perform measurements in opposite directions and to use advanced evaluation procedure for the data analysis.

* Retired

Erstellt:	Unterschrift:	Datum:	Geprüft:	Unterschrift:	Datum:
D. Gavillet		3.2.1998			

Verteiler

Abt.	Empfänger / Empfängerinnen	Expl.	Abt.	Empfänger / Empfängerinnen	Expl.
4000	W. Kröger	1	Extern	Belgonucléaire	5
	K. Foskolos	1			
4300	G. Bart	2			
4320	G. Ledergerber	1			
4324	Ch. Hellwig	1			
4325	Z. Kopajtic	1			
	B. Wernli	1			
4326	F. Ingold	1			
4330	F. Groeschel	1			
4332	R. Bühner	1			
4333	D. Gavillet	1			
	M. Martin	1			
	R. Restani	1			
	O. Gebhardt	1			

	Expl.
Bibliothek	3
Reserve	5
Total	28
Seiten	54
Anzahl Beilagen	
Informationsliste	
~~0~~ ~~1~~ ~~2~~ ~~3~~ ~~4~~ ~~5~~ ~~8~~ ~~9~~ ~~A~~	
Visum Abt./Laborleitung:	

Blank Page

Table of contents

1. Introduction 4
2. Specimen description and radiochemical data 4
3. SIMS Measurement and data evaluation procedures 7
3.1 SIMS Measurement procedure 7
3.1.1 Preliminaries 7
3.1.2 Conductivity effect 8
3.1.3 Geometric effect 8
3.1.4 Measurement 9
3.2 SIMS Data evaluation procedure 9
3.3 SIMS Error Estimation 13
4. SIMS results and discussion 15
4.1 Local isotopic uranium composition 15
4.2 Relative Pu isotope and total Pu contents 15
4.3 Local Isotopic Plutonium Composition 16
4.4 Local Isotopic Neodymium Composition 16
4.5 Burn-up 16
4.6 Relative Fission Product Distribution 16
4.6.1 Non-volatile Fission Products 17
4.6.2 Volatile Fission Products 17
4.7 List of data files 17
4.8 Figures 17
5. Conclusion 53
6. References 53
7. Acknowledgement 54

1. Introduction

On the basis of interesting results obtained with Secondary Ion Mass Spectroscopy on irradiated Uranium Oxide and Mixed Oxide fuels in previous international research programs, an extension of the ARIANE program has been proposed. SIMS measurements and analysis of isotopes of specific interest have been included in this work package.

The research scope proposed by PSI has been summarised in a proposal in April 1996 [1]. The final agreement between BELGONUCLEAIRE (Co-ordinator of the ARIANE program) and PSI on the scope and financial arrangement for this extension have been finalised in January 1997 [2].

The subcontracted work to be performed by PSI included the SIMS measurement of three samples and additional radiochemical analysis.

This report includes all SIMS measurements and analysis, using the results of the burn-up analysis made on neighbour specimens for the quantification of the results.

2. Specimen description and radiochemical data

Three specimens have been investigated all from the assembly M109 irradiated during five cycles in the Beznau power plant in Switzerland. Specimens were sampled from rods B6 and D3 [12].

In this report the specimens are named according to the corresponding radio-chemical specimens (neighbour specimens) names. The analysis of the PIE data has lead to the reassessment of the identity of the rods investigated in the ARIANE program [12]. A cask rotation in the transport was discovered and all rod names were changed. The original as well as new identification or name of the rods are given in table 2-1 with the cutting position of the SIMS specimens and corresponding radiochemical samples.

Table 2-1 SIMS specimen description

SIMS specimen Name	Sample name [4]	Rod [12]	Cutting position from bottom of rod [mm]	[mm]	Length [mm]	Corresponding radiochemical sample
BM4S	G5-ES	**B6**	276.25	278.75	2.5	BM4-D [4]
BM3S	G5-PB	**B6**	919.25	921.75	2.5	BM3 [3]
BM1S	E11-PC	**D3**	916.25	918.75	2.5	BM1 [3]

The SIMS specimens have been prepared by our standard procedure for MOX fuel. The 2.5 mm thick slice is first fixed with conductive glue on a steel holder and embedded in an epoxy resin. It is then ground and polished down to a fuel thickness of about 1 to 1.5 mm followed by polishing with diamond paste. The final surface finish has been achieved with 1 µm diamond paste.

Table 2-2 Radiochemical (burn-up) specimen description

Radiochemical Specimen Name	sample name	Rod [12]	Cutting positions from bottom of the rod [mm]	[mm]	Length [mm]
BM4-D	G5-D [3]	**B6**	239.25	275.75	36.5
BM3	G5-R [3]	**B6**	935.25	972.75	37.5
BM1	E11-R [3]	**D3**	935.25	972.75	37.5

Table 2-3 Radiochemical data for specimen BM1, BM3 and BM4-D [5]

Specimen Name		**BM1**	**BM3**	**BM4-D**
Corresponding SIMS sample		BM1S	BM3S	BM4S
Uranium data [at%]	^{234}U	0.0095	0.0110	0.0106
	^{235}U	0.1092	0.1129	0.1382
	^{236}U	0.0324	0.0333	0.0288
	^{238}U	99.8489	99.8428	99.8224
Plutonium data [at%]	^{238}Pu	3.270	3.3646	2.946
	^{239}Pu	36.020	36.65	39.21
	^{240}Pu	35.415	35.77	35.41
	^{241}Pu	14.002	13.713	12.931
	^{242}Pu	11.290	11.506	9.50
Plutonium content [at%]	$\frac{Pu}{(U+Pu)}$	4.01	4.15	4.43
Neodymium data [at%]	^{142}Nd	0.3999	0.401	0.4713
	^{143}Nd	21.113	21.56	22.75
	^{144}Nd	27.739	28.13	27.14
	^{145}Nd	16.565	16.416	16.95
	^{146}Nd	17.524	17.464	16.971
	^{148}Nd	10.463	9.89	9.635
	^{150}Nd	6.196	6.14	6.083
Burnup [%FIMA]		4.76	4.83	4.35

To improve the relative poor conductivity of the specimens, four conducting bridges were made with liquid metal (Ag) between the fuel and the cladding material as shown on figure 3-1. This greatly improves the secondary ion count rate.

Video pictures of the three specimens installed in the SIMS machine are presented in figures 2-1 to 2-3.

Neighbour samples have been used for the burn-up analysis. The position of these samples with the original name as well as the corrected name [4, 12] is given in table 2-2. Due to a high axial burnup gradient in the zone there the SIMS specimen BM4S has been cut, it has a higher burnup (~ 3%) than the adjacent BM4-D specimen used for the radiochemical data determination as it can be seen on the γ-spectrometry [4]. The quantification of the SIMS data has nevertheless been done with the radiochemical data obtained from BM4-D without correction.

The radiochemical data used for the quantification of the SIMS data in this analysis has been obtained from these neighbour samples [5]. They are given in the table 2-3.

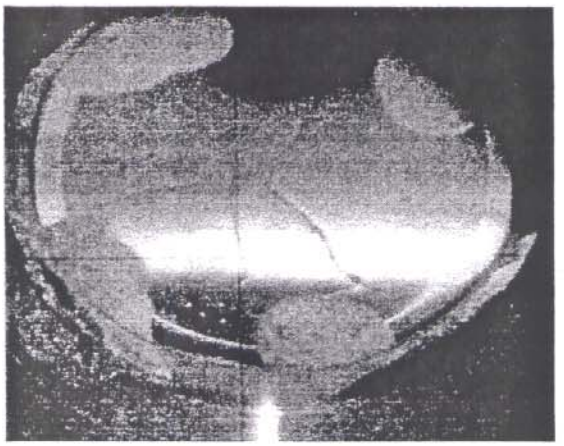


Figure 2-1 Video picture of he specimen BM4S in SIMS

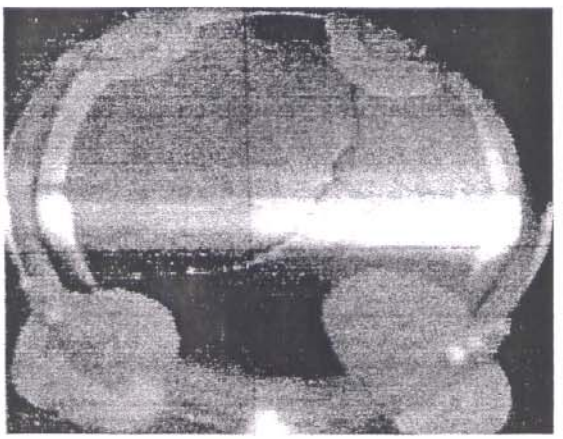


Figure 2-2 Video picture of he specimen BM3S in SIMS

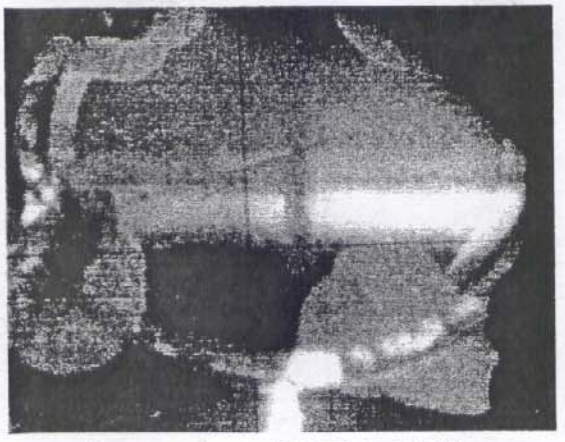


Figure 2-3 Video picture of he specimen BM1S in SIMS

3. SIMS Measurement and data evaluation procedures

The measurement procedure used for the three specimens, the data evaluation procedure and the error estimation are presented in the following paragraphs.

3.1 SIMS Measurement procedure

3.1.1 Preliminaries

This measurement campaign has been realised with the same instrument (A-DIDA-SIMS) than the one used in previous campaigns [6, 7]. An oxygen (O_2^+) primary ion beam of 12 keV energy was applied and the atomic masses of Uranium, Plutonium and some selected fission product nuclides were measured as M, MO and for Uranium also MO_2.

During one counting cycle, all masses given in table 3-1 are acquired. The isotope ^{103}Rh, mentioned in the agreement of January 1997 [2], has not been measured due to the mass interference with the molecule ($^{87}Rb^{16}O$) which corrupts the data. Also, the distribution of $^{147}Pm/Sm$ has not been measured due to an extremely low extraction rate / counting rate. The distribution of the ^{235}U and ^{238}U has been extracted from the $^{235}U^{16}O_2$ and $^{238}U^{16}O_2$ count rate respectively because they are systematically higher than the corresponding UO count rate.

The primary beam, about 50 µm in diameter, was scanned over a surface of 100 x 100 μm^2 in order to average local inhomogeneities. The specimen is moved 0.1 mm along the measurement direction (A → B on figure 3-1) between two counting cycles. Five parallel traces separated by 0.1 mm were made, sequentially always with the same orientation (A → B on fig. 3-1).

Table 3-1 Mass list and acquisition time for SIMS measurements.

Nb.	Mass [amu]	Isotope / molecule	Acquisition time [s]
1	16	^{16}O	10
2	85	^{85}Rb	5
3	87	^{87}Rb	3
4	88	^{88}Sr	5
5	90	$^{90}Sr/Zr$	3
6	97	^{97}Mo	10
7	99	^{99}Tc	10
8	106	$^{90}Zr^{16}O$	3
9	133	^{133}Cs	3
10	134	^{134}Cs	3
11	135	^{135}Cs	3
12	137	^{137}Cs	3
13	138	^{138}Ba	3
14	155	$^{139}La^{16}O$	3
15	156	$^{140}Ce^{16}O$	3
16	159	$^{143}Nd^{16}O$	5
17	160	$^{144}Nd/Ce^{16}O$	5
18	161	$^{145}Nd^{16}O$	7
19	162	$^{146}Nd^{16}O$	7
20	164	$^{148}Nd/Sm^{16}O$	10
21	166	$^{150}Nd/Sm^{16}O$	7
22	251	$^{235}U^{16}O$	20
23	254	$^{238}U^{16}O$	5
24	255	$^{239}Pu^{16}O$	20
25	256	$^{240}Pu^{16}O$	20
26	257	$^{241}Pu^{16}O$	20
27	258	$^{242}Pu^{16}O$	20
28	267	$^{235}U^{16}O_2$	20
29	270	$^{238}U^{16}O_2$	5

3.1.2 Conductivity effect

Due to the elementary and morphological inhomogeneities of the irradiated fuel and the presence of the pores and cracks, the conductivity of the fuel varies across the pellet cross-section, leading to variations of the secondary ion emission, which are in addition mass dependant. This may lead to difficulties in the data analysis, because it is sometimes difficult to determine if a variation of count rate is a real variation of the isotope content, as it can happen in Pu enriched zone of MIMAS-MOX fuel, or simply a modification of the conductivity of the specimen. However this influence is locally proved to be small in non cracked zones. Also the normalisation of the raw data (§ 3.2) helped to reduce this factor. Cracks produce large variation of count rate that can not be removed by the normalisation procedure and that are isotope dependent (not the same effect on all measured masses).

3.1.3 Geometric effect

In addition, the sample displacement under the steady primary ion beam leads in the present arrangement to extraction field variations [6, 8, 11] called "geometric effect", which exhibits a systematic asymmetry of the recorded data. Although this is greatly corrected by the normalisation

procedure, there is still a rest deficiency which is sample and element dependent. This effect was observed and discussed in previous measurement campaigns [6, 11] and can be enhanced or compensated by the conductivity variations on the specimen.

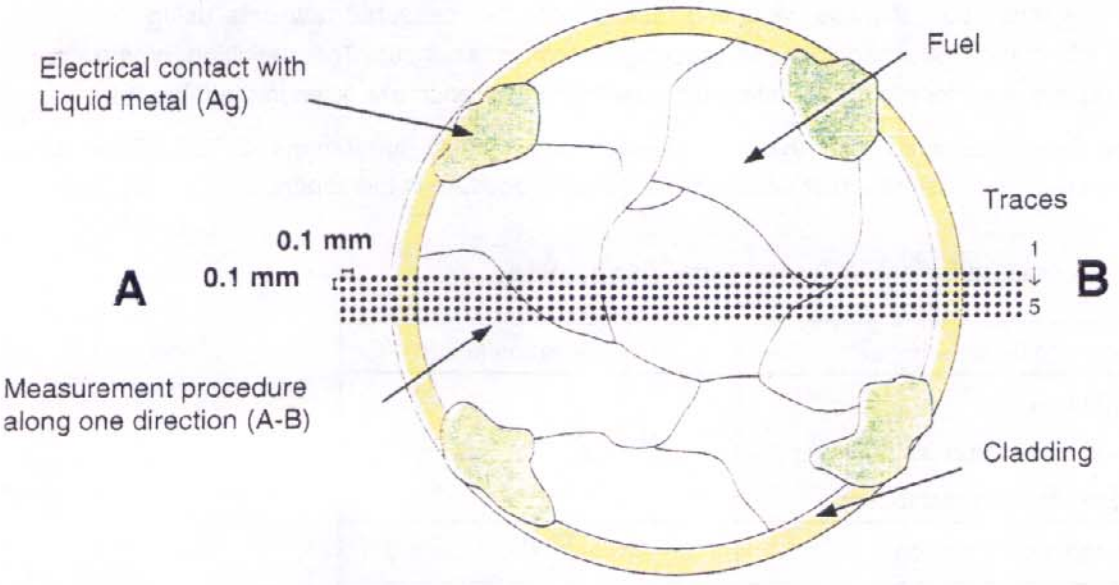


Figure 3-1 Specimen preparation for SIMS measurement and measurement method. Each trace starts at position A and finishes at position B. The five traces are recorded one after the other.

3.1.4 Measurement

Due to the two basic problems described before, the three specimens have been measured along two perpendicular diameters and a third time along one of the previous diameter but in the other direction. This is graphically explained in figure 3-2. The reproducibility of the measurement has been checked along one direction on specimen BM1S (A-B) which has been measured twice successively (direction 1 and 2). The rotational positioning between two measurements was not perfect, so that small differences had to be envisaged.

3.2 SIMS Data evaluation procedure

The raw count rate obtained during the SIMS measurement has to be normalised in order to remove the variation of machine parameters like the primary ion beam intensity or the size of the beam. This is made by dividing the count rate of the mass of interest by one or the sum of other signals obtained at the same position and time representing an absolute constant.

For example : the sum of all U atom, Pu atom and fission events can be considered as constant at all points of the specimen. This value can be obtained by adding the weighted count rate of all U and Pu isotopes to the weighted count rate of the ^{148}Nd isotope which is proportional to the number of fission events at the measured position. Weighting factors are introduced to compensate the variation of the ion extraction yield between the U and Pu isotopes and to allow the calculation of the number of fission event from the ^{148}Nd signal. A software (named SIPLO [9, 10]) has been developed for the evaluation of these weighting factors from the measured raw data using the radiochemical information obtained in a neighboring specimen as input. The definition of the normalisation factors used for the data treatment presented in this report are given in the table 3-2.

The raw data were processed with the normalisation and plotting programme SIPLO. This procedure is referred as the standard or usual normalisation procedure in this report.

Table 3-2 Normalisation constant used in the data analysis

Quantity to be determined	Normalisation factor
Burn-up distribution Relative Plutonium isotope distribution Relative fission products distribution	$N_F + \sum Pu_i + \sum U_i$
Plutonium isotopic composition	$\sum Pu_i$
^{235}U isotopic composition	$\sum U_i$
Pu/(U+Pu) ratio distribution	$\sum Pu_i + \sum U_i$
Neodymium isotopic composition	$\sum Nd_i$

The transformation of the evaluated relative count rates into absolute local isotopic compositions has been achieved by comparing the local and average SIMS values with the radiochemically determined compositions of the adjacent samples. The fission yield for ^{148}Nd is needed for the normalisation of the burn-up, relative Pu isotope distribution and relative fission product distribution. A value of 0.0175 has been used in the analysis for the three specimens. The normalisation and quantification procedure is not very sensitive to this parameter. The following data have been quantified using the radiochemical data : ^{235}U isotopic distribution, Pu isotopic distribution, Pu/(U+Pu) ratio distribution, burnup distribution, Nd isotopic distribution. The fission product and Pu isotope distribution are given qualitatively with an average value of 1. The radiochemical data has also been used for the quantification of the isotopic distribution (U, Pu, Nd) because the measurement parameter used for each isotope of one element have been optimised separately for maximisation of the count rate and mass resolution. Therefore the count rates obtained can not be quantitatively compared.

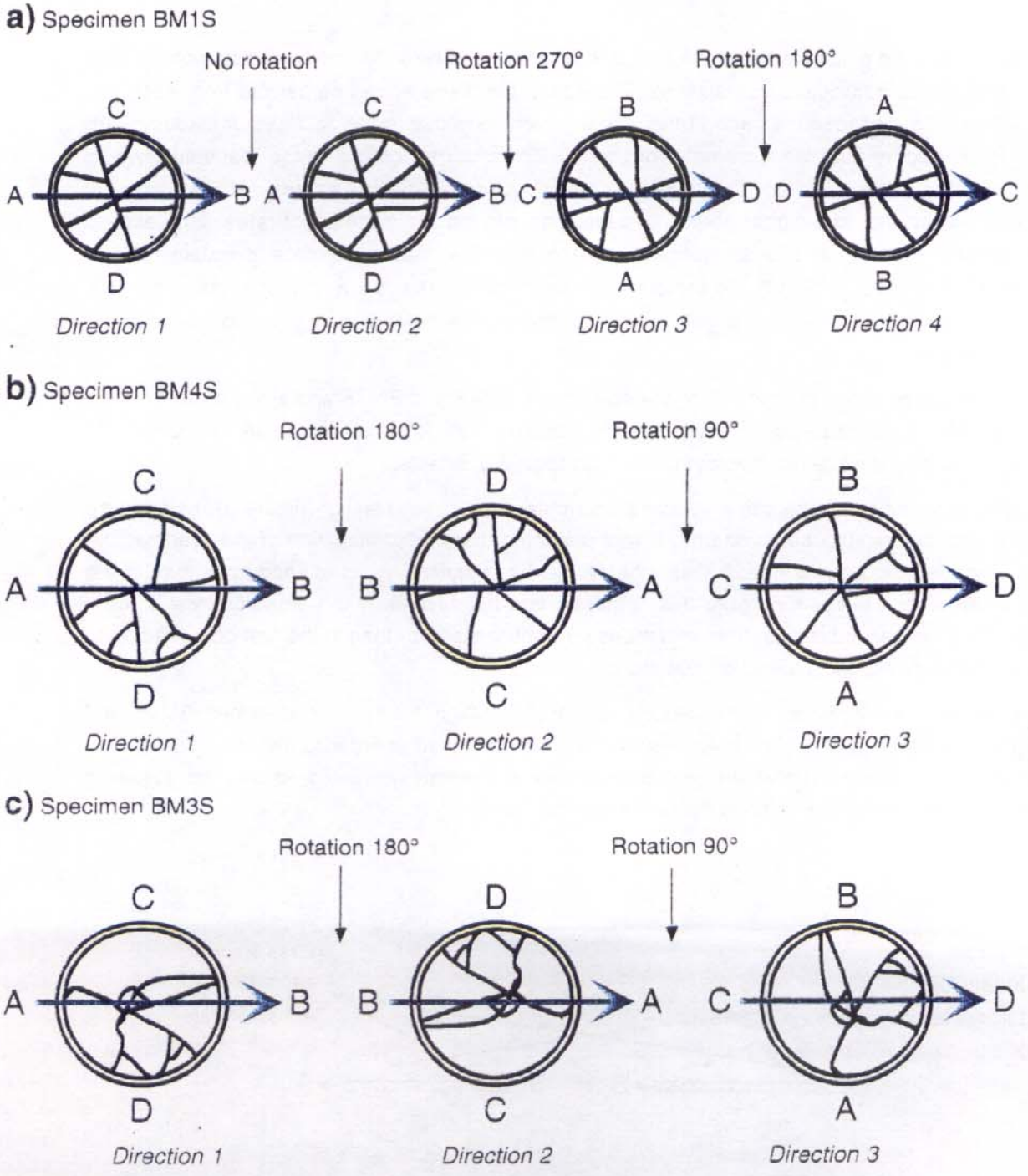


Figure 3-2 Orientation of all measurement directions for the SIMS data acquisition.
a) specimen BM1S
b) specimen BM4S
c) specimen BM3S

Normally a reduced pellet diameter of 8.8 or 8.9 mm has been taken for the processing of the data depending on the individual circumstances. The size of the diameter can be derived from each plot (Fig. 4-1 to 4-35) because the parts of the signal, which were due to the cold gap or cladding, are removed. For some nuclides a diameter of up to 9.6 mm, corresponding to the real value, would have been preferable in order to truly follow up the rim concentrations. But there was the danger of misinterpretation due to a higher portion of pellet/clad information in the count rates. That excess of information in the end systematically deteriorates the measured data because of the normalisation procedure [9, 10]. So the diameter used for the analysis was kept smaller than the real pellet diameter. The relative large reduction of the real diameter is mainly due to the relatively large beam size.

The data acquired along direction 3 for the specimens BM4S and BM3S and along direction 1 for specimen BM1S are treated/normalised with the standard method [10]. They present variation that are produced by the so called „geometric" and „conductivity" effects.

The data acquired along the same specimen diameter in reverse direction (figure 3-2) should be identical and can directly be compared. It was observed that the combination of the "geometrical effect" and the "conductivity effect" is stronger in the first acquired radius of each trace than in the second radius as sketched in figure 3-3. It means that the secondary ion emission rate is more stable along the second radius (from mid measurement to the end) than in the first one, leading to a better measurement of the nuclide distribution.

Therefore, the data acquired in the second radius of direction 1 and 2 for specimen BM4S and BM3S and direction 3 and 4 for specimen BM1S were combined in order to get the most reliable distribution. It is assumed that the real distributions are rather symmetric so that the following procedure, sketched graphically on figure 3-4 can be used.

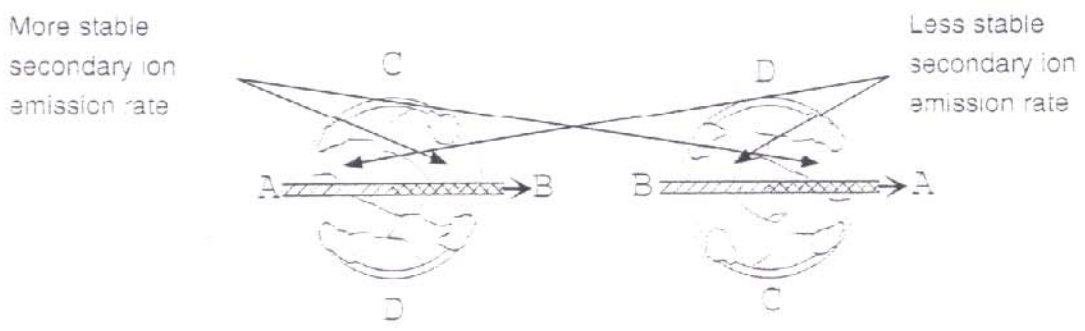


Figure 3-3 Secondary ion emission rate stability along a sample diameter.

Only the data obtained on the second radius of both directions are taken. Fully symmetrical data are generated in order to simulate the first radius (Step 1 in figure 3-4) so that the usual

normalisation procedure can be used (step 2 in figure 3-4). Then, only the second radius of the normalised data are used (figure 3-4). The same procedure is used for the data of both directions and so normalised data are generated for the first radius. The data obtained from the direction 2 represent the isotope content variations from position A to centre and the one obtained from the direction 1 the isotope content variations from centre to position B. Therefore, the distribution of the nuclide content along the full diameter (position A to B) can be plotted by adding the two data sets (step 3 in figure 3-4).

The two radial data sets have been obtained during two different measurements. As it was already said, the positioning of the specimen can be slightly different regarding to the rotation angle and the target position. This leads to small changes of the quantified values obtained after normalisation. Therefore the data treated in this way have to be re-normalised in order to get a perfectly joined curve in the centre. Usually, six points on each side of the centre were taken for the arithmetic mean. This procedure consists simply in adding half of the difference Δh obtained in the centre position to one radius data and subtract it from the other half curve (step 4 in figure 3-4). In the case of specimen BM4S, the presence of large cracks in the centre of the specimen produce large variation of the count rates that are not real, therefore this last step of the normalisation has been done by calculating the mean value on about 30 point instead of 6 on each side.

Finally the average value of the new data set is calculated and all values are normalised so that the average is equal to the original value (radio-chemical value or 1.0 for the relative content).

This method is very effective for removing most of the "geometrical effect" and a large part of the "conductivity" effect. Differences are still observed mainly for the fission product distribution. This will be discussed more in detail in the next chapter.

3.3 SIMS Error Estimation

The counting times for all recorded masses have been chosen large enough in order to accumulate a large number of counts, but as small as possible in order to keep the total data acquisition time reasonable (about 30 hours per direction).

For most of the masses, more than 250 counts have been accumulated. The statistical error of a single count rate is therefore lower than 3.5 %. The error on the average values calculated from 5 adjacent points is, according to error propagation rules, lower than 3 %. The normalisation procedure uses measured data (mainly ^{238}U and Pu isotope count rates), but the statistical error after normalisation is still lower than 5 %. This means, that the random error of an isotopic fraction of an individual isotope at one position is lower than 7 %. This does not include variations due to cracks or pores on the sample surface which may also lead to systematic local deviation not completely removed by normalisation.

The variation of the count rate due to the presence of a crack is isotope dependant. Therefore the effect on the error can not be quantified.

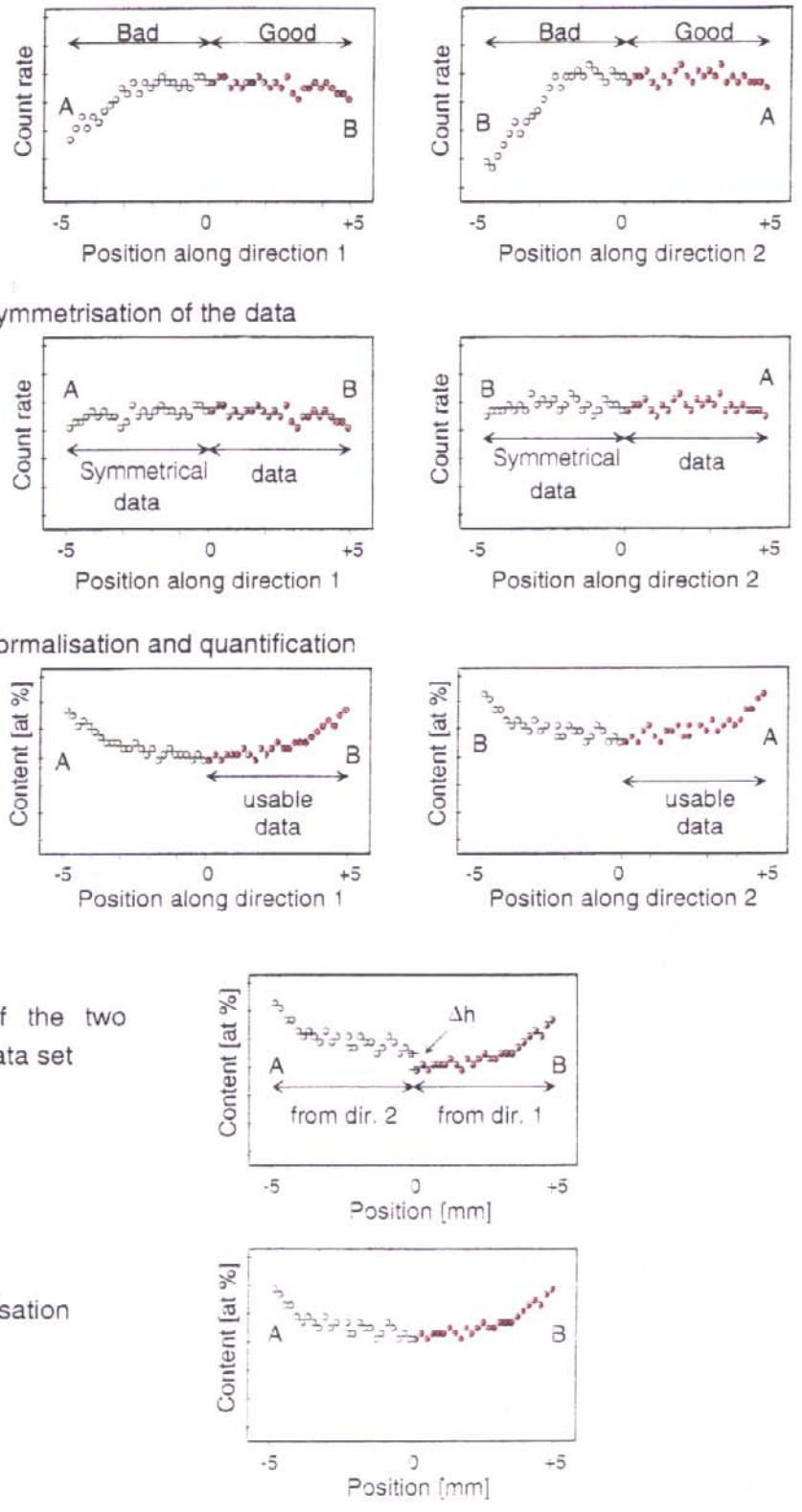


Figure 3-4 Data analysis procedure along reverse directions 1 and 2.

4. SIMS results and discussion

The SIMS data are presented in figures 4-1 to 4-13 for specimen BM1S in figures 4-14 to 4-24 for specimen BM4S and finally in figures 4-25 to 4-35 for the specimen BM3S.

All plots are presented in the last paragraph 4.7. For a better readability of the report we have commented, discussed and compared the results obtained on the three specimens in the following paragraphs (§4.1 to 4.6), each one being dedicated to a specific isotope or element distribution.

All data have been normalised with the SIPLO procedure. The data acquired along one diameter in both directions have been combined with the method presented in the paragraph 3.2 and are coupled in one plot.

To get an indication of the reproducibility of the measurements, one diameter of the BM1S specimen has been measured two times in the same direction (dir. 1 and 2). The measurements were slightly shifted one from the other and therefore the materials analysed are not completely identical. The ^{235}U, the Pu / (U+Pu) ratio, the burn-up and the ^{137}Cs relative distribution for both directions are plotted together in figures 4-1 and 4-2. For all data presented, the two curves are basically identical. The small differences observed can easily be explained by the shift between two measurements implying that the cracks or local Pu variations in the material are not exactly at the same position for example. This demonstrates the reliability of the measurements.

4.1 Local isotopic uranium composition

The ^{235}U distributions, given in at% = $^{235}U/U$ (Fig. 4-3, 4-14, 4-25), are relatively flat. A systematic apparent concentration increase in all specimens is visible on the direction 1 of BM1S and direction 3 of BM4S and BM3S. This behaviour is known to be produced by the so called "geometric effect". This effect is greatly removed by the combining of the measurements made in two opposite directions (dir. 3 & 4 for BM1S and 1 & 2 for BM4S and BM3S). ^{235}U is also a good "monitor" for surface anomalies, as very often a crack causes an apparent peak concentration, which is not only restricted to the cold gap. So any local nuclide concentration changes should also be checked with the ^{235}U concentration at the same position.

4.2 Relative Pu isotope and total Pu contents

The relative Pu isotope distributions are presented in the figures 4-4, 4-5, 4-15, 4-16, 4-26 and 4-27. The total Pu content distribution is presented in figures 4-6, 4-17 and 4-28.

The presence of cracks in the specimen, which produces unreal Pu content changes make the analysis of these curves difficult. Part of the peaks observed in the distribution are clearly due to cracks, but there is also variations that are produced by the presence of Pu rich zones in the fuel.

The dualism of breeding and fission at the periphery is also clearly visible here for all specimens. The increase of ^{239}Pu in the first 300 µm expresses the high breeding rate of this isotope through epithermic neutrons in the periphery. A clear decrease of the ^{240}Pu content in the periphery

expresses probably the capture resonance at about 1 eV for the reaction $^{240}Pu(n,\gamma)\,^{241}Pu$. The general distribution of the ^{239}Pu and ^{240}Pu show a clear increase in the center of the pellet in contrary of the ^{241}Pu and ^{242}Pu.

The total Pu content, calculated as the sum of the 4 Pu isotopes measured shows a different distribution in BM1S than in the two other specimens. It is relatively flat for specimen BM1S (Fig. 4-6) but shows a clear increase in the center of the pellet for specimens BM4S and BM3S, similar to the variation of the ^{239}Pu and ^{240}Pu isotopes in the center of the pellet.

4.3 Local Isotopic Plutonium Composition

On all three samples the central symmetry is retained (Fig. 4-7, 4-18 4-29). The ^{239}Pu content is slightly higher in the BM4S specimen due to the lower burn-up. The rim zone is also clearly observable on these distributions.

4.4 Local Isotopic Neodymium Composition

The local isotopic Nd compositions are given in figures 4-8, 4-19 and 4-30. They are in general symmetric and quite flat. There is a slight ^{143}Nd consumption toward the rim through n-capture. A slight asymmetry of the isotope ^{145}Nd and ^{144}Nd is observed in specimen BM4S and BM3S. This is probably due to the rod position at the periphery of the bundle, that implies an asymmetry of the neutron spectrum.

The peak observed in the center of the distribution in direction 3 for specimen BM4S or along direction 3 and 4 in specimen BM1S are due to the surface erosion produced by the measurement in the perpendicular direction leading to a slightly modified secondary ion yield.

4.5 Burn-up

The ^{148}Nd distribution is used for the determination of the burn-up profile across the pellet. The local burn-up is calculated by the normalisation of the ^{148}Nd relative distribution with the average burn-up (table 2-3) of the specimen [10].

The burn-up increase in the periphery is clearly observable in all specimen (Fig. 4-9, 4-20 and 4-31). The burn-up rises to about 6.8 %FIMA in the periphery of the fuel in specimen BM1S (about 1.4 times the average burn-up), to about 5.9 %FIMA in the periphery of the fuel in specimen BM4S (about 1.2 times the average burn-up) and to 6.1 %FIMA in the periphery of the fuel in specimen BM3S (about 1.4 times the average burn-up)

4.6 Relative Fission Product Distribution

All the relative distributions are presented in figures 4-10, 4-11, 4-12 and 4-13 for specimen BM1S, 4-21, 4-22, 4-23 and 4-24 for specimen BM4S and 4-32, 4-33, 4-34 and 4-35 for specimen BM3S.

4.6.1 Non-volatile Fission Products

The Sr, Ba and Lanthanides show all the same course and as usual they need also a symmetric correction. ^{148}Nd is not explicitly plotted as it is integrated in the burn-up distribution as the monitor nuclide (4.5). They are relatively flat in the center of the pellet with a clear increase in the periphery.

The Mo and Tc distribution show the usual strong content increase at the periphery due to the higher burn-up. In the centre of the specimen the distributions exhibit a clear increase which is attributed to a measurement artefact. Previous measurements have demonstrated that this is produced by the presence of fission product precipitates which modify the emission yield of these secondary ions. Therefore this is not related to a concentration increase of these elements in the specimen. This effect can be used to determine the size of the zone where the precipitation of these element occurs which is related to the fuel temperature during service. A rough estimation of the external radius of the zone gives values of r/r_o (with r_o = 4.8 mm) of about 0.5 for BM1S, 0.4 for BM4S and 0.45 for BM3S.

4.6.2 Volatile Fission Products

Cs isotopes and ^{87}Rb show the same distribution as the Sr, Ba and Lanthanide. This demonstrates that these volatile fission products did not diffuse outside the centre of the fuel as it can be observed in fuel running at high linear power.

The ^{85}Rb distributions show anomalies in all specimens. We have no explanation for these unusual variations.

4.7 List of data files

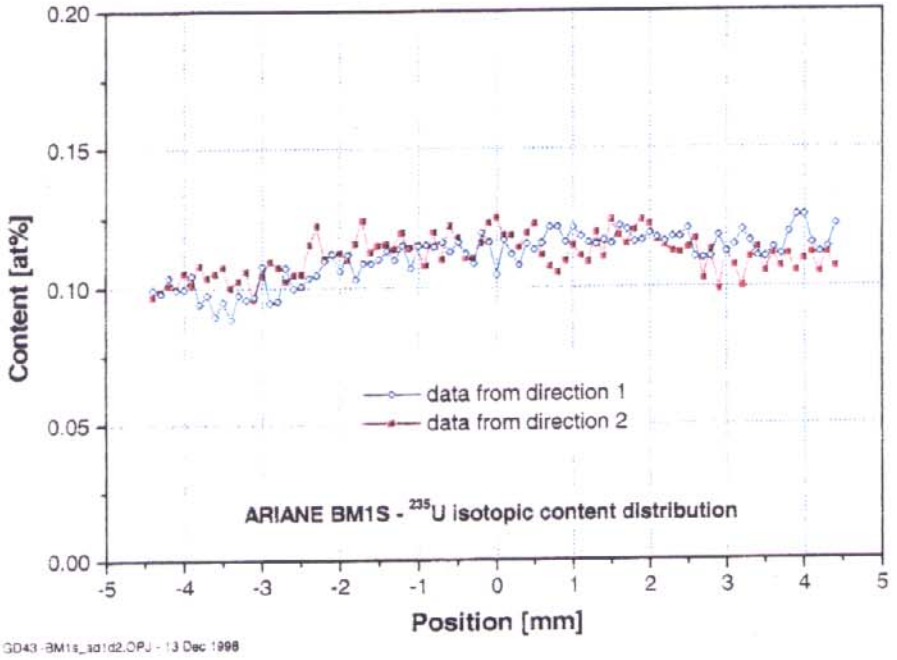
The normalised and quantified data used for the plots presented in paragraph 4.8 are contained in the following ASCII files :

Specimen BM1S	direction 1	BM1S-ad1.txt
	direction 2	BM1S-ad2.txt
	direction 3 & 4 (combined)	BM1S-sd3d4.txt
Specimen BM4S	direction 1 & 2 (combined)	BM4S-sd1d2.txt
	direction 3	BM4S-ad3.txt
Specimen BM3S	direction 1 & 2 (combined)	BM3S-sd1d2.txt
	direction 3	BM3S-ad3.txt

The plots have been produced with the graphic package ORIGIN® ver 5.0.

4.8 Figures

All isotope distribution obtained by SIMS on the three specimens are presented in this paragraph. They are organised by specimen starting with BM1S (Fig. 4-1 to 4-13), continuing with specimen BM4S (Fig. 4-14 to 4-24) and finally specimen BM3S (Fig. 4-25 to 4-35).



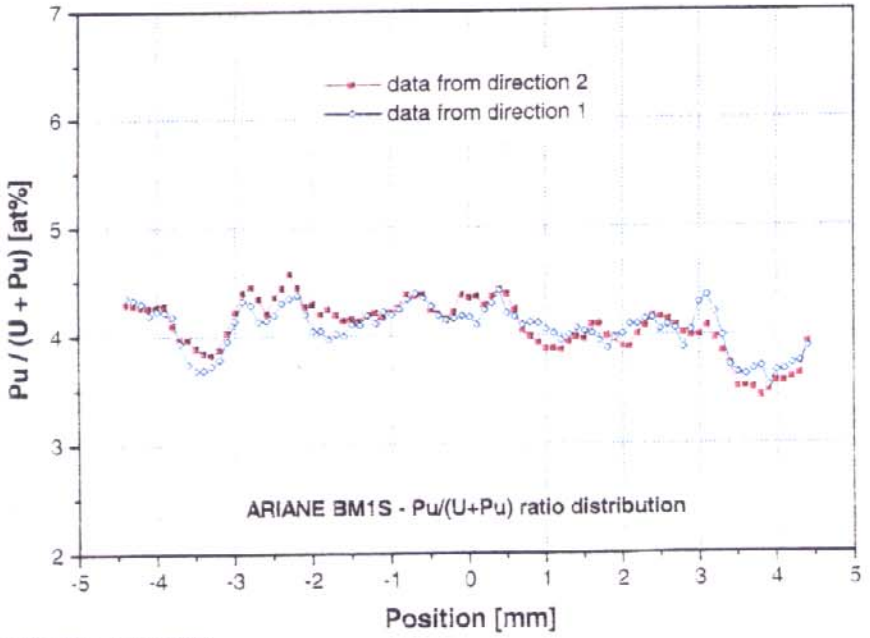
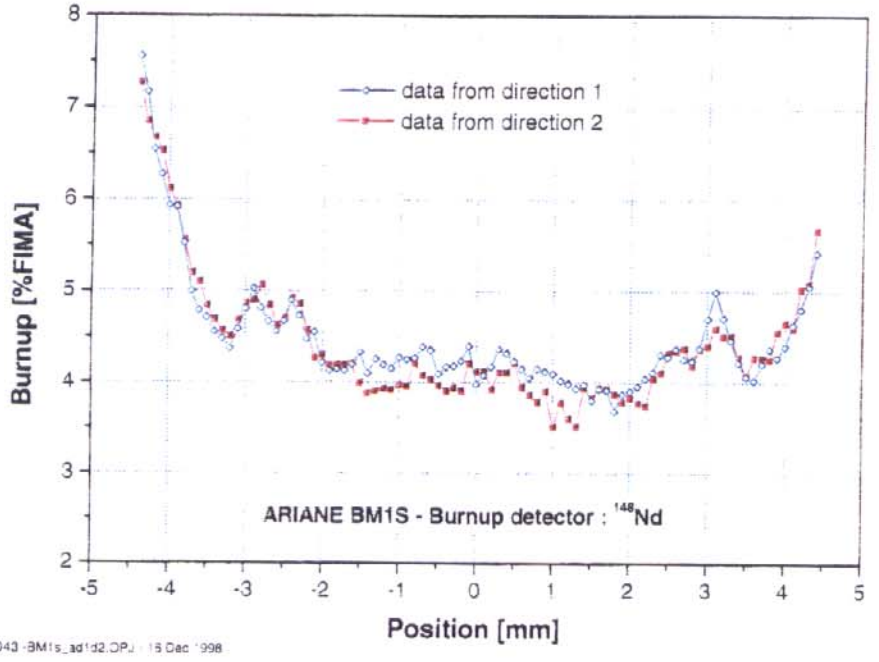


Figure 4-1 Sample BM1S, comparison of the local isotopic ^{235}U content (top) and Pu/(U+Pu) ratio (bottom) along direction 1 and 2 according to figure 3-2 (direction 1 and 2 are along the same pellet diameter in the same direction).



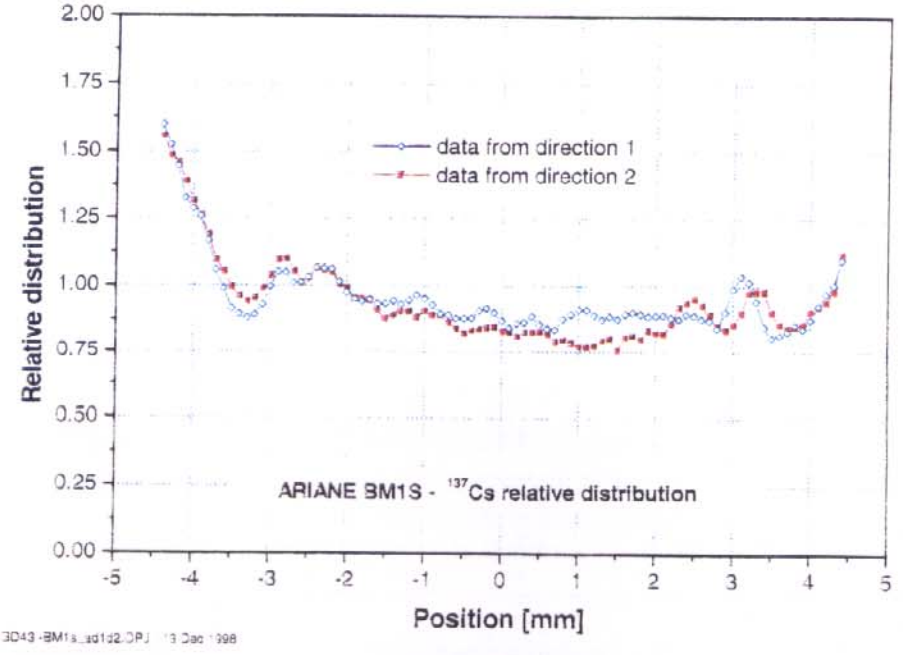
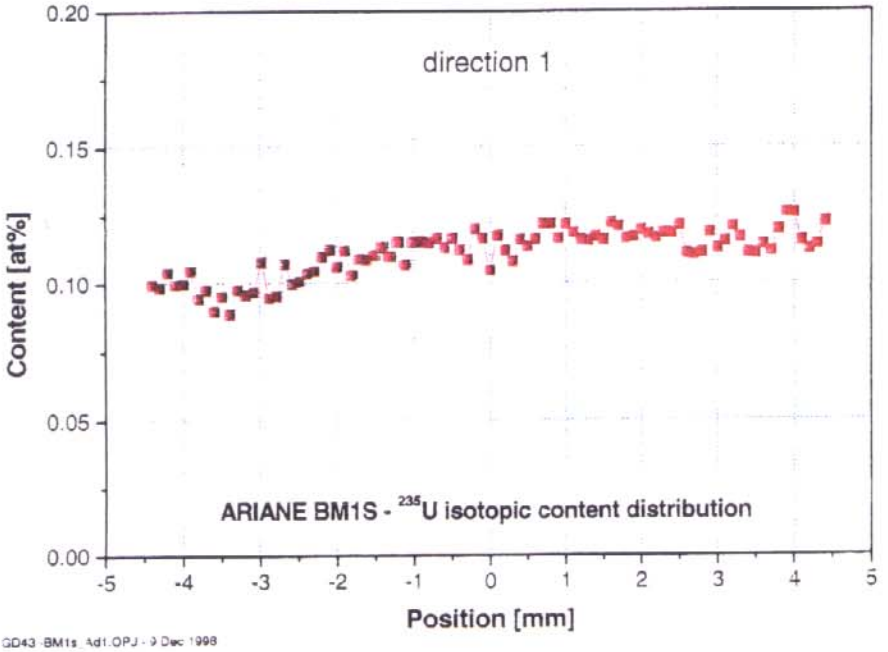


Figure 4-2 Sample BM1S, comparison of the burn-up distribution (top) and the ^{137}Cs relative distribution (bottom) along direction 1 and 2 according to figure 3-2 (direction 1 and 2 are along the same pellet diameter in the same direction).



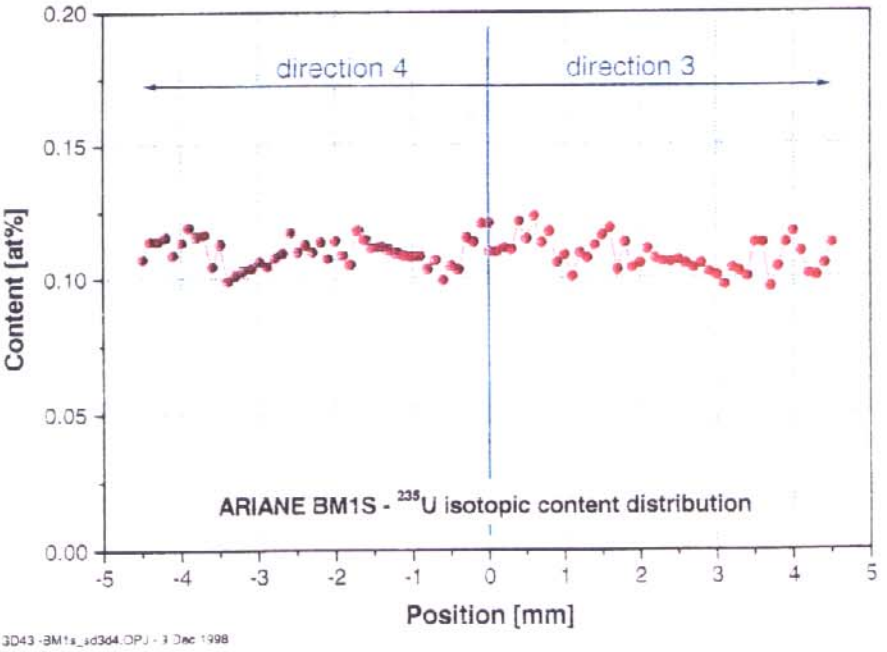
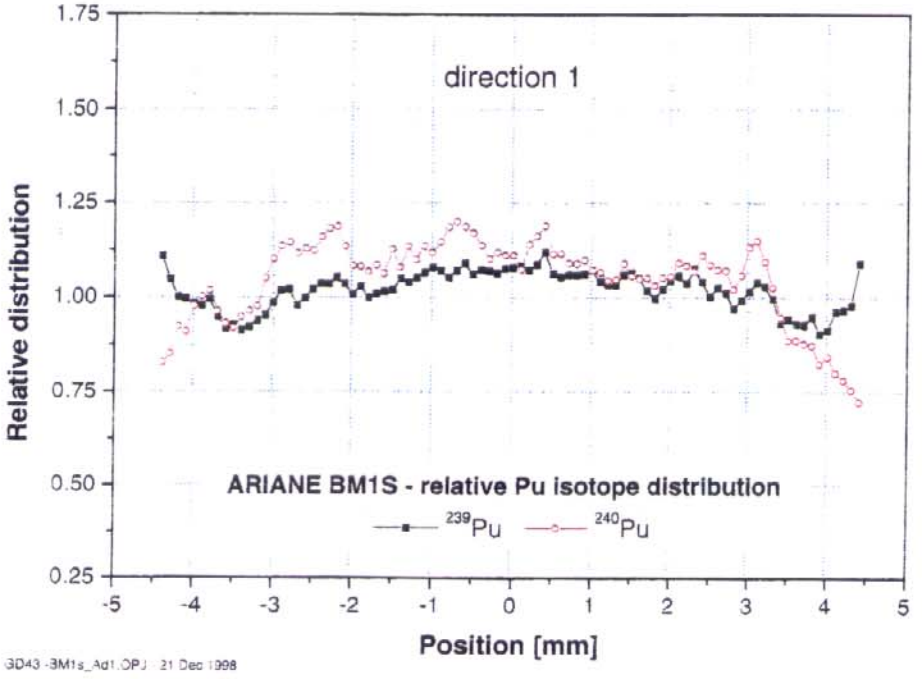


Figure 4-3 Sample BM1S, local isotopic ^{235}U distribution [at%] along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



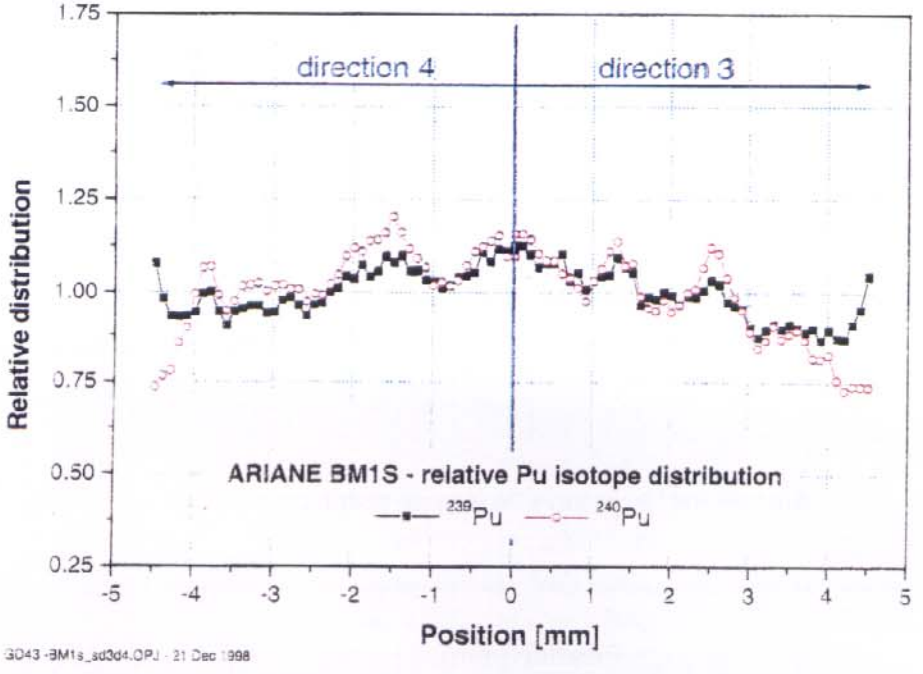
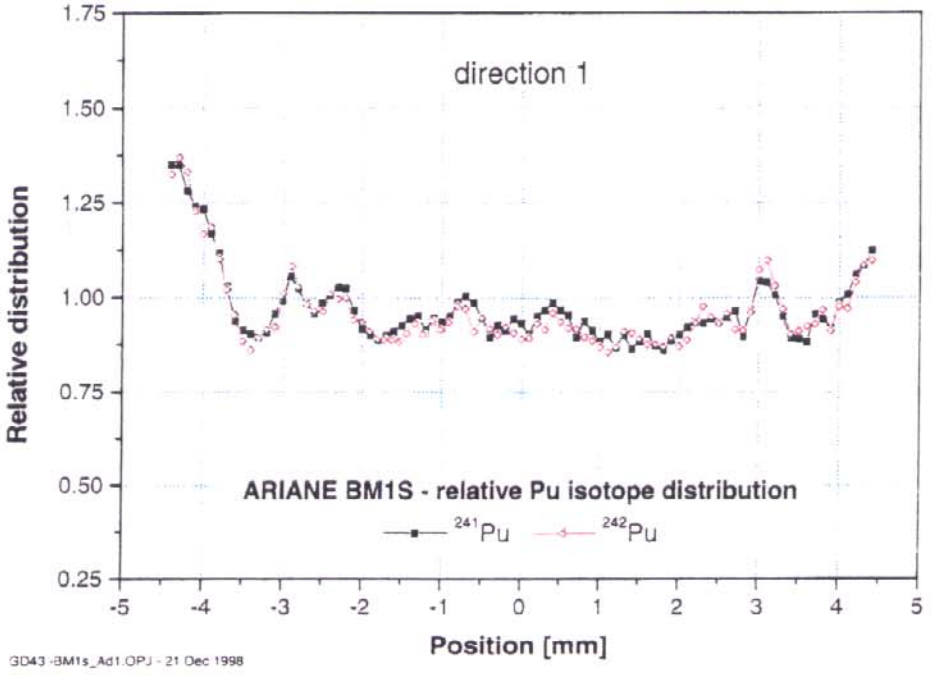


Figure 4-4 Sample BM1S, ^{239}Pu and ^{240}Pu distribution (relative to average concentration 1) along direction 1 (top) and 3 (bottom) according to figure 3-2.



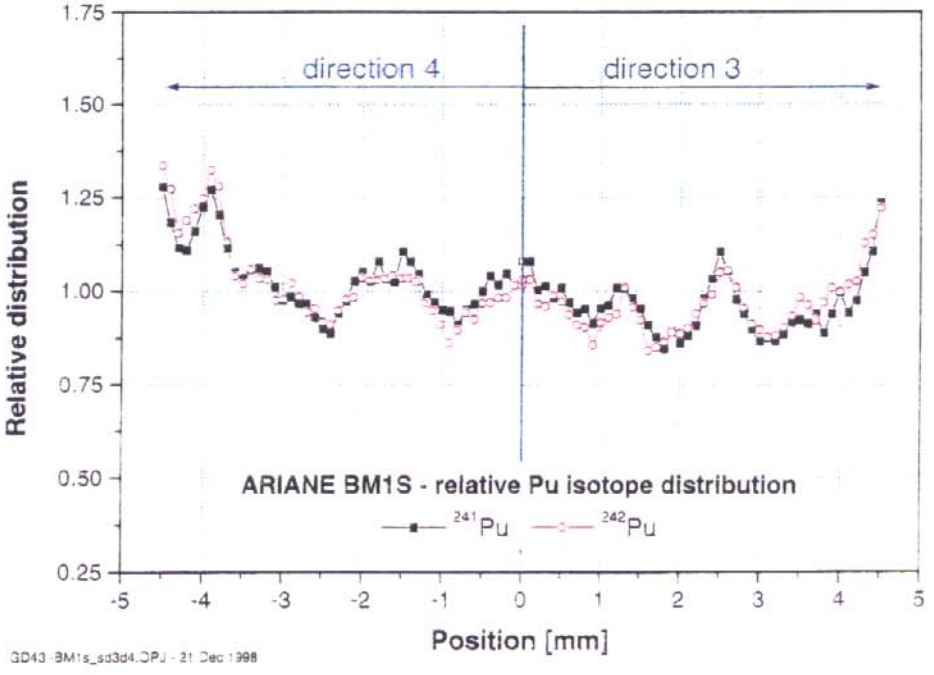
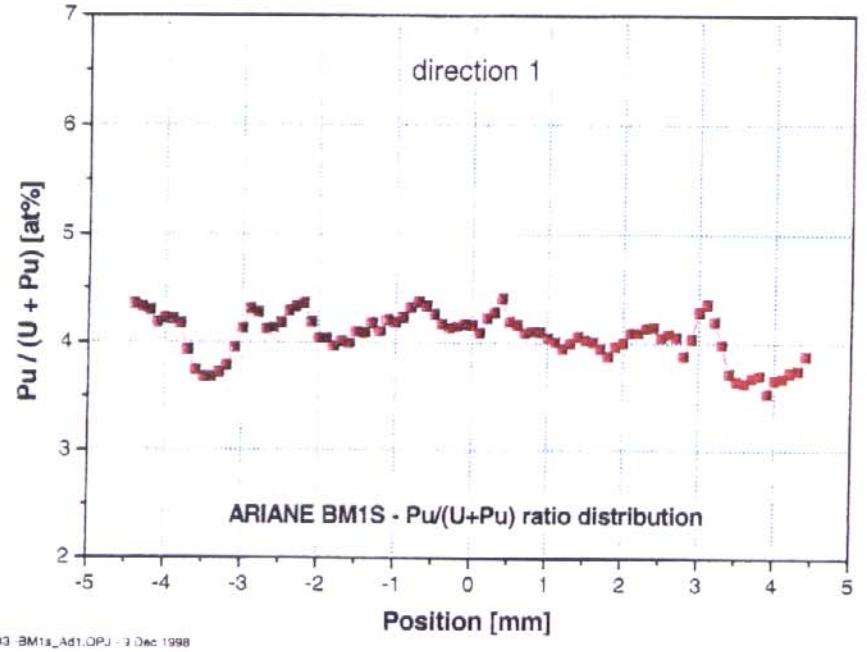


Figure 4-5 Sample BM1S, ^{241}Pu and ^{242}Pu distribution (relative to average concentration 1) along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



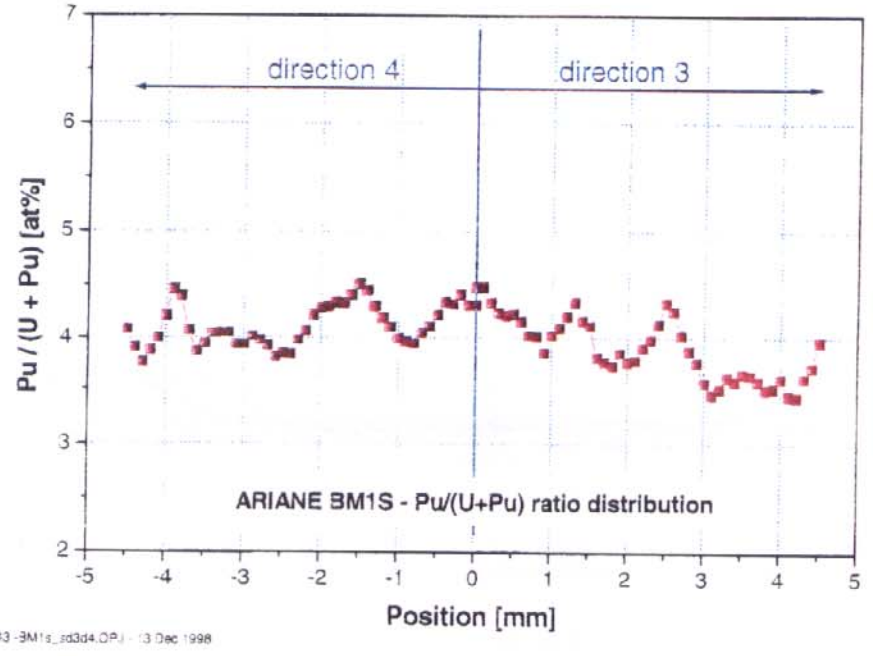
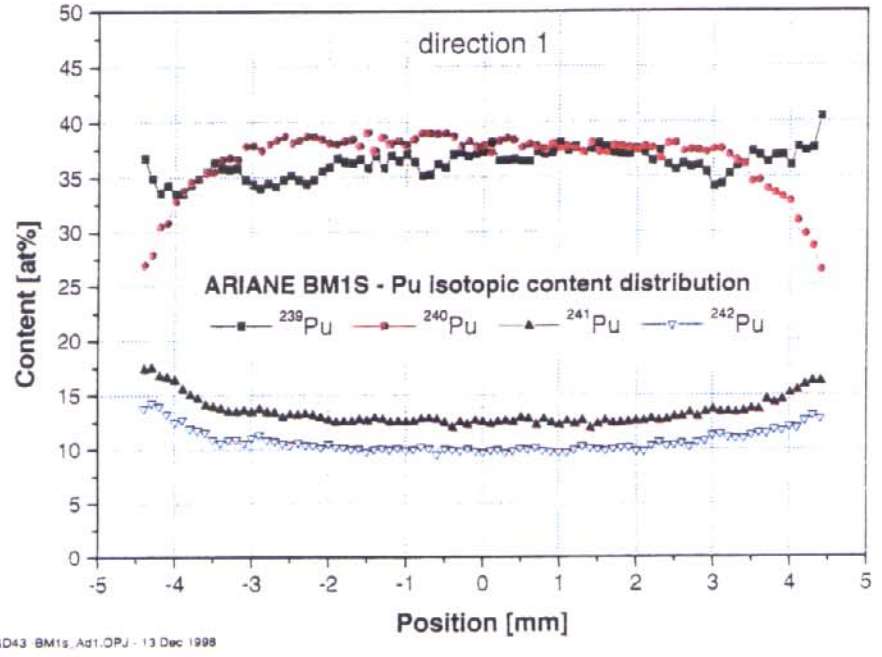


Figure 4-6 Sample BM1S, Pu/(U+Pu) ratio distribution along direction 1 (top) and direction 3/4 (bottom) according to figure 3-2.



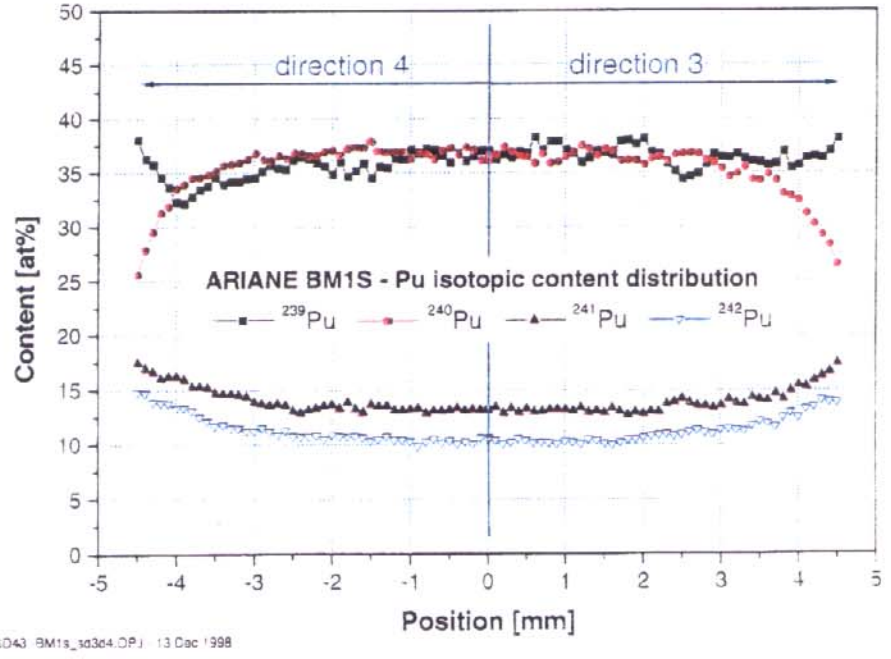
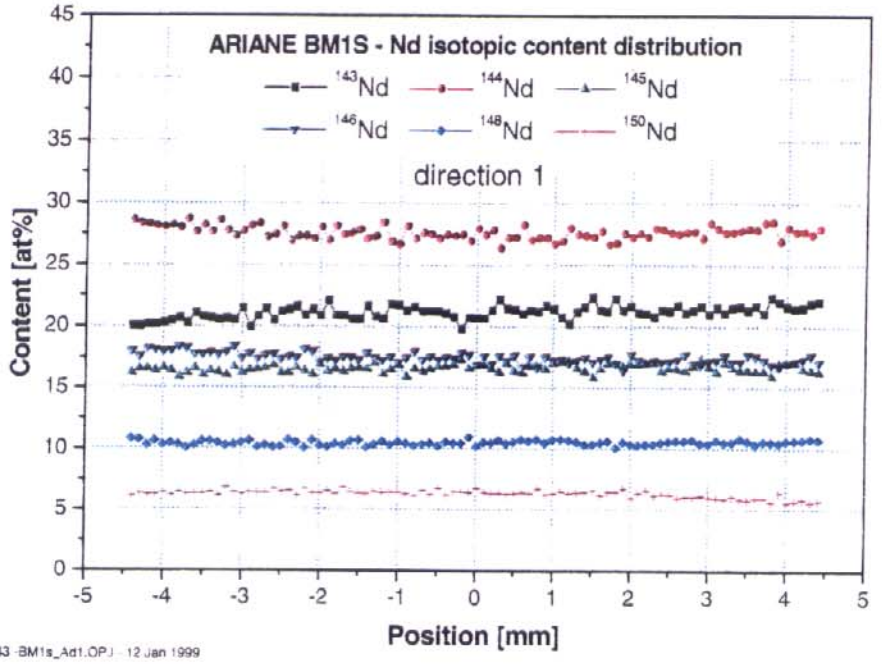


Figure 4-7 Sample BM1S, local isotopic Pu composition [at%] along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



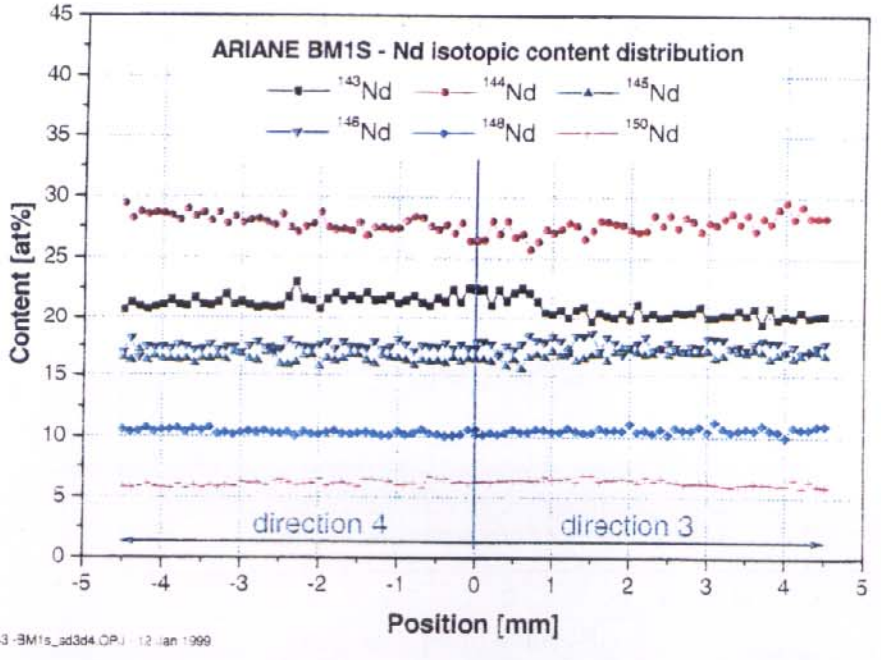
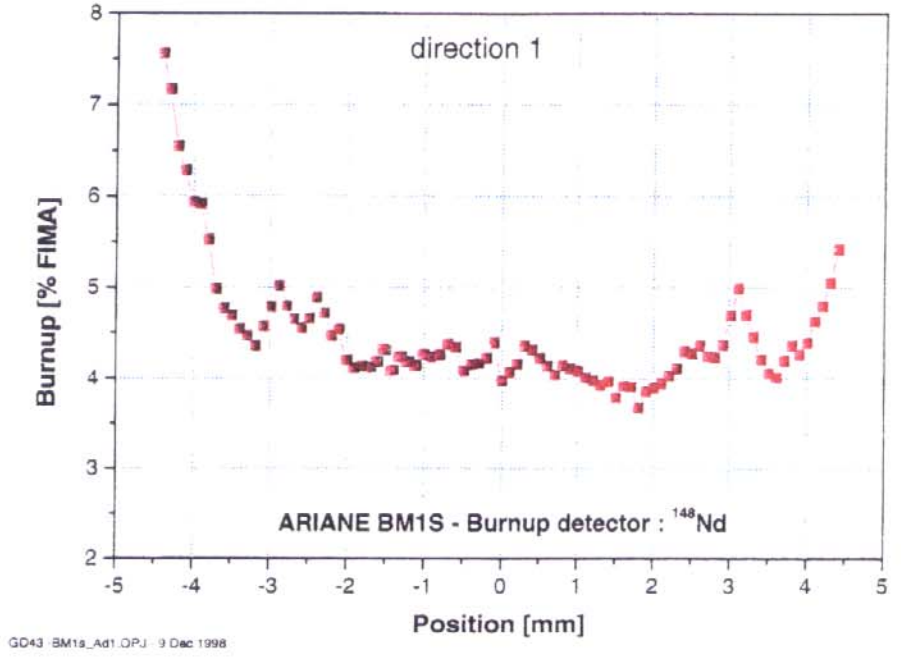


Figure 4-8 Sample BM1S, local isotopic Nd composition [at%] along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



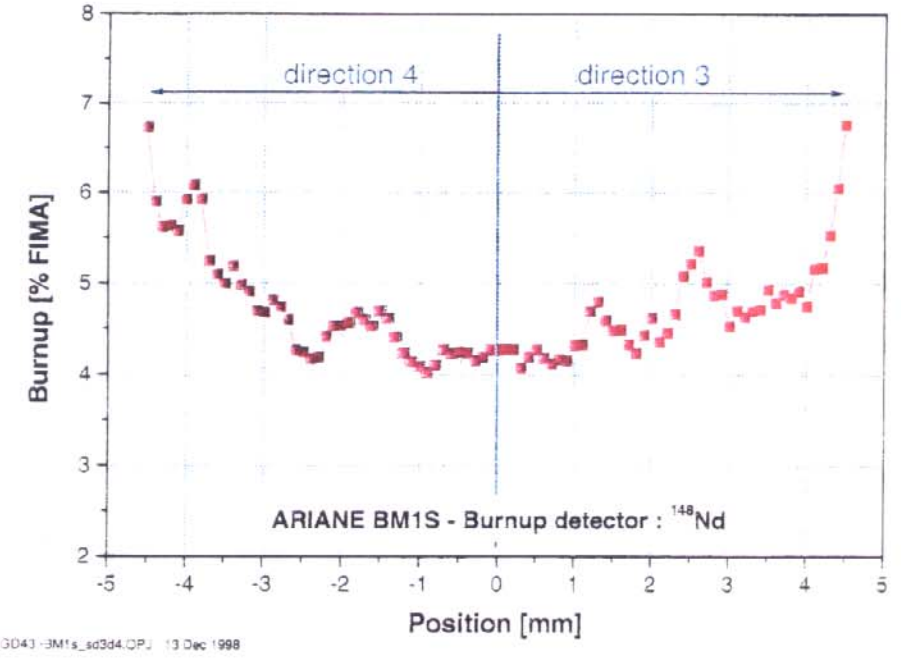
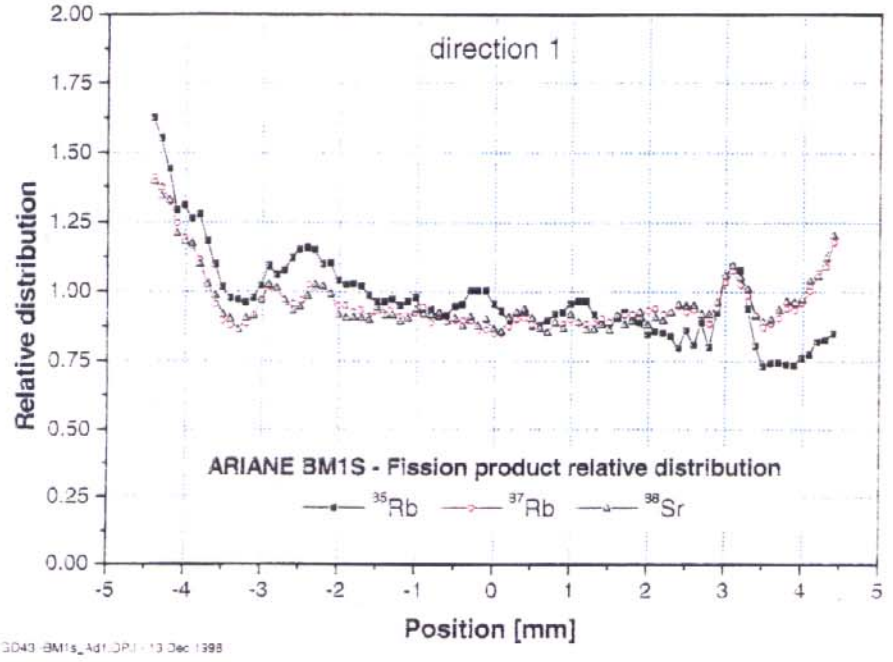


Figure 4-9 Sample BM1S, burnup distribution [%FIMA] along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



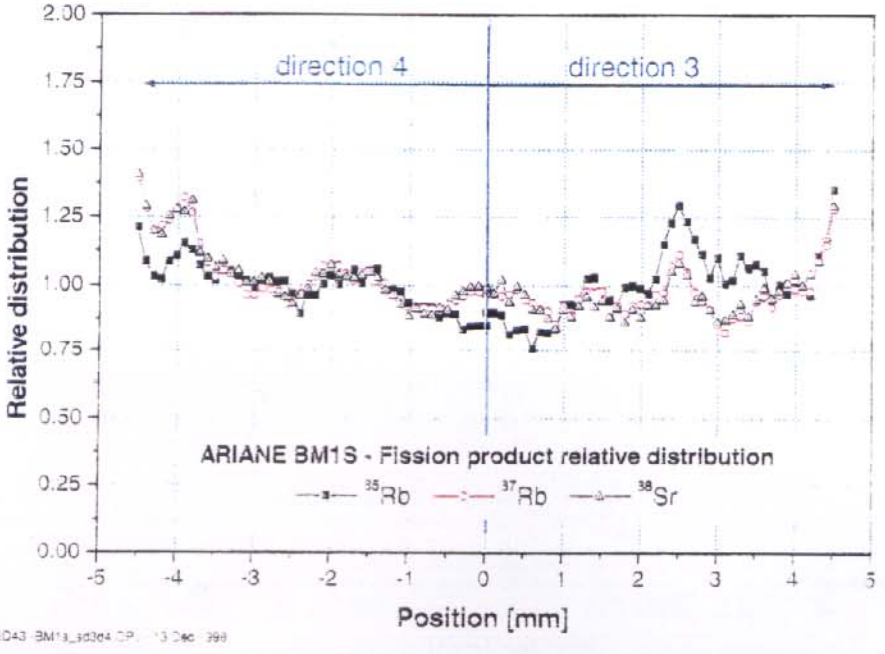
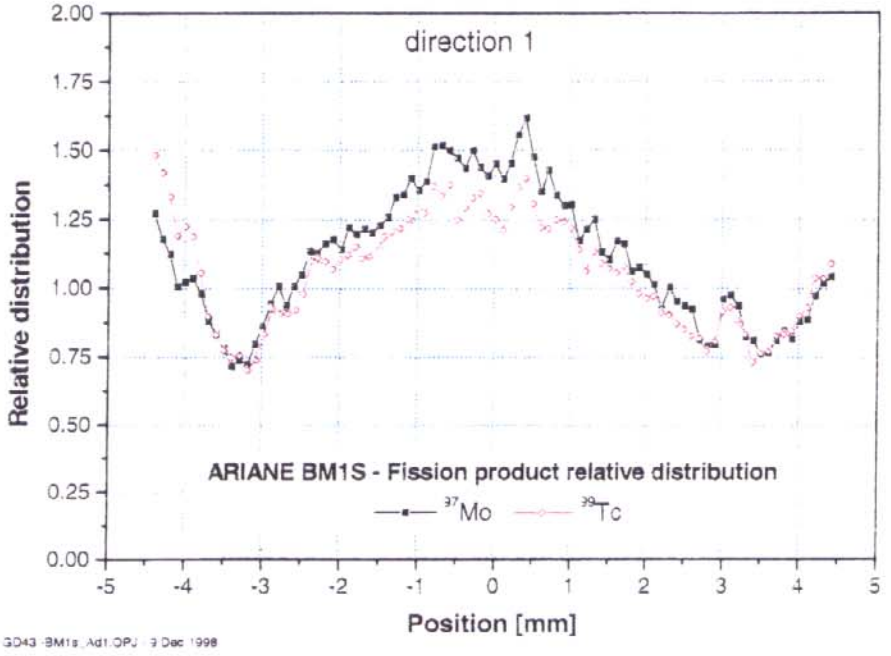


Figure 4-10 Sample BM1S, relative distribution of fission products ^{35}Rb, ^{37}Rb and ^{38}Sr normalised to an average value of 1 along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



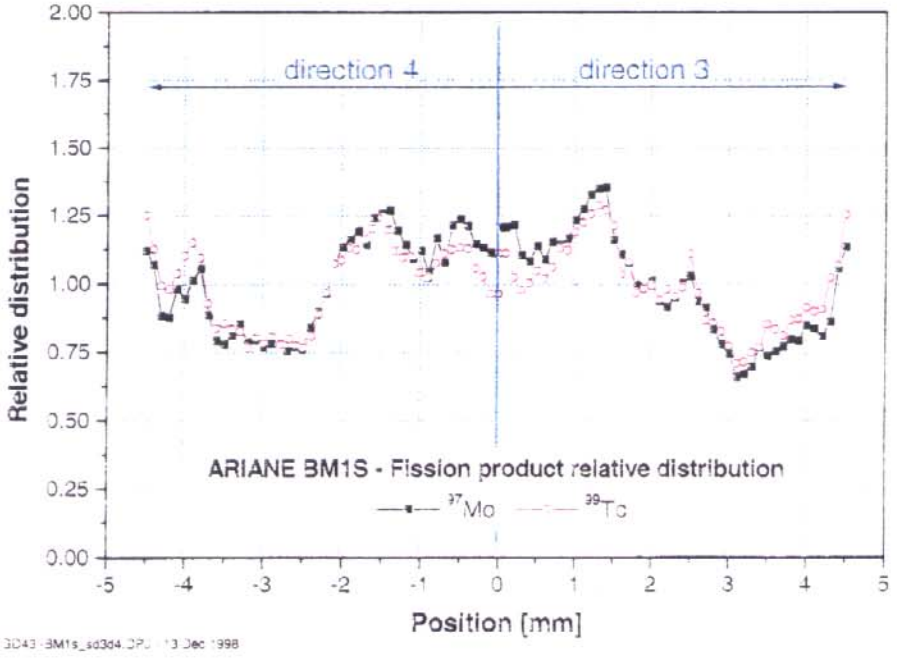
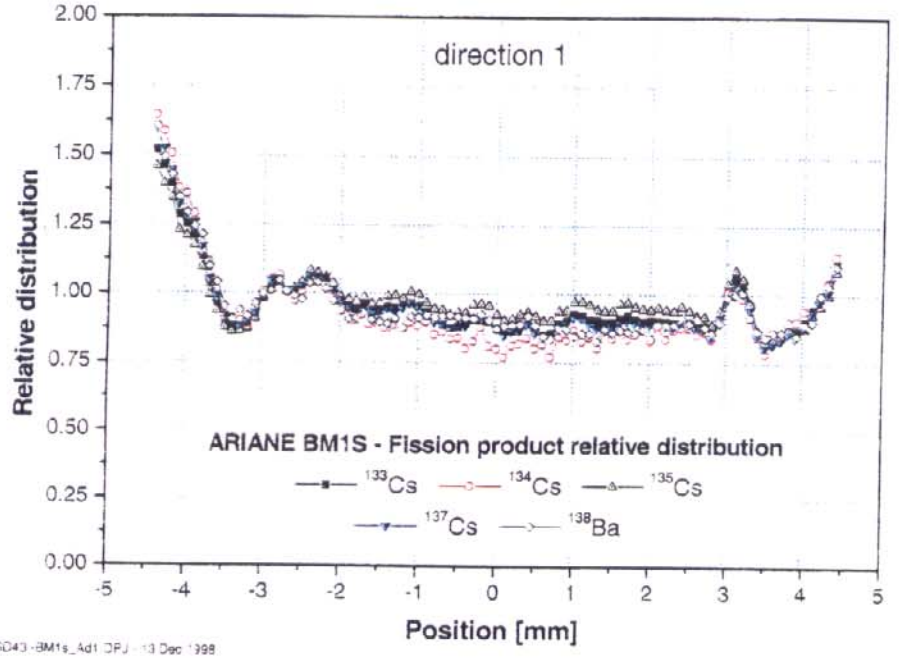


Figure 4-11 Sample BM1S, relative distribution of fission products ^{97}Mo and ^{99}Tc normalised to an average value of 1 along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



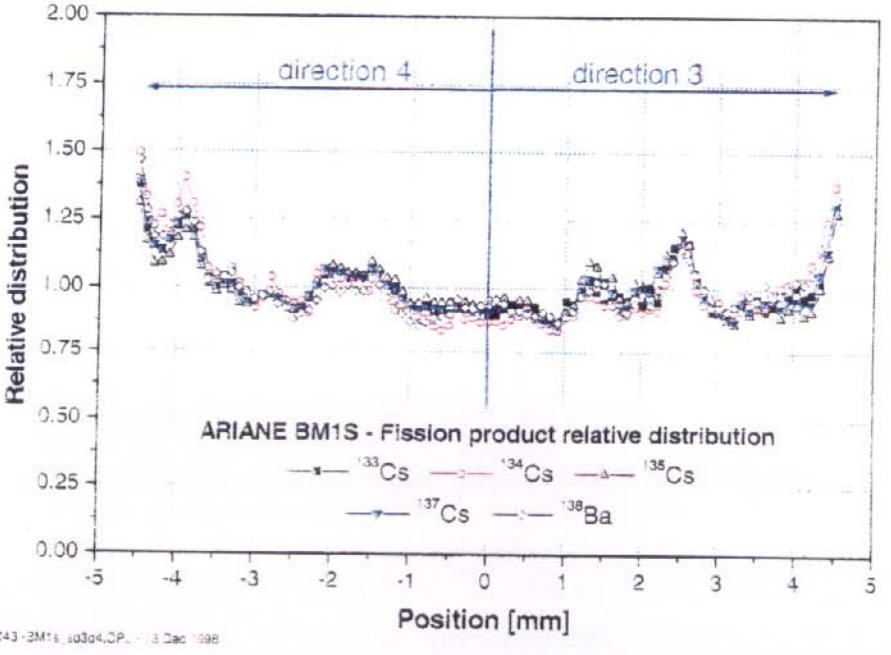
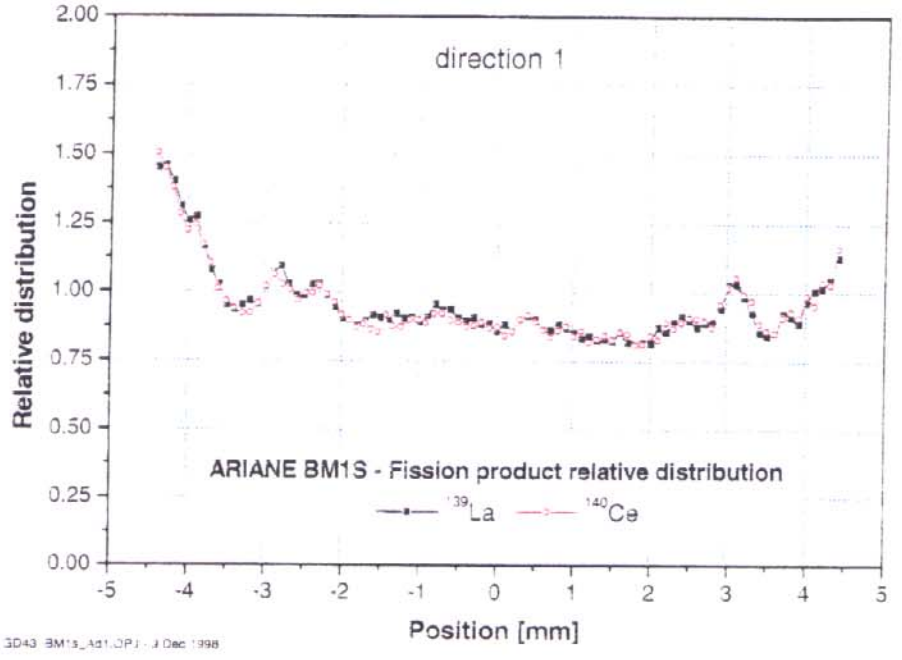


Figure 4-12 Sample BM1S, relative distribution of fission products ^{133}Cs, ^{134}Cs, ^{135}Cs, ^{137}Cs and ^{138}Ba normalised to an average value of 1 along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



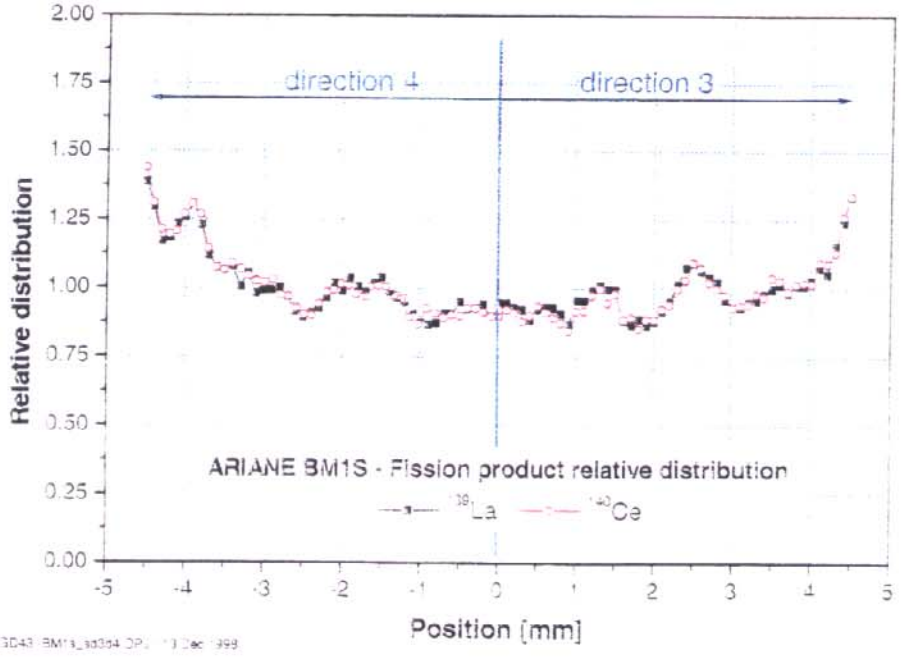
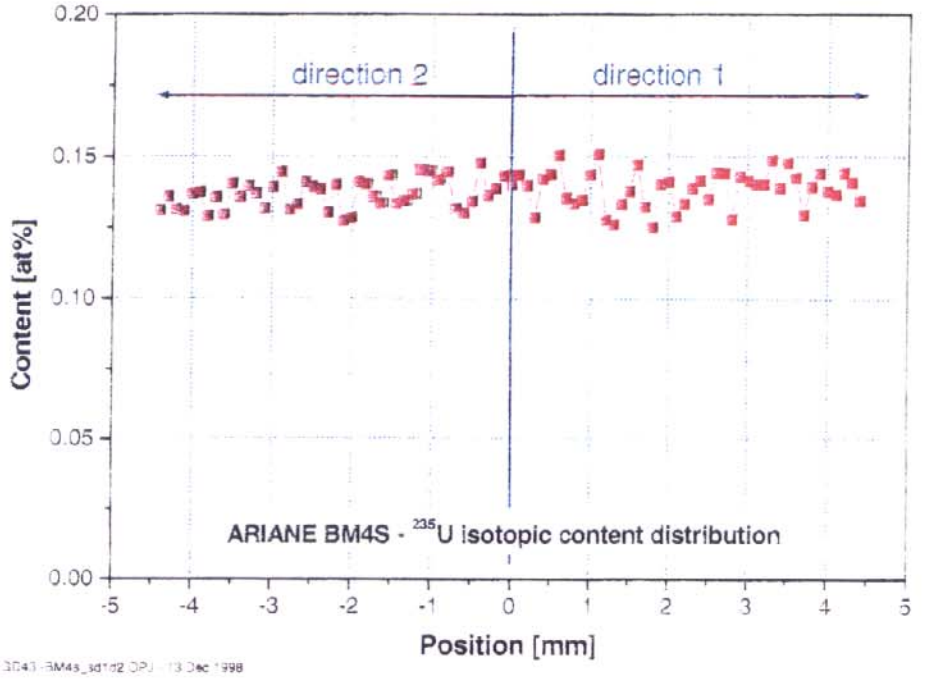


Figure 4-13 Sample BM1S, relative distribution of fission products ^{139}La and ^{140}Ce normalised to an average value of 1 along direction 1 (top) and 3/4 (bottom) according to figure 3-2.



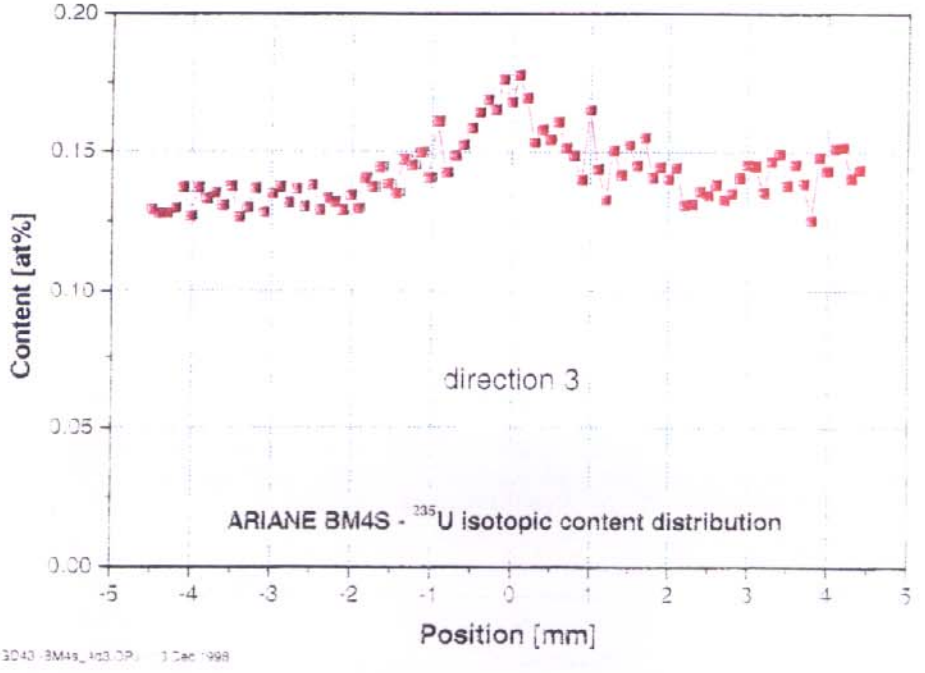
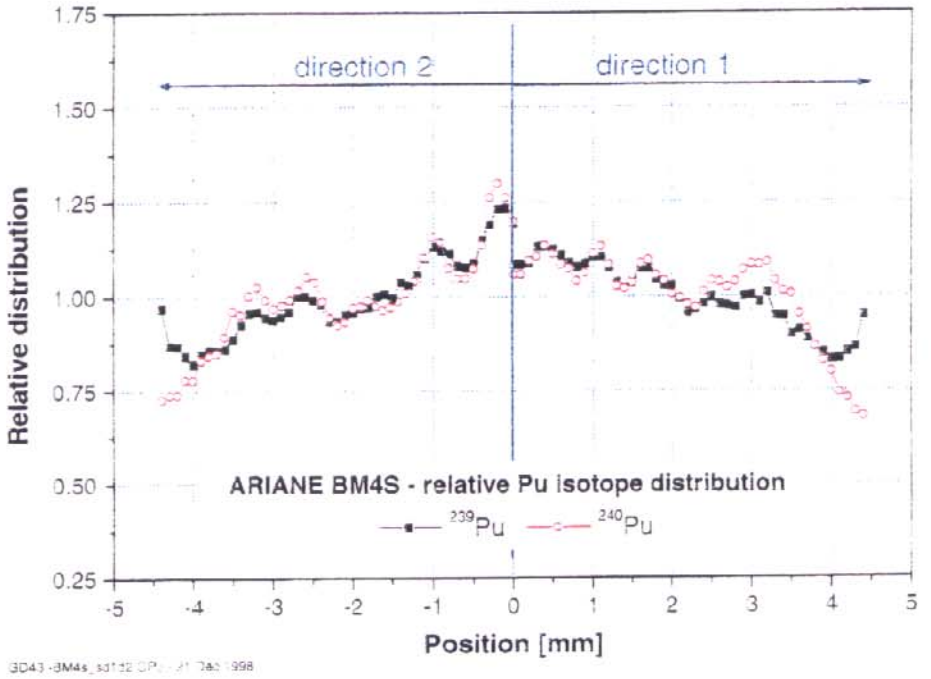


Figure 4-14 Sample BM4S. local isotopic ^{235}U distribution [at%] along direction 1 2 (top) and 3 (bottom) according to figure 3-2.



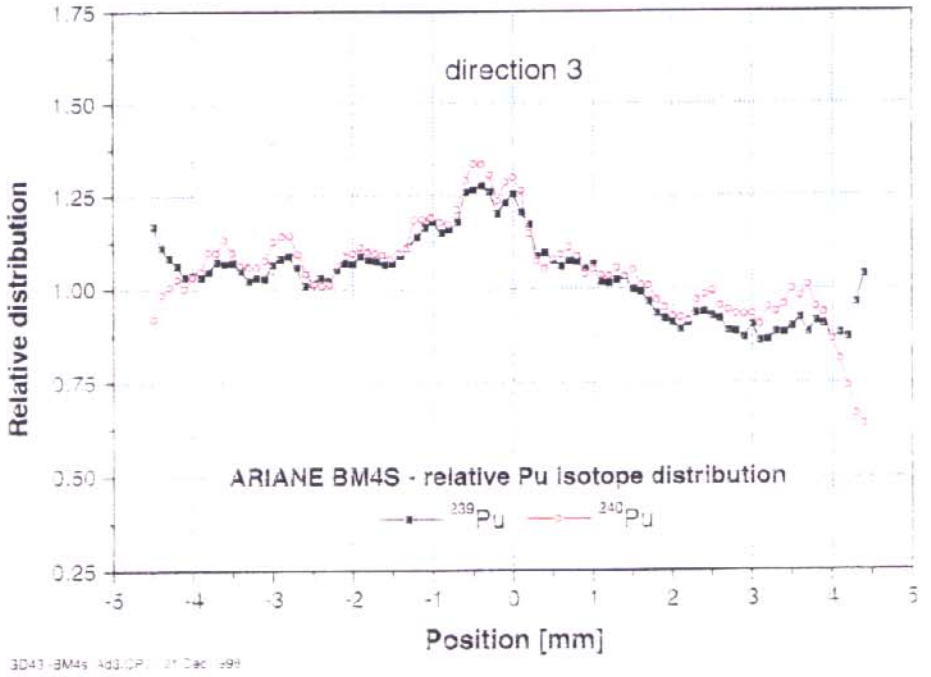
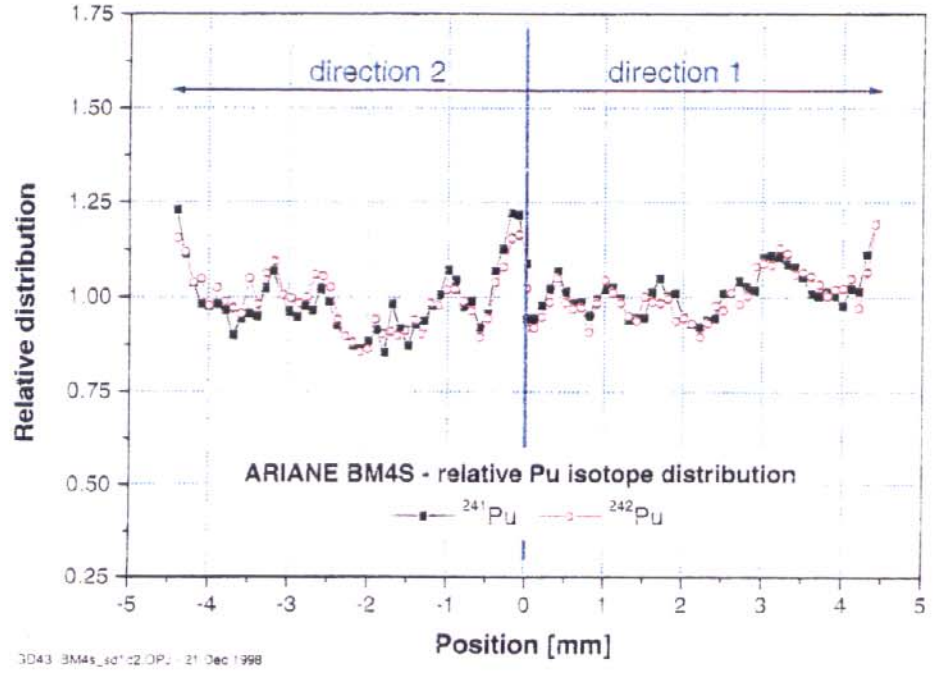


Figure 4-15 Sample BM4S, ^{239}Pu and ^{240}Pu distribution (relative to average concentration 1) along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



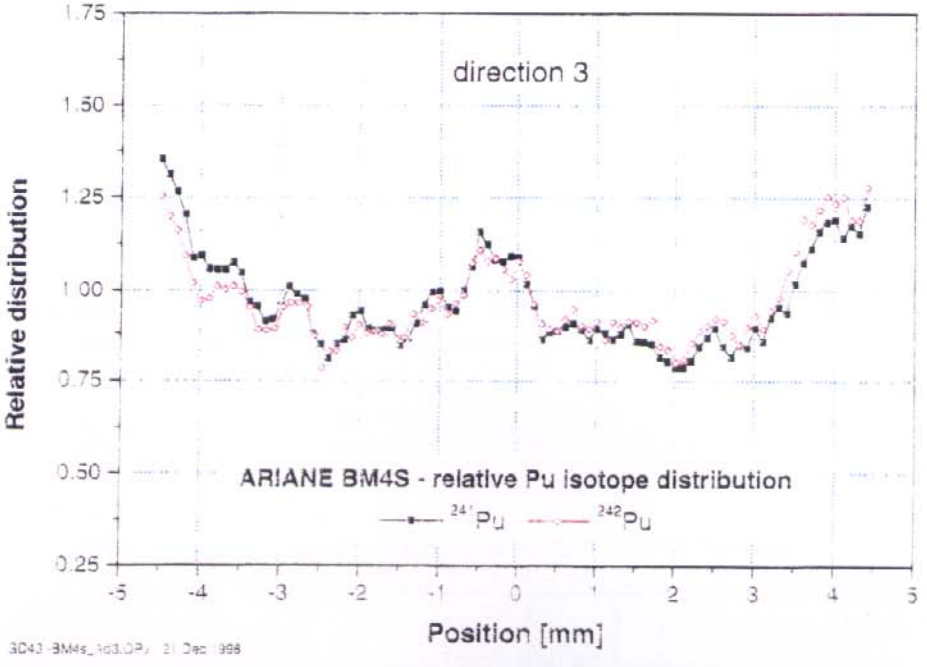
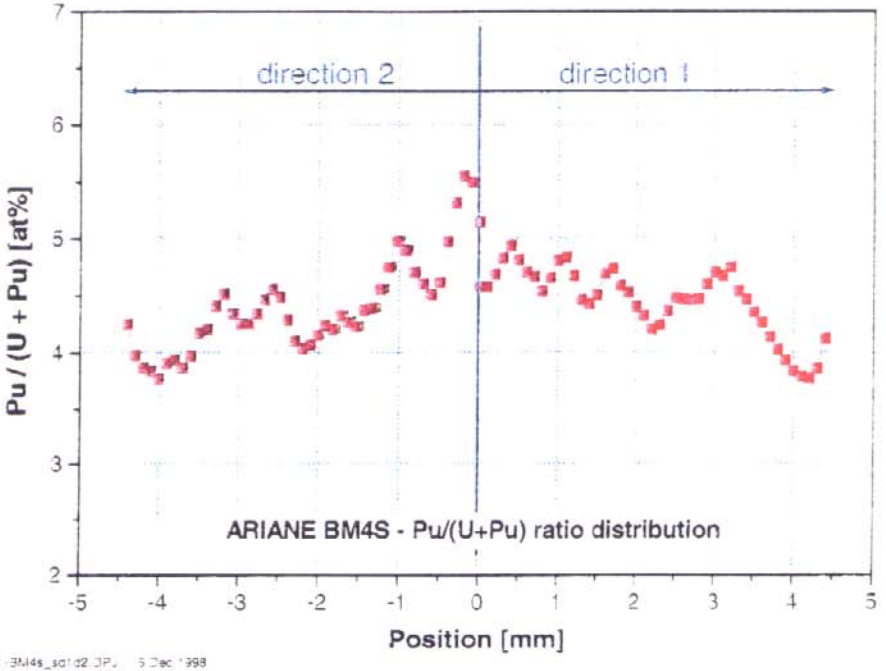


Figure 4-16 Sample BM4S. ^{241}Pu and ^{242}Pu distribution (relative to average concentration 1) along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



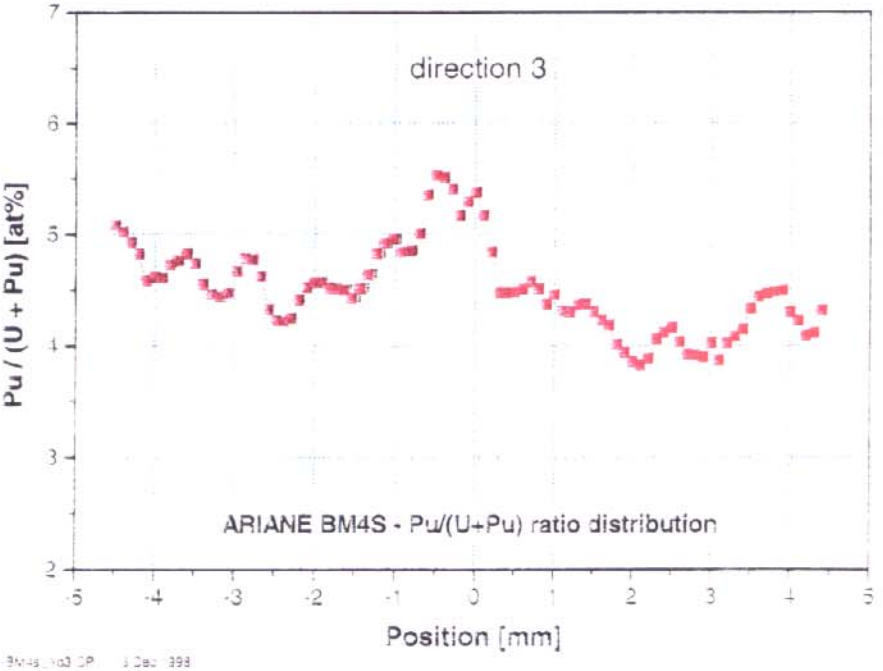
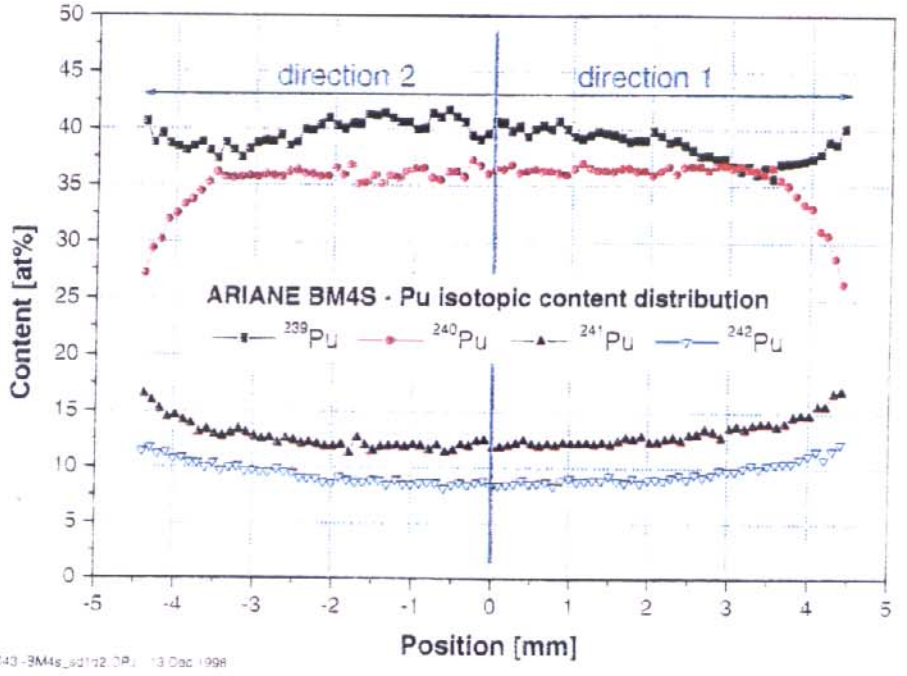


Figure 4-17 Sample BM4S, Pu/(U+Pu) ratio distribution along direction 1/2 (top) and direction 3 (bottom) according figure 3-2.



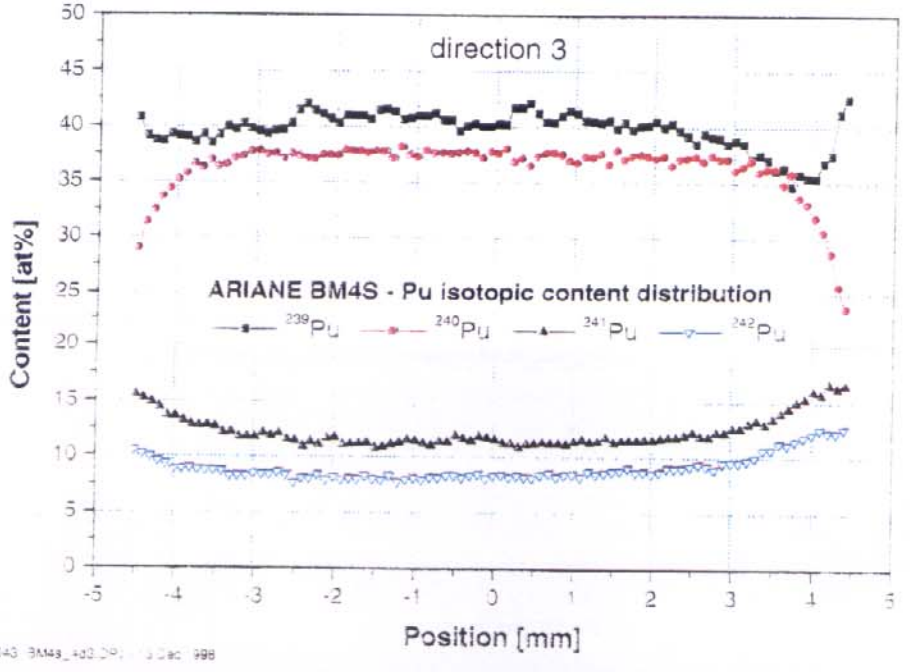
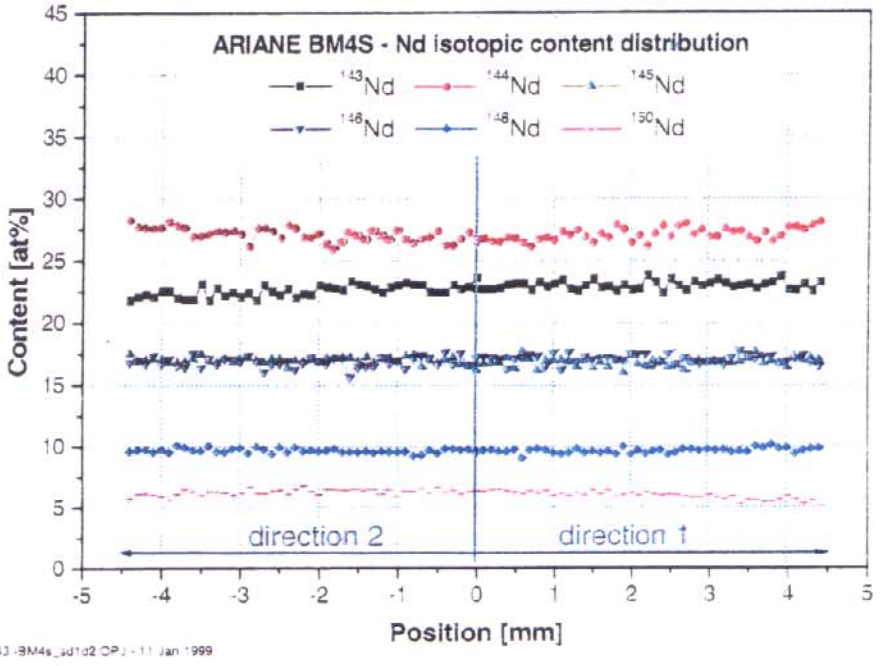


Figure 4-18 Sample BM4S. local isotopic Pu composition [at%] along direction 1/2 (top) and 3 (bottom) according to figure 3-2



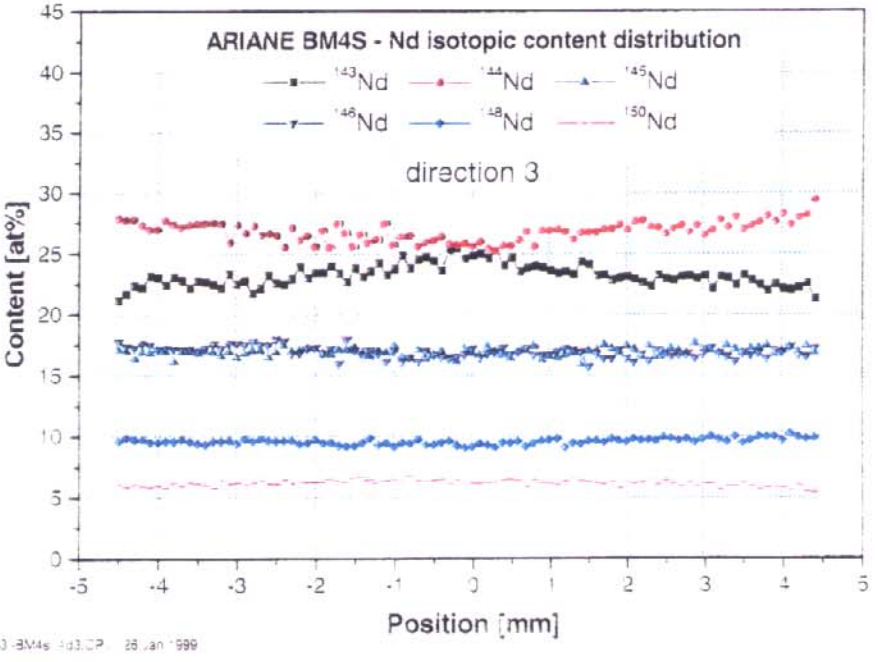
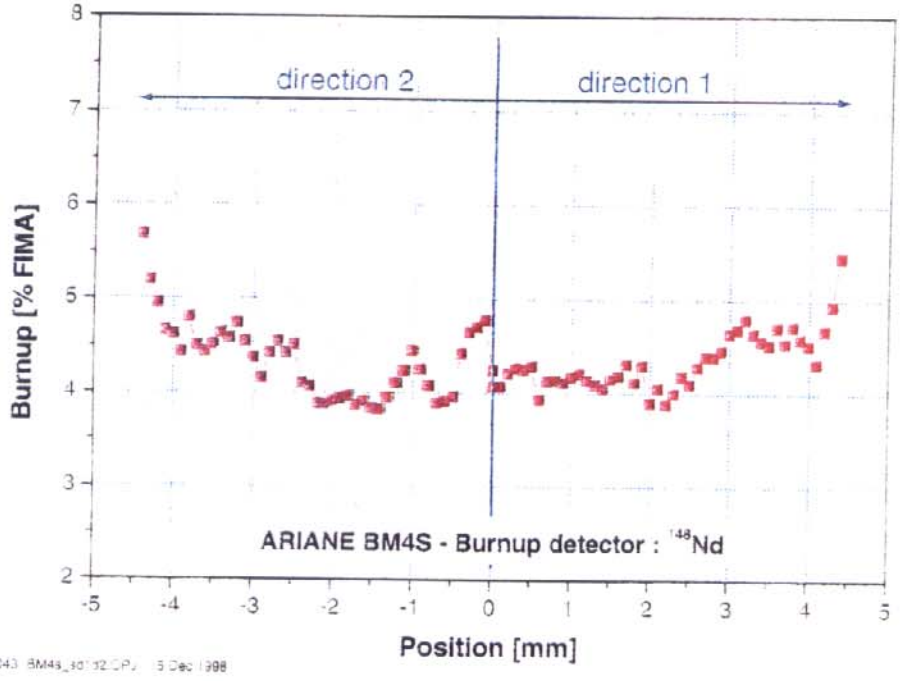


Figure 4-19 Sample BM4S, local isotopic Nd composition [at%] along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



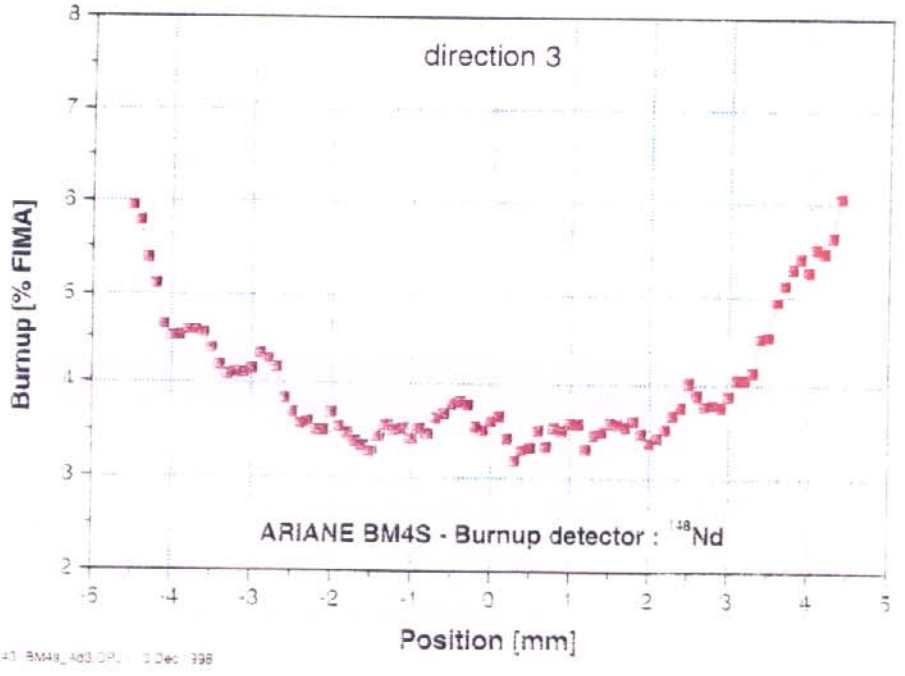
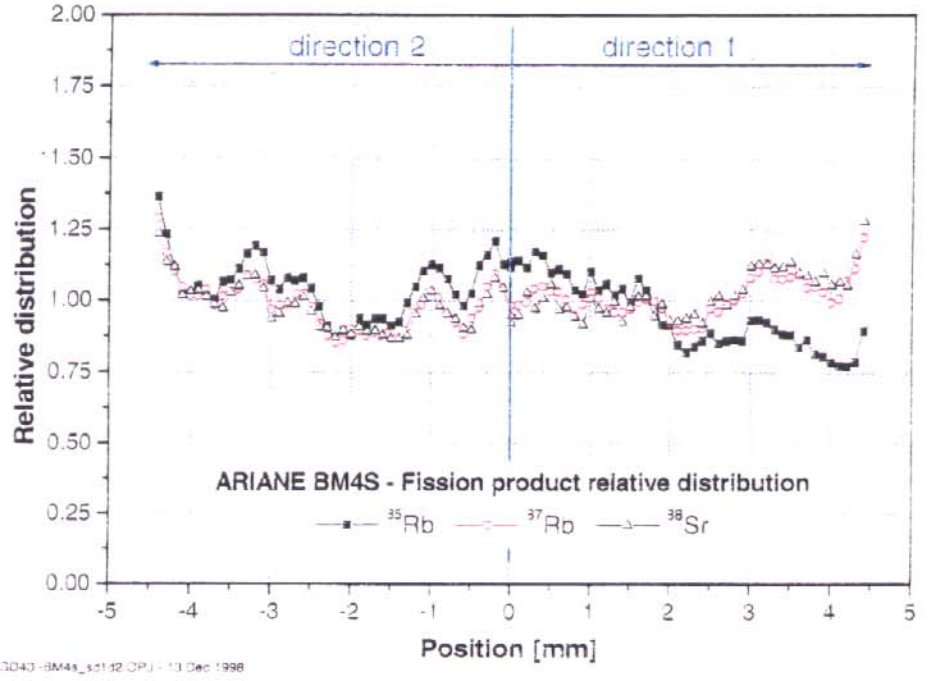


Figure 4-20 Sample BM4S, burnup distribution [%FIMA] along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



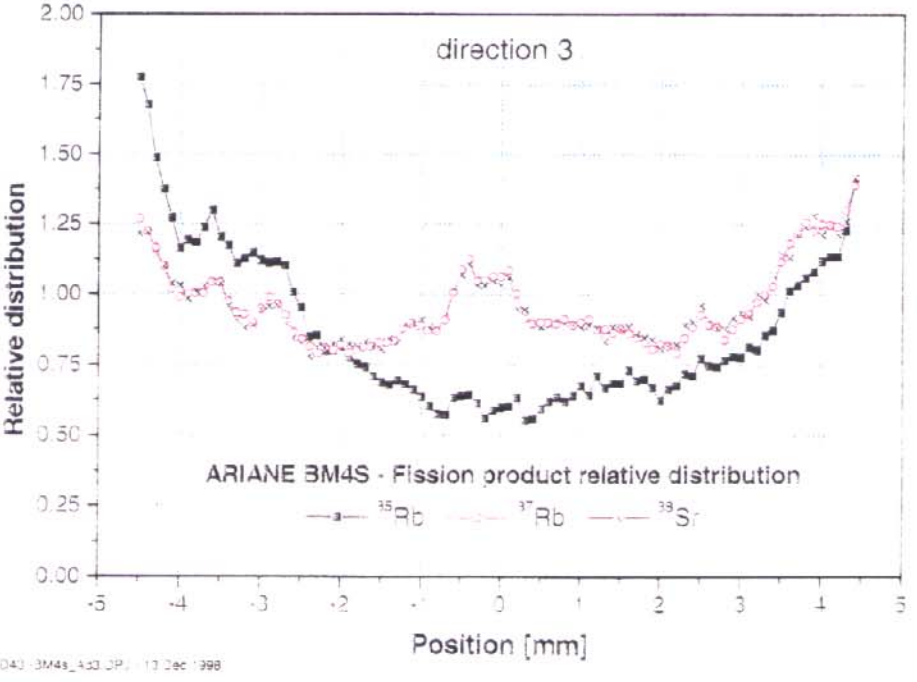
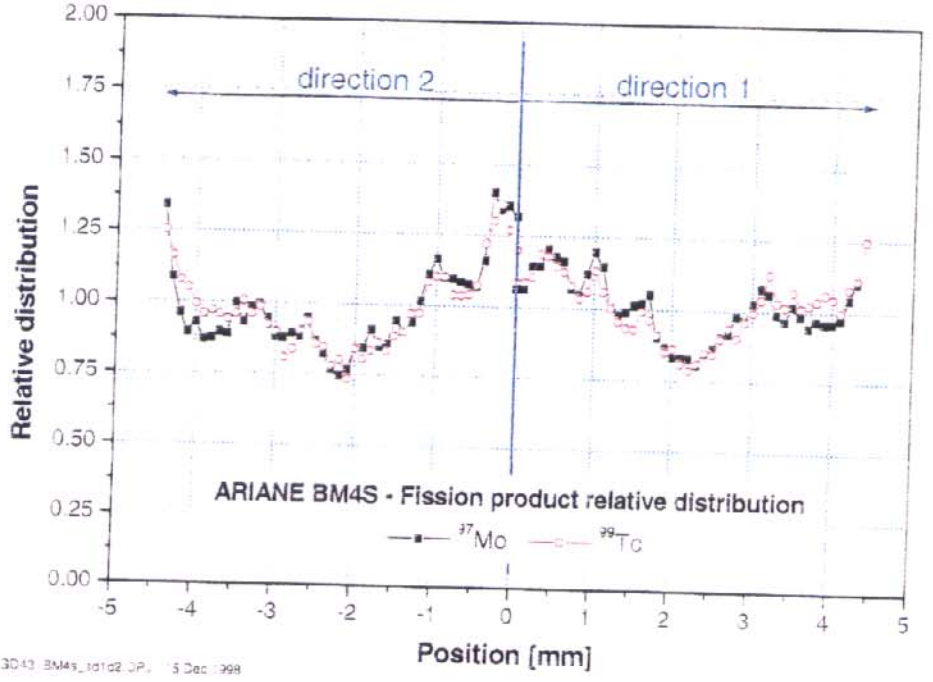


Figure 4-21 Sample BM4S, relative distribution of fission products ^{35}Rb, ^{37}Rb and ^{38}Sr normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



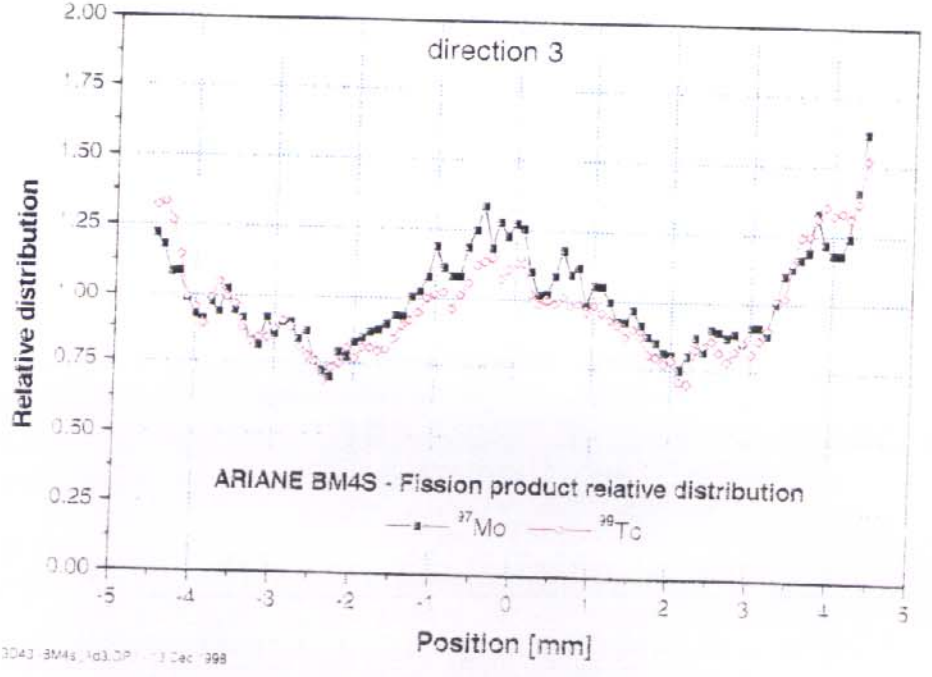
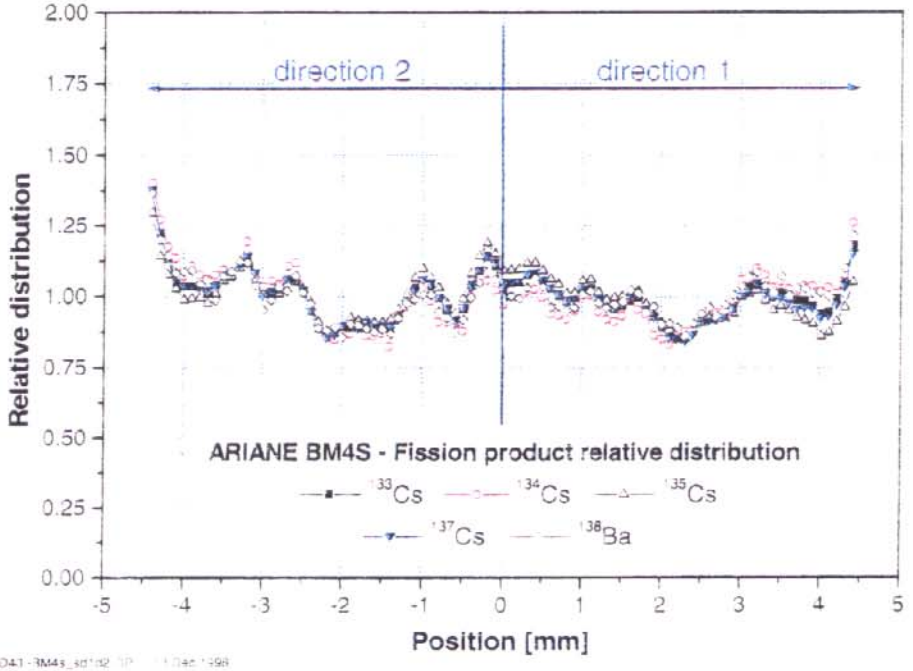


Figure 4-22 Sample BM4S, relative distribution of fission products ^{97}Mo and ^{99}Tc normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



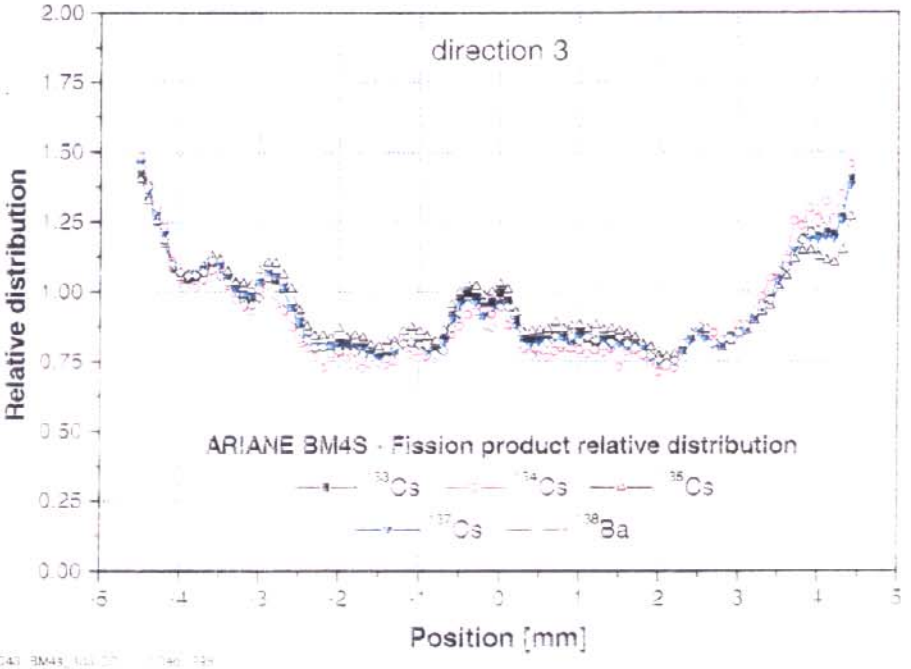
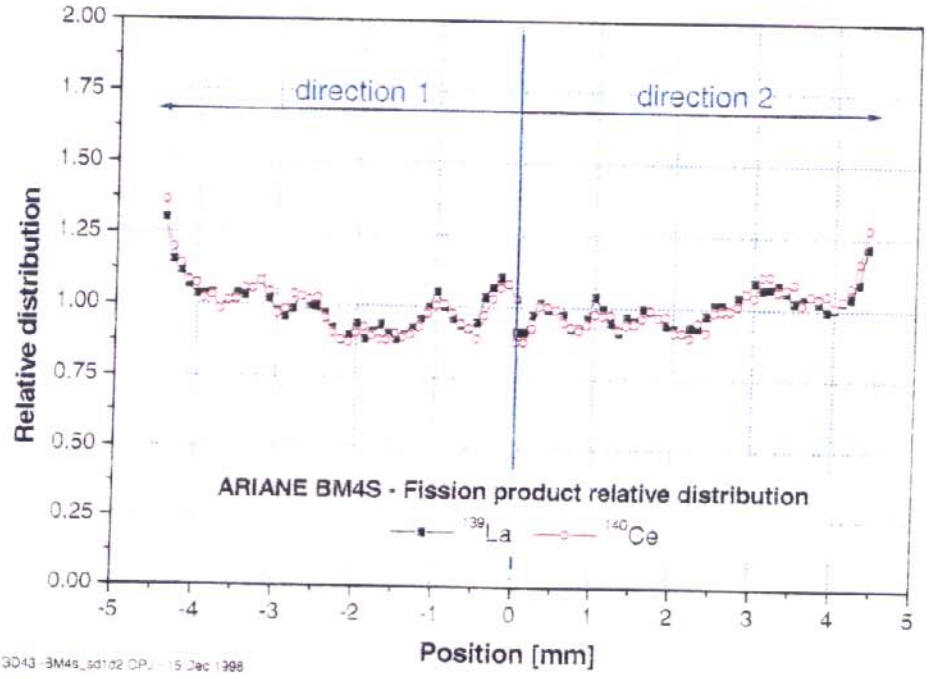


Figure 4-23 Sample BM4S relative distribution of fission products ^{133}Cs, ^{134}Cs, ^{135}Cs, ^{137}Cs and ^{138}Ba normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



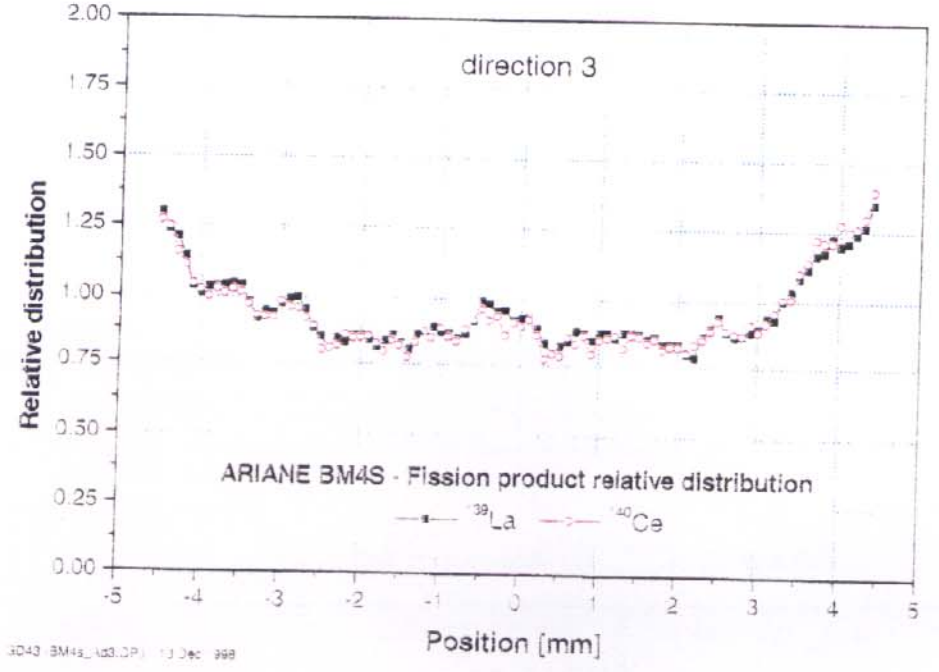
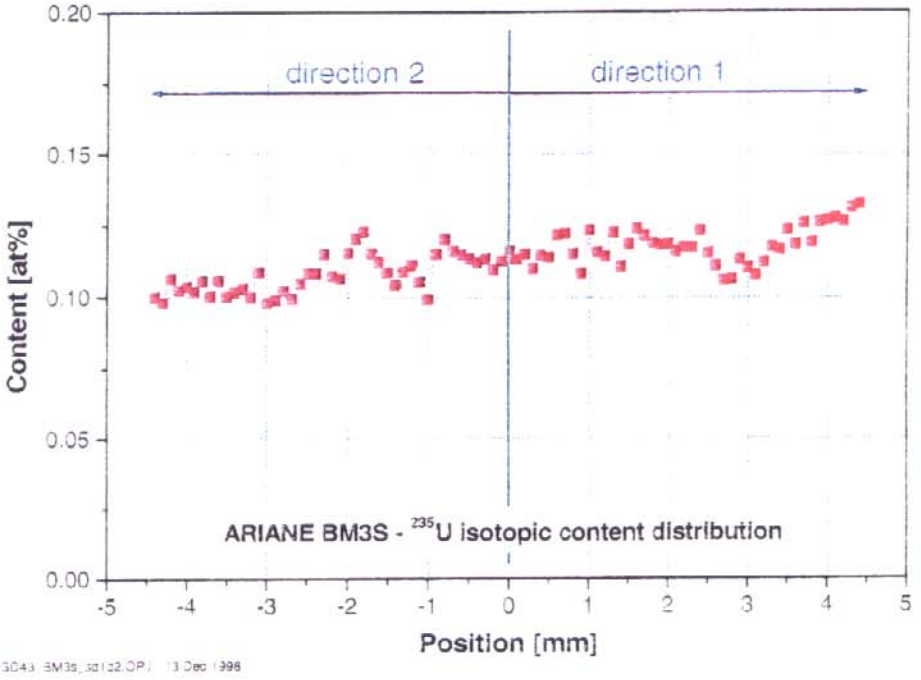


Figure 4-24 Sample BM4S, relative distribution of fission products ^{139}La and ^{140}Ce normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2



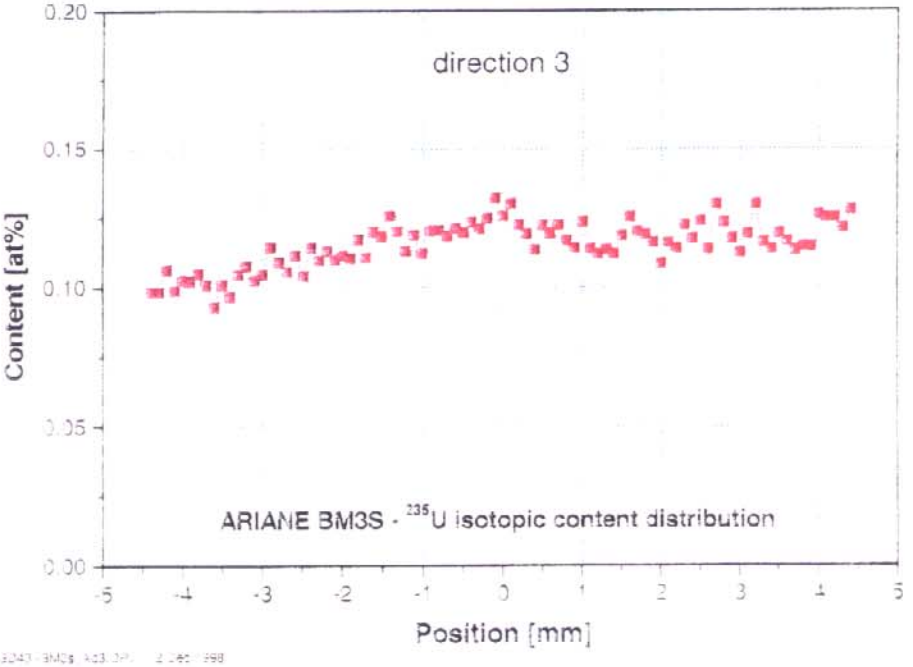
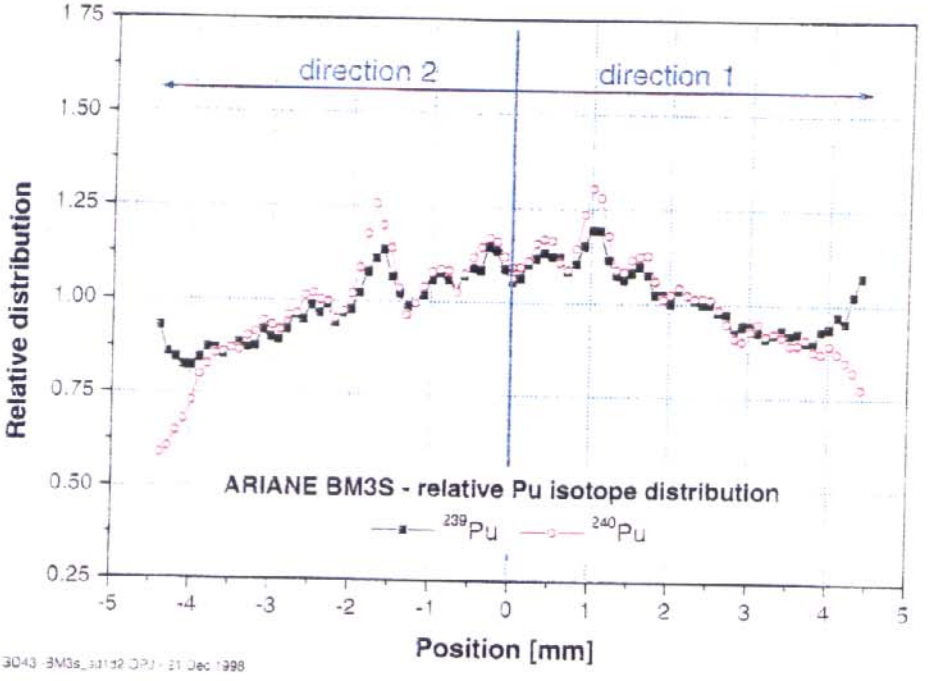


Figure 4-25 Sample BM3S, local isotopic ^{235}U distribution [at%] along direction 1/2 (top) and 3 (bottom) according to figure 3-2



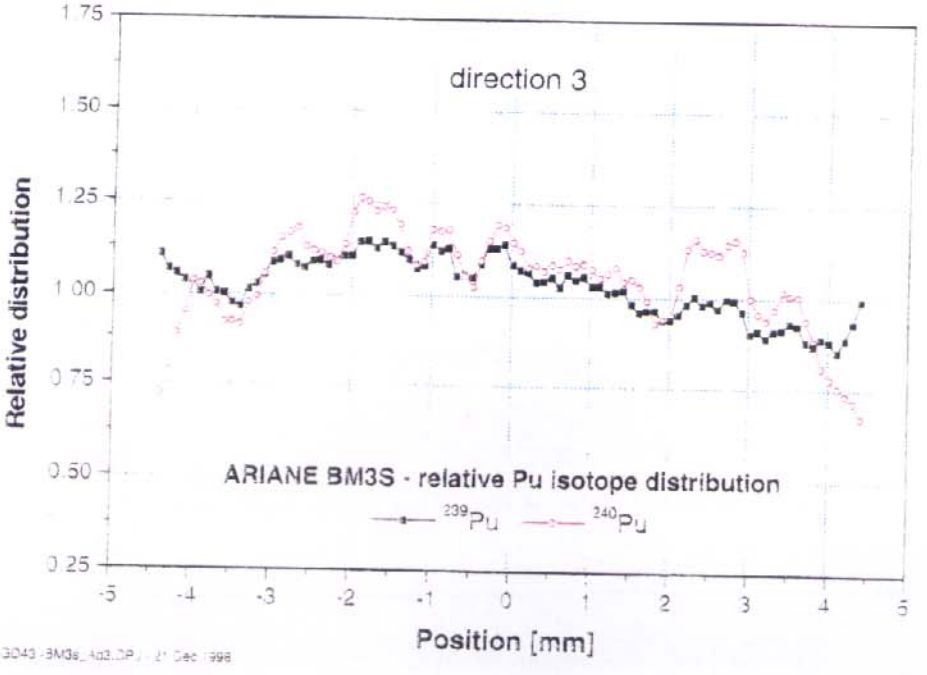
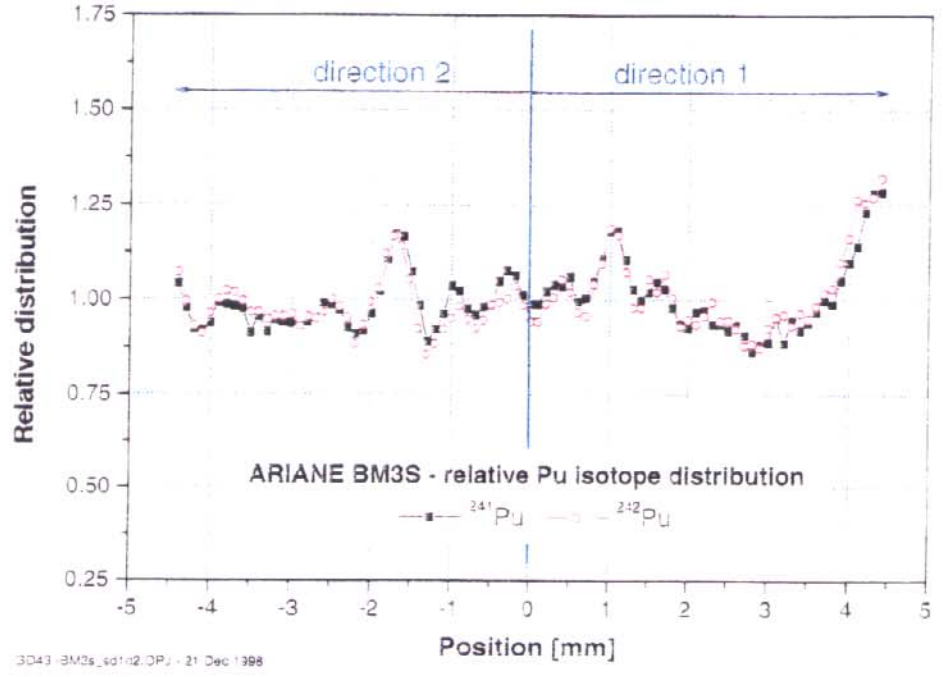


Figure 4-26 Sample BM3S, ^{239}Pu and ^{240}Pu distribution (relative to average concentration 1) along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



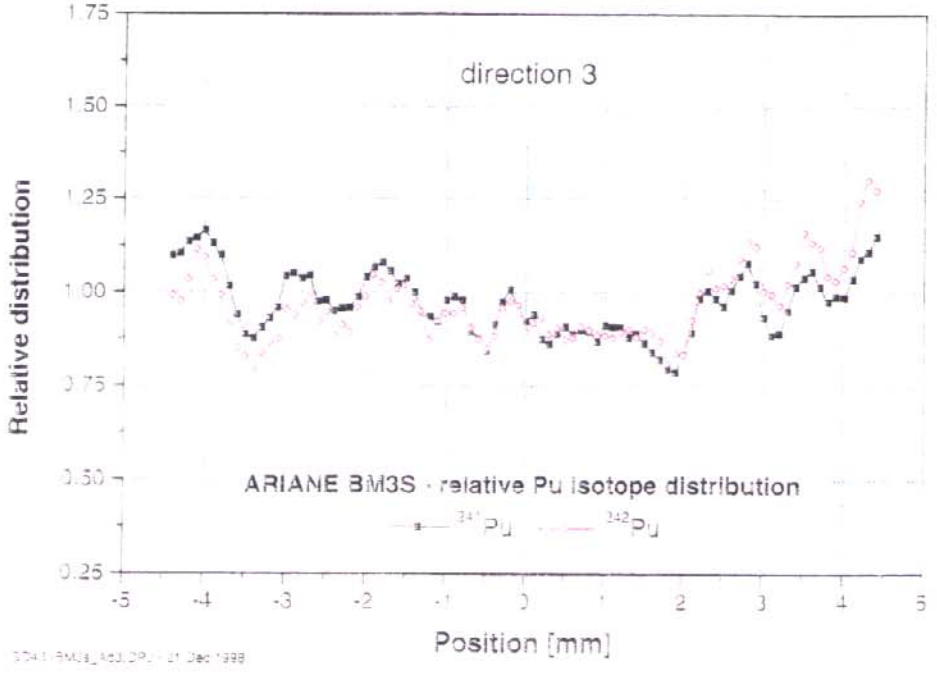
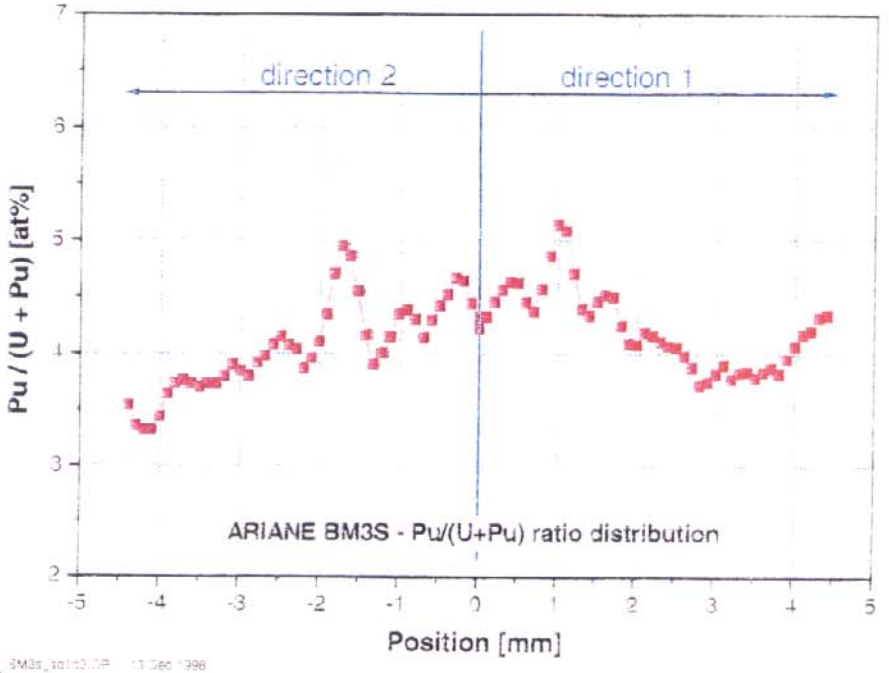


Figure 4-27 Sample BM3S, ^{241}Pu and ^{242}Pu distribution (relative to average concentration 1) along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



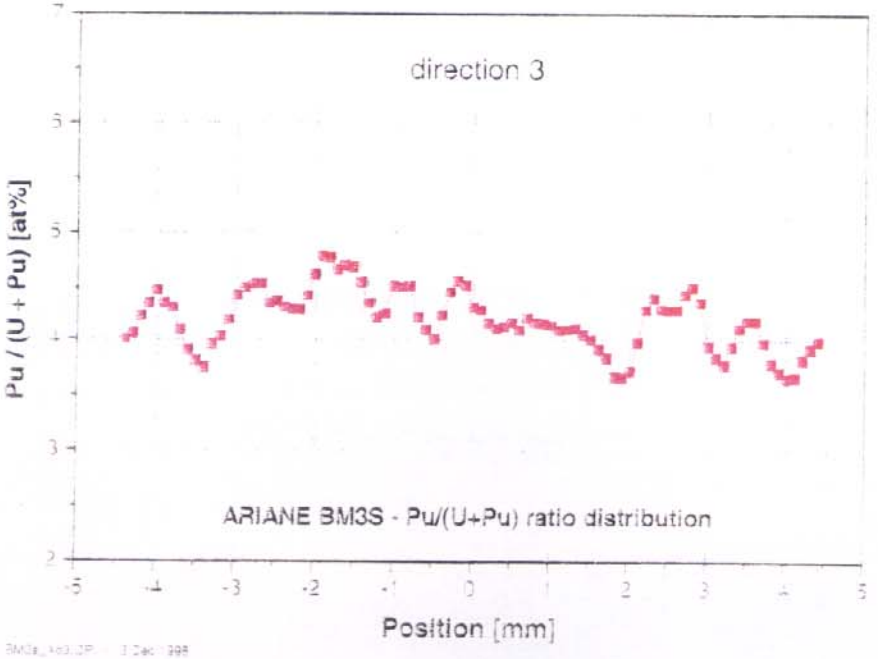
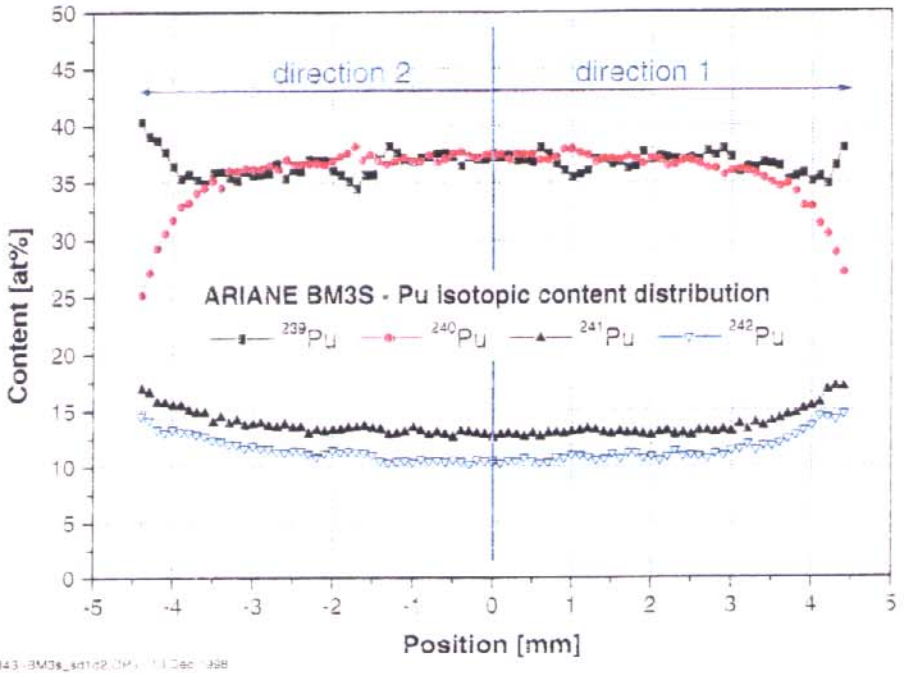


Figure 4-28 Sample BM3S: Pu/(U+Pu) ratio distribution along direction 1/2 (top) and direction 3 (bottom) according figure 3-2



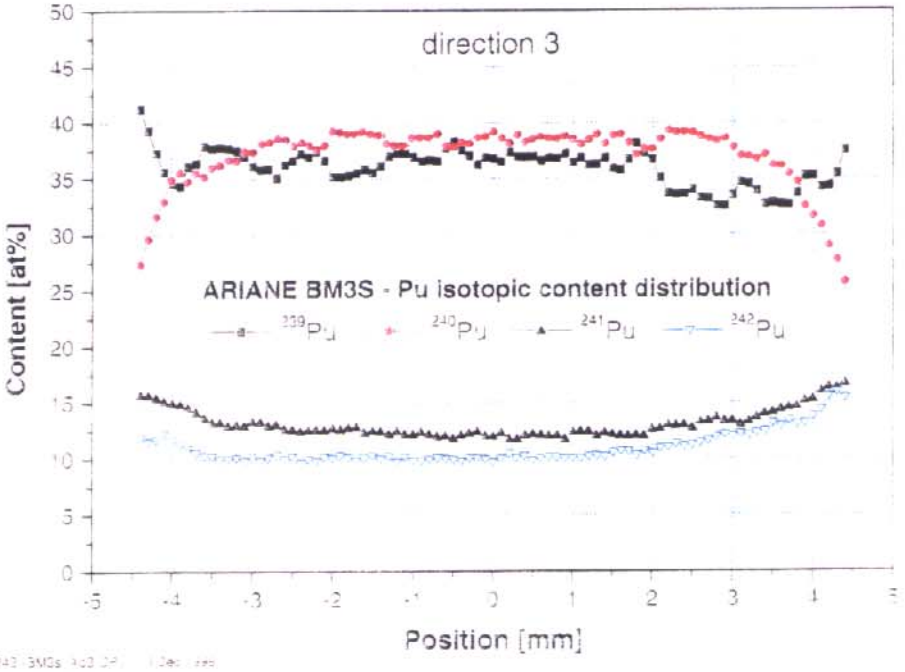
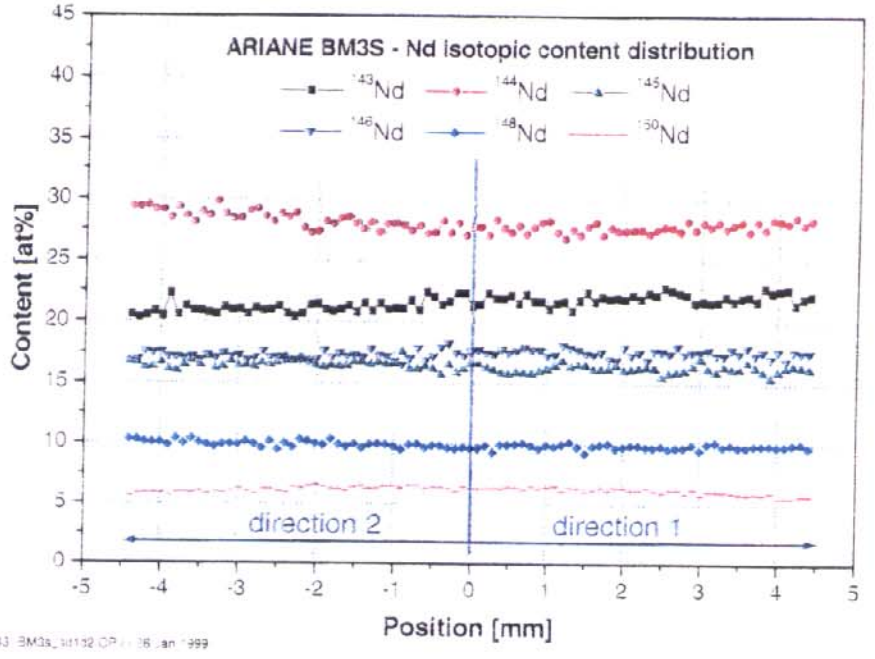


Figure 4-29 Sample BM3S local isotopic Pu composition [at%] along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



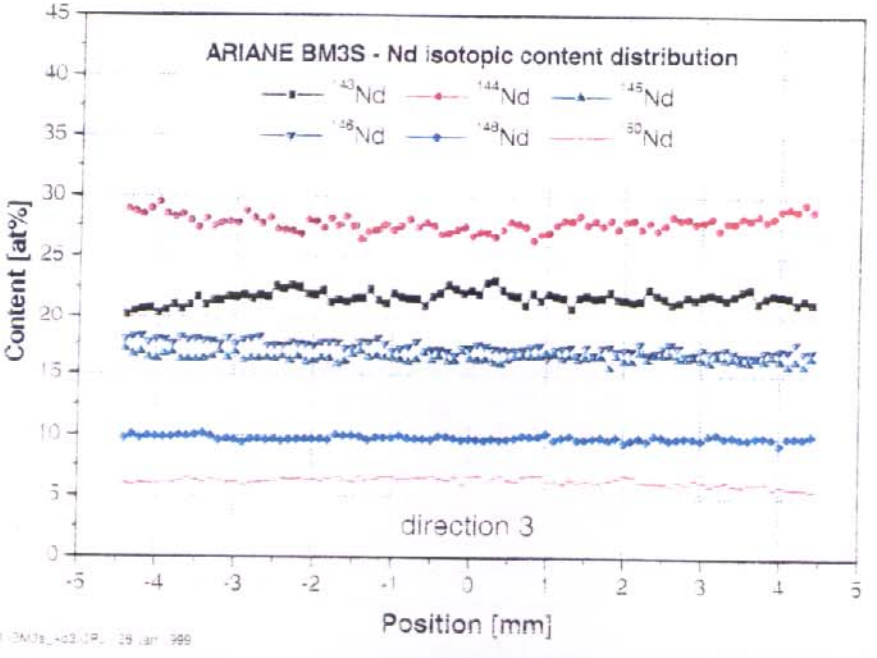
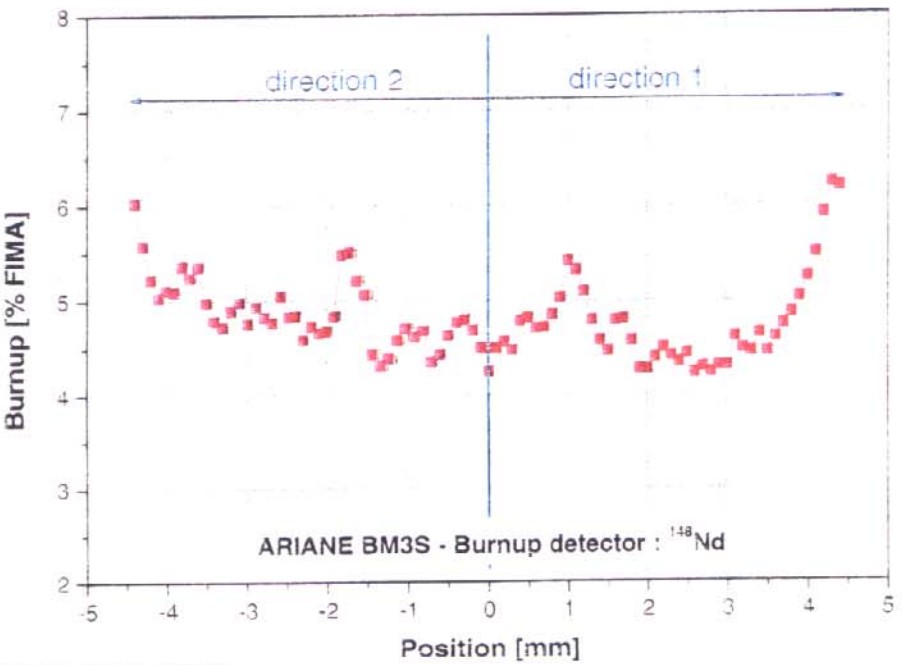


Figure 4-30 Sample BM3S, local isotopic Nd composition [at%] along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



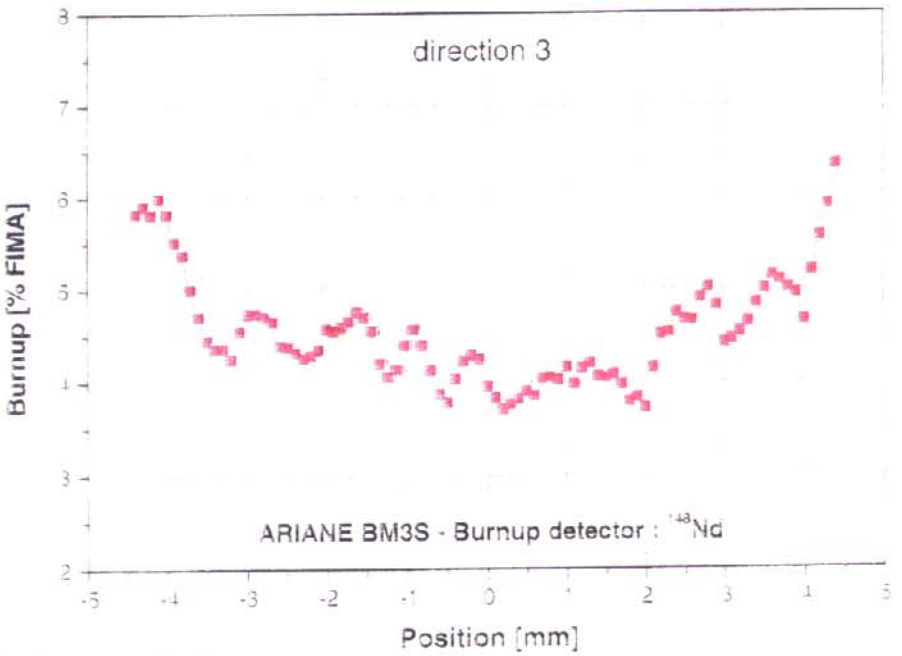
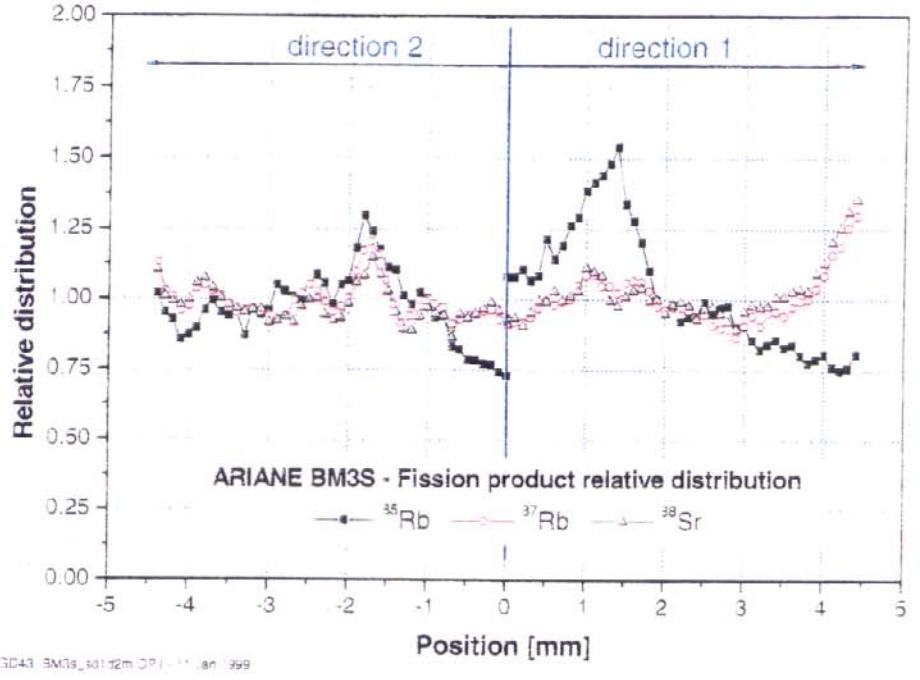


Figure 4-31 Sample BM3S, burnup distribution [%FIMA] along direction 1,2 (top) and 3 (bottom) according to figure 3-2.



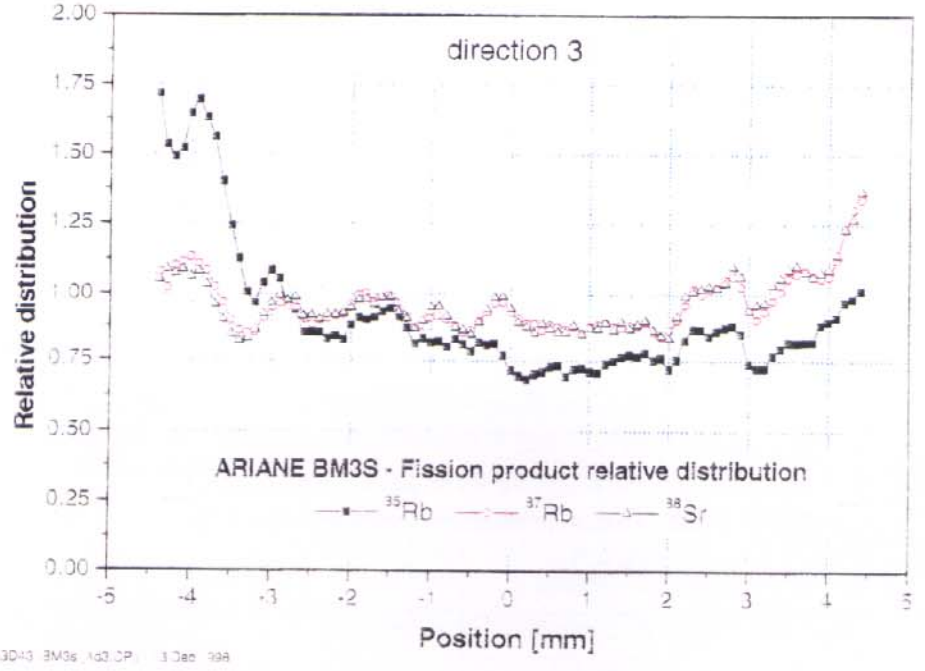
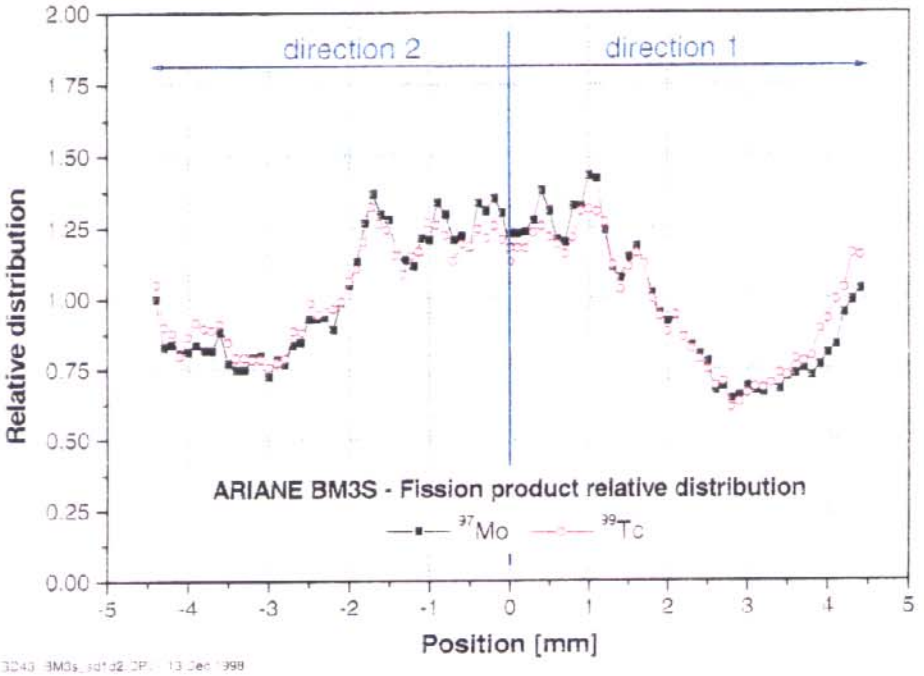


Figure4-32 Sample BM3S, relative distribution of fission products ^{35}Rb, ^{37}Rb and ^{38}Sr normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



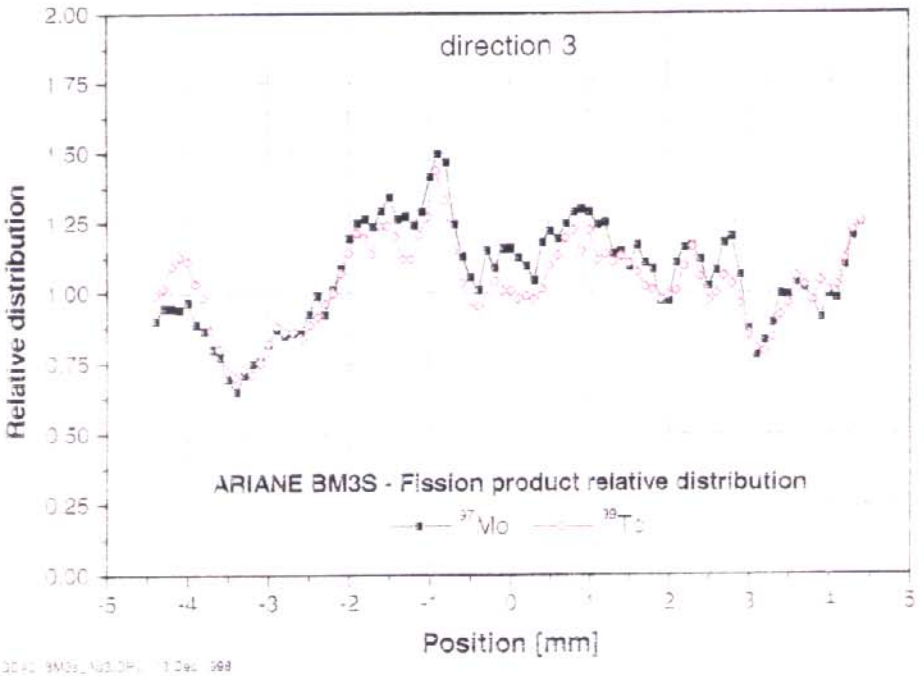
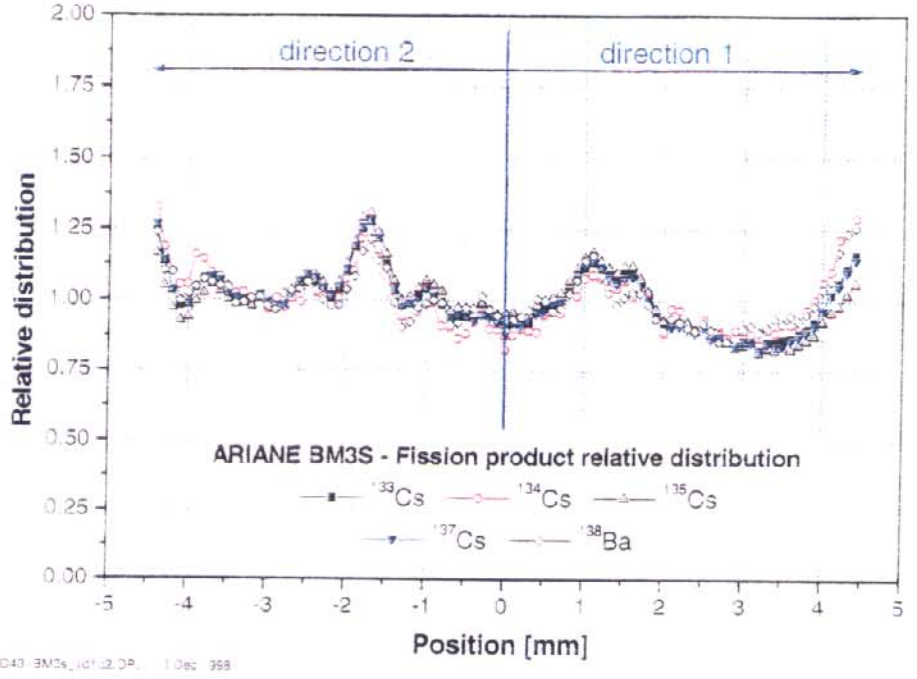


Figure 4-33 Sample BM3S, relative distribution of fission products ^{97}Mo and ^{99}Tc normalised to an average value of 1 along direction 1 2 (top) and 3 (bottom) according to figure 3-2.



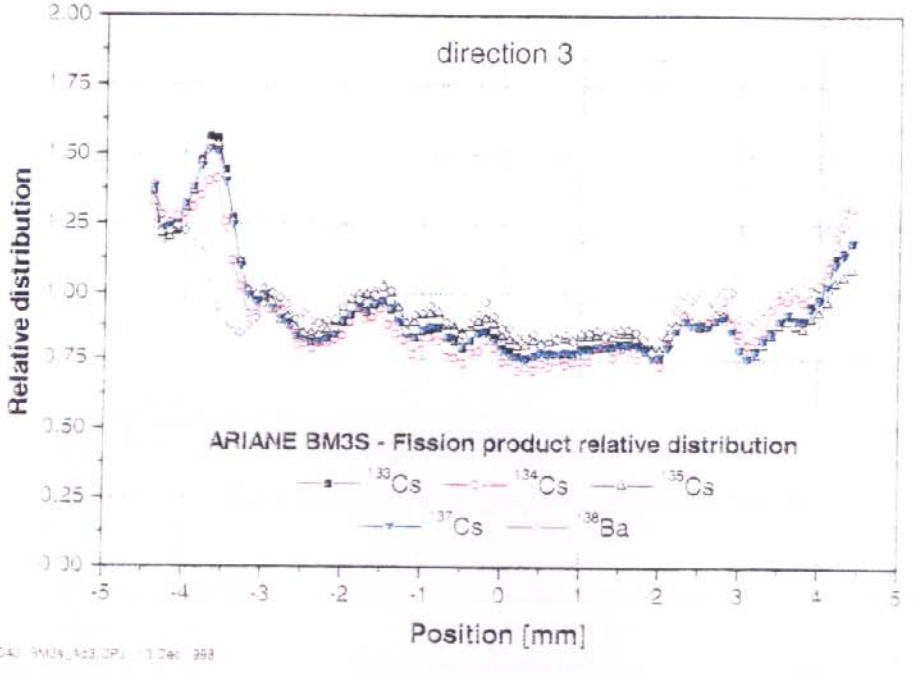
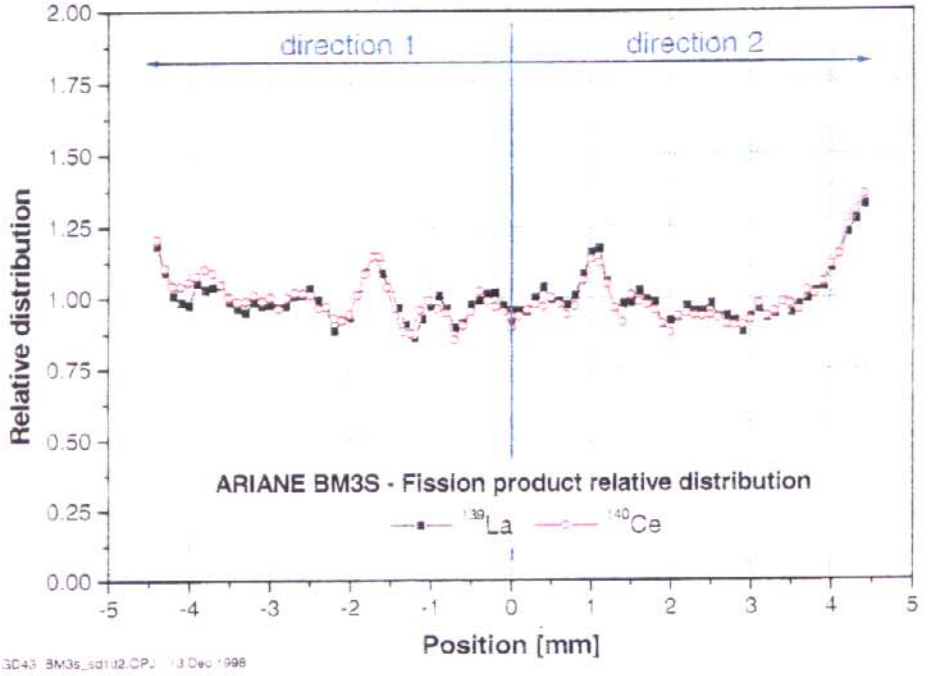


Figure 4-34 Sample BM3S, relative distribution of fission products ^{133}Cs, ^{134}Cs, ^{135}Cs, ^{137}Cs and ^{138}Ba normalised to an average value of 1 along direction 1/2 (top) and 3 (bottom) according to figure 3-2.



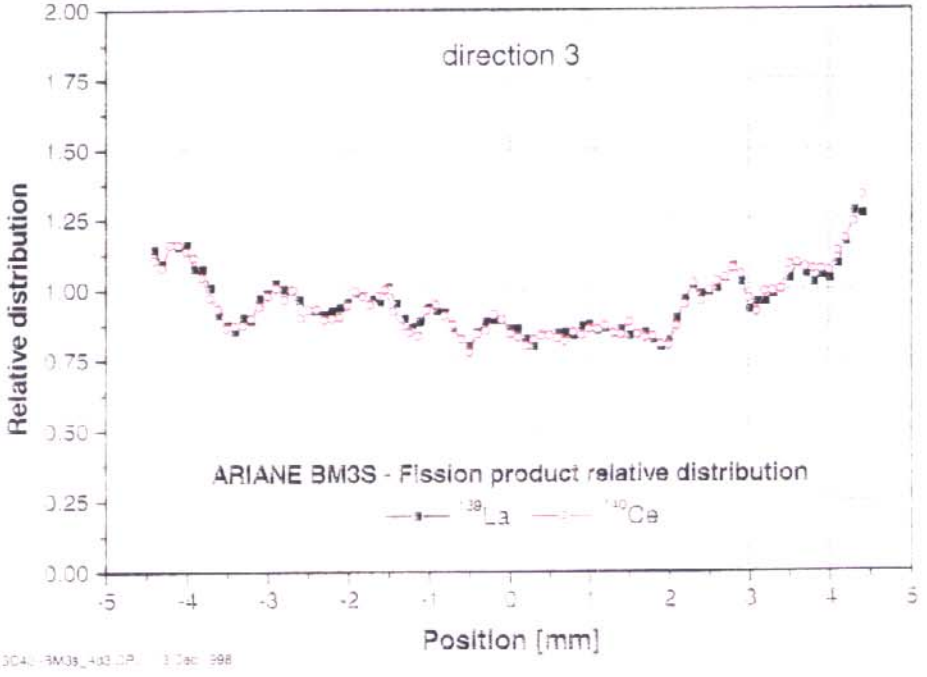


Figure 4-35 Sample BM3S, relative distribution of fission products ^{139}La and ^{140}Ce normalised to an average value of 1 along direction 1,2 (top) and 3 (bottom) according to figure 3-2.

5. Conclusion

Successful SIMS analysis have been performed on three specimens and neutronic effects based on radial nuclide measurements were demonstrated.

Central symmetry of the irradiation could be verified.

The double measurement method of the same direction combined with a complementary evaluation procedure is necessary to overcome difficulties in the data acquisition produced by the SIMS system geometry and poor conductivity of the fuel.

Local variation in the isotope profile can be produced by the fuel structure (cracks).

On a global view the same characteristics were found for the three different specimens.

The rim effect is clearly visible, in particular on the Pu isotope distributions and the burnup.

Finally it can be noted that the observed behaviours of the isotopes in the specimens are conform at what was expected for the burn-up and the low linear heat rate of the irradiation.

6. References

[1] Fax from Beat Wernli to Mr. P. van der Heyden, Ref. ARIANE/FAX/EXTENS1.DOC, April 4, 1996.

[2] Amendment to the Memorandum of Understanding (M.O.U), Ref. : 9501163/221 "A" Between PSI and Belgonucleaire for the "ARIANE" international program, January 10, 1997.

[3] B. Wernli, P. Schleuniger, H. Schweikert, R. Zumsteg, *"ARIANE - Programm : Schnittplan für 2 MOX-Brennstäbe"*, PSI technical report TM-43-95-29 (Rev. 1), October 30, 1995.

[4] Beat Wernli, ARIANE programme : *"Cutting scheme fo two additional burn-up samples and three samples for SIMS measurements"*, PSI technical report TM-43-96-39 (Rev. 1), October 9, 1996.

[5] B. Wernli, I Leopold, *"ARIANE : Radiochemical data"*, PSI Technical report TM-43-98-54.

[6] R. Restani, E.T. Aerne, A. Hermann, H.U. Zwicky, DOMO Campaign 1: *"SIMS and Radiochemical Analysis on BWR irradiated MOX Fuel"*, TM-43-93-14, DOM 93/47 (1993)

[7] R. Restani, E.T. Aerne, A. Hermann, S. Röllin, B. Wernli, DOMO Campaign 2 : *"SIMS and Radiochemical Analysis on BWR irradiated MOX Fuel"*, TM-43-95-25

[8] R. Restani, E.T. Aerne, M. Martin, *"DOMO-I-MOX fuel measurements with the updated A-DIDA-SIMS"*, PSI internal report: TM-43-95-22 (1995)

[9] H.U. Zwicky, E.T. Aerne, A. Hermann, H.A. Thomi, M. Lippens, *"Radial plutonium and fission product isotope profiles in mixed oxide fuel rods evaluated by secondary ion mass spectrometry"*, J. Nucl. Mat., 202(1993)65

[10] D. Gavillet, J. Dunn, R. Restani, M. Martin, E.T. Aerne, *"Irradiated fuel analysis by Secondary Ion Mass-Spectroscopy. **SIPLO** (SIMS Plotting program)."*, TM-43-96-27

[11] R. Restani, E.T. Aerne, D. Gavillet and B. Wernli; "*DOMO Campaign 3 : SIMS and Radiochemical Analysis on BWR irradiated MOX fuel*"; PSI internal report TM-43-96-19, August 1996

[12] M. Lippens, "*Reassessement of the identity of rods irradiated in assembly M109 and used in the framework of the programmes M109, ARIANE and FIGARO*", BN 9805422/221-"-"1, 9-7-1998.

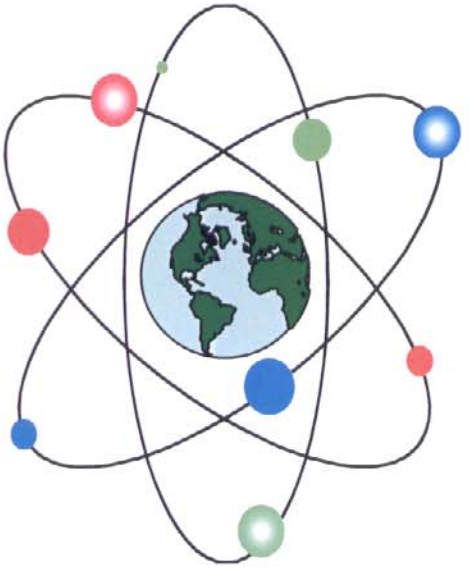
7. Acknowledgement

The authors are grateful to Mr. M. Gehringer for the expert specimen preparation. They thank also G. Ledergerber, B. Wernli and R. Restani for their critical review of the paper and their help in the interpretation of the results.

The authors are also very grateful to Mrs. Abeloos and Lippens from Belgonucléaire for their thorough review of the report and numerous comments.

AR 2000/15
BN Ref. 0000253/221
Rev. B

ARIANE
International Programme



Final Report

Issued December, 2000

BELGONUCLEAIRE
Avenue Ariane, 4 - 1200 Brussels.

	Type of document : Report	BN reference N° / File - « Rev. » - Page **0000253 / 221- « B » 1** Other reference : AR 2000/15
Client : ARIANE Participants		Author(s): D. BOULANGER M. LIPPENS

Project: ARIANE International Programme

Subject:

ACTINIDES RESEARCH IN A NUCLEAR ELEMENT

Final Report

Rev.	Date	Chrono Filing n°	Status	Typist's Initials	Initials	Visa N°1	Initials	Visa N°2	Initials	Visa N°3	Initials	Visa N°4	Initials	Visa N°5	Number of Pages
					Author		Verified by		Approved by		Q.A.		Issued by		
C															
B	Dec 2000	0100290	FIN	ND	BD		ML		BJ				HBe		59 + 216
A	May 2000	0002992	PREL	JS	ML		BD		BJ				HBe		40 + 220
--	Jan 2000	0000253	PREL	JS	ML		BD						BJ		158

Distribution : see ARIANE Distribution List
+ BN : Mrs Boulanger
Messrs. Vanderborck, Lippens, Basselier, Maldague, A. Renard

All industrial property rights and copyrights are reserved. Any communication, publication, reproduction, use of exploitation of this document or its content without prior written approval is prohibited. Any infringement of this rule entitles to claim damages from the infringer, withjout prejudice to any other right. .

BELGONUCLEAIRE S.A.
Avenue Ariane, 4 - 1200 Bruxelles
TVA : BE 403.126.258
RCB : 271.300
TEL : 32-2-774 05 11
FAX : 32-2-774 05 47

LIST OF MODIFICATIONS

DATE	REVISION	OBJECT
January 2000	-"-"-	Preliminary issue, to be completed
May 2000	-"A"-	Second preliminary issue, to be completed
Dec 2000	-"B"-	Final issue

NOTICE

* * *

PERSONNEL IN CONFIDENCE / NOT FOR PUBLICATION

* * *

All property rights and copyrights are reserved. Any communication or reproduction of this document and any communication or use of its content without explicit authorization of the ARIANE Programme Committee is prohibited. Any infringement to this rule is illegal and entitles to claim damages from the infringer, without prejudice to any other right in case of granting of a patent or registration in the field of intellectual property.

LIABILITY

* * *

This document was prepared by BELGONUCLEAIRE (BN). Neither BN nor any person acting on behalf of BN

(a) gives any warranty, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this document, or that the use of any information, apparatus, method or process disclosed in this document may not infringe third party rights, or

(b) assumes any liabilities with respect to the use of, or for damage resulting from the use of any information, apparatus, method or process disclosed in this document.

ARIANE INTERNATIONAL PROGRAMME

DISTRIBUTION LIST

SIEMENS (D)	:	Dr. G. Schlosser	2 copies
SCK•CEN (B)	:	Mr. P. D'hondt	5 copies
GNB (D)	:	Dr. R. Hüggenberg	2 copies
MHI (JP)	:	Mr. S. Abeta	2 copies
BNFL (UK)	:	Mr. C.M. Zimmerman	2 copies
TOSHIBA (JP)	:	Mr. Nakajima	2 copies
HITACHI (JP)	:	Mr. T. Mochida	2 copies
ORNL (USA)	:	Mr. R.T. Primm III	2 copies
NEL (JP)	:	Mr. H. Naito	2 copies
JRI (JP)	:	Mr. T. Kaneko	2 copies
NOK (CH)	:	Mr. G. Devillaz	2 copies
GKN (NL)	:	Mr. W.R. Van Engen	2 copies
PSI (CH)	:	Mr. C. Hellwig	2 copies
TRACTEBEL (B)	:	Mr. R. de Wouters	2 copies

TABLE OF CONTENTS

1.	**Chapter 1 : Introduction**	6
1.1	The ARIANE Project	6
1.2	Fuel selection and work matrix.	8
1.3	Selection of isotopes for analysis	11
2.	**Chapter 2 : Laboratory work**	12
2.1	Introduction	12
2.2	Sample cutting and dissolution	12
2.2.1	Fuel cutting	12
2.2.2	Dissolution	12
2.3	Dilutions, separations and measurements	17
2.3.1	SCK-CEN	17
2.3.2	P.S.I.	19
2.3.3	ITU	22
3.	**Chapter 3 : Radiochemical results**	24
3.1	General	24
3.2	Measurement results	24
4.	**Chapter 4 : SIMS Measurements**	28
4.1	Introduction	28
4.2	Measurement procedure and data processing	28
4.2.1	Procedure	28
4.2.2	Secondary Effects	29
4.2.3	Data processing	30
4.3	Results	32
5.	**Chapter 5 : Result Analysis**	36
5.1	Introduction	36
5.2	Experimental results uncertainty	36
5.3	Results cross-check and analysis – Recommended values	38
6.	**Chapter 6 : Conclusions**	52
References		54
Appendix		56
Tables		T1 to T186
Figures		F1 to F30

Chapter 1

Introduction

1.1. The ARIANE Project

The aim of the ARIANE project is to provide improved knowledge of the inventories of actinides and fission products in UO_2 and MOX fuels irradiated at various burnups for both PWRs and BWRs.

The project is justified by the necessity to predict the source term of actinides, fission and activation products in numerous nuclear areas, such as :

- The prediction of the fuel isotopic composition at various steps of the irradiation cycles and at the end of life for the definition of basic licensing data for $U0_2$ and MOX fuels;
- The current increase of fuel enrichment for power reactors with a possible re-evaluation of criticality licenses for transportation, storage and reprocessing of spent fuel based on burnup credit;
- The fundamental research programmes on actinides ;
- The necessity to improve the calibration of recent source term codes for high burnup conditions and for MOX fuel recycling scenario;
- The safeguards issues.

The project focuses on two objectives :

- Provide a large experimental data set regarding fuel selection for examination and the number of measured isotopes, some of them in very low concentration.
- Emphasize the accuracy of measurements by using various methods of analysis, and by exchanging aliquots between laboratories for cross-checking.

To fulfil these objectives, the project is centered along four axes :

- selection of suitable LWR irradiated UO_2 and MOX fuel samples. This selection includes UO_2 and MOX fuels irradiated in the Dodewaard (NL) BWR, MOX fuel irradiated in Beznau (CH) PWR and UO_2 fuel irradiated in Goesgen (CH) PWR.

- selection of three laboratories performing routine radiochemical measurements after fuel dissolution, each according to its own procedures of fuel analysis. Radiochemistry departments of the nuclear centres of SCK•CEN (B), PSI (S) and ITU (D) were selected for this programme. This selection is based on past experience of these laboratories in radiochemistry, on fuel on site availability, and on wish of the laboratory to participate to the ARIANE programme.

- exchange between laboratories of solid or liquid aliquots. These last ones are sampled from some dissolved fuel solutions prepared in source laboratories. The aliquots are submitted to a common programme of measurements of the same isotopes in an other laboratory.

- providing of neutronic characterisation of the selected fuel samples, with detailed power history and macrocell description allowing to generate accurate cross-sections for source term codes.

On this basis, the project has been launched end 1994 [1.1] with the participation of 15 organizations (Table 1.1) representing more than 20 different companies.

The analysis by radiochemical method covers the inventory of up to 49 different isotopes, grouped in the so-called "base" programme (39 isotopes) and the "TOP 25" programme (10 isotopes). In addition, the SIMS (secondary ion mass spectrometry) technique is used to characterize the radial distribution across pellets of various selected isotopes.

The next sections, 1.2 and 1.3, give the characteristics of the different fuels examined (type, reactor, burnup, ...) and the selection of isotopes chosen for analysis.

Difficulties were encountered in the course of the project as regards the reliability of some results from PSI and ITU laboratories. For that reason, a proposal of project reorganization was made in Spring 1998 [1.2], with withdrawal of some samples and analysis from the initial programme, and introduction of new samples and a revised analysis programme.

Section 1.2 provides details on the initial scope of work and on the new work definition officially decided in Spring 1999 [1.3].

Chapter 2 deals with the description of the laboratory work, including sample preparation and analysis methods. Chapter 3 is devoted to the presentation of the results.

The results presented correspond to the work agreed on within the project after its redefinition in Spring 1998 and aceptance on Spring 1999. These results, are those validated by the project, i.e. considered as being reliable and sufficiently accurate to be useful.

The results of SIMS analysis are given in Chapter 4.

The results interpretation is summarized in Chapter 5 in terms of fuel burnup evaluation, inter-laboratory comparison and general evaluation of result validity.

1.2. Fuel selection and work matrix.

Fuels irradiated in Beznau-1 PWR (Switzerland), Goesgen PWR (Switzerland) and Dodewaard BWR (the Netherlands) and available at PSI (Würenlingen Switzerland), ITU (Karlsruhe, Germany) and SCK•CEN (Mol, Belgium) respectively, were selected for analysis in ARIANE project. Their main characteristics are summarized in Table 1.2.

MOX PWR fuel comes from BELGONUCLEAIRE fuel fabrication for BEZNAU 1-reload 1. Special attention was given to assembly M109 irradiated during 6 cycles to a discharge burnup of 42 GWd/tM. Ten rods were extracted from assembly M109 and sent to PSI in the framework of different programmes.

Rods E11 and G5 (named by position in assembly) were selected for examination in the framework of ARIANE programme. They have respectively the highest burnup (close to a water hole) and the lowest burnup (fully surrounded by MOX rods) in the assembly. Calculations give burnups of 42.6 and 38.7 GWd/tM for rods E11 and G5 respectively [1.4]. From each of these rods, two samples are cut, BM1, BM3 respectively at maximum burnup level, and BM2-D, BM4-D respectively at about 2/3 of maximum burnup (Figure 1.1).

In the course of the post-irradiation examinations of the 10 rods of assembly M109, numerous experimental results showed discrepancies with values expected on the basis of the fabrication and irradiation data. A detailed analysis of the reason for discrepancies concluded that the rod names used during their analysis did not match the assembly positions these rods were supposed to come from.

This results from a misinterpretation of the reference mark position identifying the relative rod position in the cask used to transport the rods from Beznau to PSI [1.2, 1.5]. Consequently, the rods from which samples BMX were cut are D3 and B6 instead of E11 and G5 respectively, with burnups of 41.7 and 43.1 GWd/tM. Rods D3 and B6 are close to a water hole, B6 being also adjacent to the zone of intermediate Pu content and near the assembly border.

This confusion in rod naming led to a redefinition of the work performed at PSI as well as in the companion laboratories for ARIANE project.

The redefinition of the ARIANE work in 1998 was also the result of the poor reliability of some experimental results [1.2]. The work matrix defined before May 1998 is given at Table 1.3 a. The redefinition of the work led to matrix given at Table 1.3 b.

The early test matrix includes the work defined at the beginning of the project and an extension of this initial work as discussed during the third programme committee Meeting at the end of 1996 [1.6].

The initial work was mainly devoted to radiochemical analyses of the so-called "Base" isotopes (see section 1.3.). At the end of 1996, the programme was extended to include inventories of "TOP 25" isotopes and SIMS analysis. These measurements were not foreseen in the initial programme. The extension includes also new samples (DM3, DM4) from the Dodewaard reactor.

The new work matrix of mid 1998, redefines the work according to the following changes for Beznau samples :

- rods D3 and B6 are almost identical from neutronic and burnup points of view. Therefore sample BM2-D is withdrawn. Samples BM1, BM3 and BM4-D are kept to support SIMS results. Aliquot of sample BM1 is also analysed at SCK•CEN to keep "full isotopes programme" of the first work matrix and validate part of the early PSI work made on the fuel samples from M109 assembly.

- new samples BM5 (BM5') and BM6 are introduced to compensate for loss of information on assembly M109. They come from one segmented MOX fuel rod K7 fabricated by BELGONUCLEAIRE and irradiated in Beznau PWR during 6 cycles in assembly M308, reaching a burnup of 52 GWd/tM (peak pellet 59 GWd/tM). BM5 (BM5') and BM6 are cut from maximum and 2/3 of maximum burnup levels respectively (see fig. 1.1).

The UO_2 fuel irradiated in PWR comes from a SIEMENS fabrication for the Goesgen plant. Two samples GU1 an GU2 were proposed for analysis. They come from assembly 12-40 from which rods were extracted after 2 and 4 cycles, to give samples GU2 and GU1 with respective burnups of 28.8 and 54.4 GWd/tM.

Due to difficulties encountered at ITU and PSI for the analyses, their work on samples GU1 and GU2 was withdrawn from the initial matrix. The work on the aliquot from GU1 at SCK•CEN proceeded and remains included in the matrix redefined in 1998. To compensate for the lack of information on GU1 and GU2, SIEMENS proposed to examine two new samples, GU3 (GU3') and GU4, coming from a rod also irradiated in Goesgen plant, to 53 GWd/tM. Samples GU3 (GU3') and GU4 are cut from maximum and 2/3 of maximum burnup levels respectively.

BWR fuel comes from the Dodewaard plant. Segmented UO_2 and MOX fuel rods fabricated by Japan Nuclear Fuel and BELGONUCLEAIRE respectively, were irradiated during 4 and 5 cycles, reaching a peak pellet burnup of 55.6 GWd/tM.

BWR neutron spectra being sensitive to local void fractions, samples were selected at different axial levels along core height. Two MOX (DM1, DM2) and one UO_2 (DU1) samples were selected at the beginning of the programme. Samples DM1 and DU1 sustained a void fraction of 50-54 v %, achieving after 5 cycles a burnup of 55.6 and 54.4 GWd/tM respectively. Sample DM2 (void fraction 2-6 v %) reached 33.5 GWd/tM after 4 cycles .

Two additional MOX samples, DM3 and DM4 (burnup of 46.5 (38.1) GWd/tM in 4 (5) cycles and a void fraction of 53-56 (60-63) v % for DM3 (DM4)), were introduced in the programme extension decided at the end of 1996.

Experimental difficulties encountered at ITU obliged withdrawal of the ITU work on the Dodewaard (and Beznau) aliquots from the project. The work scope in the companion laboratories remained unchanged.

The guidelines used to set the first test matrix were :

- Source laboratory, defined as place where solid fuel is available :
  - makes the fuel chemical dissolution,
  - prepares aliquots sent to companion laboratories,
  - makes agreed analysis on its own dissolution and on the aliquots received from companion laboratories.
- Performance of the "base programme" is made in source laboratory on all the dissolved samples.
- Performance of "TOP 25 programme" is made on samples chosen for their representativity of the fuel type, reactor and neutron spectrum types and burnup extremes.

- Aliquots are determined so as to have the three laboratories analysing at minimum its own fuel (e.g. BM1 for Beznau / PSI, GU1 for Goesgen / ITU, DU1 for Dodewaard / SCK•CEN). "Base" and "TOP 25" programmes were generally performed on aliquots, except iodine, the stability of which is not guaranteed during transport.

The new work matrix decided in 1998 is based on the same guidelines, with however a reduced scope :

- New samples are examined at PSI (BM5 and BM6) and ITU (GU3 and GU4) – BM5 and GU3 have aliquots (BM5' and GU3') analysed at SCK•CEN. These aliquots are transported as solid material and dissolved at SCK•CEN

- Some work made on aliquots at PSI (DM1, DU1) and SCK•CEN (BM1, GU1) in the framework of the early programme is kept in the new matrix.

1.3. Selection of isotopes for analysis

The more relevant basic Actinides, minor Actinides and Fission Products were chosen for analysis. They are grouped in "Base" and TOP 25" programmes aiming at determining the various isotope concentrations at pellet level.

The "Base Programme" includes 39 isotopes (Table 1.4). It covers the two main actinides (uranium from mass 234 to 238, and plutonium from 238 to 244). The most relevant minor actinides (Np237, Am from 241 to 243, Cm from 242 to 245) are also analysed.

The selection of fission products results from their ability to evaluate the burnup (Nd, Cs), their high neutron cross section absorption (Sm, Eu, ..) or their long term radioactivity (I129, Tc99,...).

The "TOP 25 Programme" (Table 1.5) results from a wish to extend the range of analysed actinides (U232 of very low content) and Fission Products. The latter are lanthanides (Pm, Gd of strong neutron absorption) or metallics requiring special procedures of dissolution and techniques of measurements.

Finally the programme involves the determination of the radial distributions across pellet of several isotopes of interest (actinides, fission products). Secondary Ion Mass Spectrometry (SIMS) technique available at PSI was selected for this determination. The list of proposed isotopes (Table 1.6) is a compromise between the list of isotopes proposed for radiochemical analysis (Tables 1.4 and 1.5) and what is reasonably achievable by SIMS technique. Isotopes like Mo97, Ce140 or some isotopes of elements like Rb, Sr, Ba and La are "easily" evinced in SIMS spectra.

* * *

Chapter 2

Laboratory work

* * *

2.1. Introduction

Chapter 2 deals with a description of the laboratory work, starting from sample cutting till final experimental result. This includes sample dissolution, solution handling, use of standards, element separation and measurement methods.

Most of the methods used by SCK•CEN, PSI and ITU laboratories are today standard in the field of radiochemistry. A detailed description of these methods is however given in [2.1., 2.2. and 2.3.] and summarized hereafter in order to emphasize the methodology followed to obtain the requested results, allowing appreciating of their quality.

2.2. Sample cutting and dissolution

2.2.1. Fuel cutting

Fuel pieces from source rods or segments are cut from mid pellet to mid pellet. Cut pieces have generally a length of three pellets. The mid pellets cuts allow to increase the representativity of collected caesium in fuels operating at high power in which caesium volatilizes at pellet centre and reaccumulates in cracks and at pellet interfaces.

2.2.2. Dissolution

2.2.2.1. Preamble

The fuel chemical dissolution has for objective to prepare liquid solutions for the elements measured later on, generally by mass spectrometry (MS). The fuel is dissolved in boiling HNO_3. Most of the actinides and fission products present in the solid fuel are found in the solution obtained, except iodine which volatilizes and some fission products which precipitate during irradiation and are found in a small undissolved residue.
To match the objectives of the ARIANE project, special procedures of dissolution have been set up to trap iodine released during first dissolution.

The residue is also dissolved following specific conditions to obtain the elements of interest in liquid solution.

These dissolution steps are made systematically in the three laboratories, with small nuances between them. These operations are described hereafter.

2.2.2.2. SCK•CEN

2.2.2.2.1. First dissolution and iodine trapping

The description of the dissolution process is taken from reference [2.1]. It is specific of dissolution of sample DU1. The description however illustrates the general process and is applicable to a large extent to all ARIANE samples.

> *« Figure 2.1 shows the system used in the hot cell for the first dissolution of the nuclear fuel sample. The cut fuel piece is carefully weighed and brought into the reaction vessel. 1 ml 0.05M NaI is added (as carrier for the iodine in the fuel sample). 90 ml 8M HNO_3 is brought into the separatory funnel. One end of the system is closed with a waterlock and when the vacuum pump installed at the other end is started, it creates a small underpressure in the total system. The 90 ml 8M HNO_3 is slowly added through the separatory funnel. The heating mantle is started to let the solution boil. After 1 hour, another 1 ml 0.05M NaI solution is added through the separatory funnel as carrier for the iodine in the fuel sample. By heating and underpressure, the dissolver off-gases pass gently through both the 4M NaOH trapping solutions. Iodine is collected according to the reaction :*
>
> $3I_2 + 6OH^- \rightarrow IO_3^- + 5I^- + 3H_2O$. *This system is continued for another 5 to 6 hours. Heating is then stopped and after ± 1.5 hour also the pump is stopped. Overnight, the solution cools down.*
>
> *Next morning the system is opened and the « fuel »-solution filtered. The filtrate is brought into a carefully weighed 250 ml flask. The fuel cladding is carefully rinsed with a 1M HNO_3 solution and dried in the air. This cladding is weighed and the difference in weight « cut fuel sample minus fuel cladding » determines the amount fuel into solution (incl. residue). The filter is also rinsed and put back into the reaction vessel. All rinsing solutions are added to the filtrate in the 250 ml flask. 50 ml (10M HNO_3 + 0.1M HF) solution is added to the filter in the reaction vessel. This solution is again boiled under reflux during 5 to 6 hours. After cooling down overnight, the remaining residue is filtered and washed. The filtrate and the washing solution are both added to the first solution in the 250 ml flask. 1M HNO_3 solution is added to a final volume of 250 ml and the solution is carefully weighed.*

This V_0 solution is diluted by weight consecutively into V_1, resp. V_2 solutions. The radioactivity of 1 ml of the V_2 solution is low enough to be brought out of the hot cell for the consecutive separations and analyses.

The residue is dried in the air and carefully weighed.
Both the alkaline solutions of the iodine trapping device are mixed together and also carefully weighed »

2.2.2.2.2. Dissolution of the residue

The dissolution of the residue is made by alkaline fusion with NaOH and Na_2O_2.

« The filter + residue are brought into a carefully cleaned Ni crucible and covered with a Ni lid. The filter is slowly « dry-ashed » in an oven, first at 300°C for 1h followed by 1.5h at 500°C. After cooling down, the dry reagents (± 4g NaOH and ± 4g Na_2O_2) are added to the residue. The temperature of the oven is slowly increased to 550°C over 1 hour time and this final temperature is maintained during 20 minutes. During this fusion, the crucible is shaked now and then in order to guarantee a good contact between residue and reagents.

After cooling down, the solidified melt is leached with 150 ml demineralised water in a 400 ml beaker. Once the melt is dissolved, the Ni crucible is taken out of the alkaline solution and carefully rinsed with demineralised water. This rinsing water is added to the solution. The alkaline solution is then acidified with 30 ml aqua regia. This solution is filtered and the beaker is rinsed with demineralised water. Both filtrate and washing solution are collected in a carefully weighed 250 ml flask. Demineralised water is added to a final volume of 250 ml and the solution
($V_{o\text{-}res}$) is weighed. The efficiency of dissolution is checked preliminary with « cold » tests and by gammaspectrometry of the residue before and after dissolution.
The $V_{o\text{-}res}$ solution is further diluted by weight in order to reduce the radioactivity to a level which is low enough (for 1 ml) to be brought out of the hotcell for consecutive separations and analyses. »

2.2.2.3. PSI

When volatile products (e.g. iodine) have to be collected, the dissolution is made in 2 steps. The first dissolution is performed under air flow that collects volatile products. The undissolved residues from this first step are separated by filtration, and dissolved in a high pressure container.

2.2.2.3.1. Dissolution under air reflux.

2.2.2.3.1.1. Description of apparatus

The apparatus is a slightly modified SCK•CEN type (Figure 2.1). It consists of a 2-neck flask, connected to an air flow cooling system, and to a separatory funnel. The flask is heated by means of a controlled heating mantle. A small vacuum pump draws the gas, that is given off from the solution, through 3 wash bottles and an absolute filter. The 2 first wash bottles are filled with 30 ml 4M NaOH, in order to collect the iodine gas. The 3rd wash bottle which remains empty, protects the filter and the vacuum pump from spatters of liquid. Another wash bottle (water lock) is located before the funnel. It allows to visually adjust the air flow, and prevents the iodine gas to flow in the wrong direction.

2.2.2.3.1.2. Procedure

The sample, including fuel and cladding, is weighed, then transferred to a flask with 8M HNO_3 and NaI (as carrier for the iodine in the fuel sample).

The flask is heated for an hour at 130°C by means of a heating mantle. Some more iodine is then added ; the flask is heated for one hour at 150°C, then for four hours at 170°C. Finally, the solution is cooled down overnight.

2.2.2.3.2. Separation of the residues

After the dissolution step, the empty cladding and the insoluble part of the fuel are removed from the fuel solution. Whereas the cladding can be removed mechanically, a filtration is necessary to separate the insoluble residues.
For this purpose, the fuel solution (including the cladding) is poured from the 2-neck flask into the filtering system. The empty cladding is removed, rinsed carefully, and dried. After weighing, it is kept in an aluminium box till the end of the programme.

When the filtering is finished, the filter is removed from the flask, dried overnight, and weighed. The mass difference before and after filtration determines the amount of undissolved residues. The fuel concentration in the flask is calculated from the total amount of fuel in solution, and from the total amount of solution in the flask.

2.2.2.3.3. Dissolution of the undissolved residues

The insoluble residues are weighed, either together with the filter, or removed from the filter and put in a vessel. They are transferred to a quartz glass vessel, with an acid mix of 2 parts HCl and 1 part HNO_3; per mg of substance to be dissolved, 1 ml of acid mix is added.

The vessel is placed inside the high pressure container, which is then closed. The container is heated in an aluminium heating block at 180°C for 4 hours, after what it is cooled down to room temperature before opening.

2.2.2.4. ITU

Dissolution procedure at ITU is similar to those of SCK•CEN and PSI.

2.2.2.4.1. First dissolution

After cutting, the fuel sample fuel + cladding is weighed and transferred to a dissolution vessel containing 100 ml 6M HNO_3 and 1 ml 0.05 M NaI (as iodine carrier and internal standard). The dissolution proceeds for about 150 min at 90-95°C and 6-8 mbar below normal pressure (pressure in the hot cell).

After cooling to about 30°C, the solution is filtered through a 1 µm glass filter into a plastic beaker. About 200-300 µl solution remain in the dissolution vessel after filtration. The remaining solution is checked for any visible residue in the filtrate. This solution is then again filtered through a 0.2 µm PVDF (polyvinylidenfluoride) membrane filter into a 100 ml measuring glass. Weight losses in this filtration are accounted for. They yield losses of 0.2-0.5 %.

A small amount of 4M HNO_3 is added to make the solution 100 ml. The weight of this mother stock solution is measured after this addition.

2.2.2.4.2. Iodine trapping

To collect iodine, two in-line washing flasks filled with approximately 100 ml 4M NaOH solution are connected to the dissolution beaker. The fuel is dissolved as described above. After dissolution, the 100 ml 4M NaOH solutions in the two washing flasks are collected and weighed separately. Both solutions are measured for iodine.

2.2.2.4.3. Residue handling

The glass filter is washed 4 times with : 1) 25 ml 4M HNO_3 in the dissolution vessel, 2) 50 ml 4M HNO_3 in a glass beaker where most of the washing solution is transferred back to the dissolution vessel, the rest collected and centrifuged in a sample tube, 3) 50 ml 0.1M HNO_3 where the washing solution is this time pumped back and forced through the filter, 4) 20 ml deionized water, this solution is collected and centrifuged to obtain any remaining residue. The glass filter is then dried in air at 110°C and weighed to check for any remaining residue.

The glass beaker containing the washing solution from the third washing is placed in a sonic bath for about 5 min., the solution transferred to a sample tube and then centrifuged.

The dissolution beaker, containing cladding, residues and 4M HNO_3 from the washing of the glass filter is placed in a sonic bath for about 5 min. The solution is collected in the glass beaker and centrifuged. This procedure is repeated twice with 70 ml 0.1M HNO_3.

The glass beaker is dried with Kleenex paper tissue and weighed before and after rinsing.

The cladding is washed, dried and weighed, yielding the weight of the dissolved fuel without cladding.

2.2.2.4.4. Dissolution of residue.

The collected residue is homogenized with a glass pin in a plastic beaker. After this, about 25-30 mg residue and a $HCl/HNO_3/HF$ solution (9/1/0.2) are transferred to a Teflon dissolution beaker and placed in a pressure container for dissolution. The dissolution proceeds for 240 min. at 180°C, yielding normally a clear solution without traces of undissolved remaining residue. The solution is then transferred to a 50 ml measuring glass and diluted to 50 ml with 4 M HNO_3. The stock solution obtained is weighed.

2.3. Dilutions, separations and measurements

2.3.1. SCK•CEN

2.3.1.1. Main solution processing

The element content and isotopic composition are generally obtained by Thermal Ionisation Mass Spectrometry (TIMS) coupled to the Isotopic Dilution (ID) technique.

This technique allows to determine the concentration of an element by measuring the change in the ratio of (at least) two isotopes of the element of interest, induced by the addition of a spike, i.e. a known amount of the same element with a different isotope ratio of the same isotopes, to a weighed aliquot of a sample. With the known isotopic composition of the sample, the spike and blend, and the known amounts of sample and spike, the concentration of the element of interest can be calculated. Since only isotope ratios in the different materials are measured, its follows that sample treatment or recoveries of chemical separations need not to be quantitative once isotopic equilibration after spiking has been achieved. Also, variability of chemical separation recovery is generally not important.

Before performing MS, numerous separations are needed in order to obtain « clean » solutions containing the relevant elements only and from which interfering isobars have been removed.

The flowchart of analysis followed at SCK•CEN is given at Figure 2.2. It summarizes the procedure of analysis of the main solution Vo. After the addition of an appropriate amount of the different spikes and tracers to aliquot D, both solutions C (for Isotopic Analysis (IA)) and D (for Isotopic Dilution) are processed simultaneously and in parallel.

After a Redox cycle, U and Pu are first separated on a Dowex column from the other elements (fission products (FP) + Rare earth elements (REE) + Am + Cm). Ce is then separated. The details of the following successive separations are schematized at Figure 2.3.

Elements not measurable by TIMS, or measured in complement to TIMS, are determined by α spectrometry (Pu238, Cm242, Cm244), γ - spectrometry (Np237, Am241, Cm243, I129, Ru106, Sb125) and scintillation (Pm147, Sr90). These measurements allow also to verify the absence of interference in TIMS measurements (e.g. absence of Cm242 (measured by α spectrometry) when measuring Am242m by TIMS).
In the course of the programme, the method used for the measurement of Np237 and I129 (γ-spectrometry) was replaced by ICP-MS technique, more sensitive, using external calibration with matrix matched standards.

Low concentration elements like Tc99 (base programme) and U232, Mo95, Ru101, Rh103 and Ag109 (TOP 25) are analyzed by ICP-MS technique.

Separation methods were first developed and tested for the metallic elements but afterwards, a more direct approach was chosen, as follows :

- measurements are performed by ICP-MS on unseparated solutions; the statement "no isobaric interference" is tested
- external calibration is applied, using matrix matched standards

2.3.1.2 Residue solution processing

The elements contained (partly) in the residue are Mo, Tc, Ru, Rh, Ag and Sb were measured by ICP-MS technique, except for Ru-106 and Sb-125, for which gamma spectrometry is used.

2.3.1.3. Iodine solution processing.

The description of I129 determination - given in detail elsewhere [2.1] - is summarized hereafter. I129 determination is obtained by heterogeneous isotopic exchange on a precipitate of AgI using I125 as tracer. A known amount of I125 tracer is added to a carefully weighed amount of sample.
After successive additions of AgI, Na_2 S_2O_3 and Na_2S, with appropriate handling and exchange time, one obtains an NaI solution which is characterized by gamma spectrometry on I125 and I129.

The gamma spectrometry chain efficiency is controlled by measuring an I129 solution standard.

The I129 concentration in the sample is then obtained, using the I125 separation yield.

The overall efficiency of iodine in first dissolution is known - by chemical knowledge - to be > 99,9 %. The efficiency of iodine trapping in NaOH is determined in separate tests.

Gamma spectrometry is performed on the iodine trapping solution after fuel dissolution, to evince the eventual presence of other fission products. Negligible amounts of Ru106, Sb125, Cs134, Cs137, Cs144, Eu154 and 155 were found (concentrations IS/MS $< 5\ 10^{-4}$).

2.1.3.4. Thermal Ionisation Mass Spectrometry.

The thermal Ionisation Mass Spectrometry (TIMS) is the reference technique for the determination of the isotopic composition of an element. For a TIMS analysis, first a µg amount of sample is evaporated on a source filament. Mounted in the source housing of the instrument, this filament is electrically heated under vacuum. The sample evaporates and electrons generated by another filament ionise the atoms. The ions are extracted by an extraction lens and a collimator focuses the ion beam to the entrance of the MS. The MS consists of an electric sector (to filter the ion energies) and a magnetic sector (to separate different mass – to – charge ratios). At the end of the MS, the separated ions are detected by Faraday cups or a Daly detector.

To avoid possible isobaric interference during measurement, the elements of interest are separated from interfering elements prior to analysis.

On a regular basis, certified isotopic standards are measured, allowing control of isotopic fractionation and mass bias corrections.

2.3.2. PSI

2.3.2.1. General

The main equipment for the analyses of most of the nuclides is a High Pressure Liquid Chromatography device (HPLC, Dionex) coupled to an Inductively Coupled Plasma Mass Spectrometer (ICP-MS).
HPLC is used for the separation of elements, and the ICP-MS for the quantitative analysis of nuclides.

For the analysis, the solutions are diluted with 1 M HNO3. The fuel solutions are diluted to a concentration of 0.5 mg fuel per ml solution, the dissolved residues from filtration to 0.1 mg per ml solution.

With the help of the autosampler and the diluter, a 1 ml cup is filled with the solution to be analysed. The solution in the cup is injected into the chromatographic column. The elements are eluted from the column one after the other. By switching the valve at the end of the column, the eluate can be led either to the waste, or directly into the ICP-MS. The elements contained in the eluate are fed into the ICP-MS according to their respective retention time in the column.

2.3.2.2. Description of ICP-MS

The ICP-MS allows to analyse the composition of fluids or of solids in solution. The solution is first atomized and transported to a plasma via a flow of argon gas. All elements with a first ionization energy lower than that of argon (15.76 eV) generate ions in the plasma. These ions are representative of the composition of the solution sample. They are separated by a quadrupole mass filter according to their mass-to-charge ratio, and detected by a channel electron multiplier.

This system allows to analyse separately the composition in different isotopes of elements. A limit of the system is that interferences between atoms or molecular ions appear when they have the same mass-to-charge ratio.

2.3.2.3. Calibration and quantification methods

To quantify the analyses of elements, three methods can be used, depending on the definition of work and of the elements to be analysed :

- External calibration using an internal standard.
- Standard addition.
- Isotopic dilution analysis (IDA)

2.3.2.3.1. External calibration

In the external calibration, the sensitivity of the system for all isotopes is determined by means of measurements of single or multiple element standards at various concentrations. The concentrations of the analysed solution is then obtained by comparison of the signal intensity with the calibration curve. The calibration curves must be linear. The slope of the curve is defined as the sensitivity of the method.

Calibration standards are generally diluted acids containing the concerned elements in very small concentration. If the concentration of the analysed solution is much higher (> 2 mg/ml) matrix effects can become significant. In that case, calibrations using standards at similar concentrations must be performed,

The calibration curve of an isotope is determined with at least 5 different concentrations and with a blank measurement. The range of concentrations covers about 2 orders of magnitude, and includes the expected concentration in the analysed solution.

Between measurements, control measurements on certified standards are performed. A typical scheme of analysis by external calibration is as follows :

1. Blank (pure acid solution)
2. Min. 5 calibration standards
3. Blank
4. Max. 6 measurements on unknown solution
5. Blank
6. Control measurement on standard – return to point 3.

In order to detect variations in time of the sensitivity of the system, an internal standard is used additionally. An element is added in constant concentration to all measurements of calibration, blank and unknown solutions. This element must be naturally absent from all these solutions. The best choice is a stable, mono-isotope element, with a mass not too different from the mass of the elements to be detected.

2.3.2.3.2. Standard addition

In the standard addition method, the solution of unknown composition is divided into at least six aliquots. Five of these solutions are mixed, at various concentrations, to a standard solution of the element to be detected (concentration spike). The resulting solutions are called « spiked » solutions.

The signal intensities of the element in each solution, including the « unspiked » one, are measured in a 2- dimensional co-ordinate system giving intensity as a function of spike concentration. The intersection of the extrapolated (straight) line joining the experimental points with the X axis gives a negative concentration of the spike ; it corresponds to the quantity of the element that should be removed from the initial solution to obtain zero intensity of ICP-MS, i.e. zero concentration. Hence it is equal to the concentration of the element in the unspiked solution.

As for the external calibration method, the use of an internal standard is recommended to prevent the system from variations of its sensitivity.

2.3.2.3.3. Isotopic dilution analysis (IDA)

Isotopic dilution analysis can be used when at least 2 isotopes of the element are present in the solution. The method is based on the addition of a solution with a well known and specific isotopic composition (isotope spike). Three solutions are analysed by ICP-MS : the initial (unspiked) solution, the spike solution, and the mixed (spiked) solution.
From the intensity ratios of the 2 isotopes observed in these solutions, the composition in the unspiked solution can be calculated.

The best precision is obtained when the concentration (or intensity) ratio of the 2 isotopes is about 1 in the spiked solution.
The spiked and unspiked U, Pu and Nd samples are measured at least 3 times.

Before the series of measurements, at least one blank is analysed, in order to avoid memory effects in the system. A suitable series (scheme) of measurements is therefore :

1. Blank
2. Isotope standard
3. Blank
4. Unspiked sample (3 repeated measurements)
5. Blank
6. Spiked sample (3 repeated measurements)

Procedure of isotope counting set up in 1998 has significantly improved the statistics of measurements, by decreasing the number of channels used to characterize each isotopic mass in favour of an increase of the counting time per channel.

In order to detect and correct any important mass discrimination between isotopes in the apparatus, an additional calibration is necessary. A certified standard with given isotopic composition is analysed. If the intensity ratio of the 2 isotopes differs from certification by more than 1 or 2 %, the influence of mass discrimination is not negligible, and is corrected. If the difference between certified and measured ratios gets much higher, the mass calibration of the system is started again.

2.3.3. ITU

Once base solutions are obtained, depending on the final concentration 100 to 1000 ml of solution are pipetted into a weighed polythene bottle. The bottle is weighed again and the solution is diluted with 4M nitric acid to reduce the final concentration to 0.2-0.4 mg fuel/g solution. The final weight of the bottle is noted and 10 – 100 ml, portions of diluted solution are transferred to polythene bottles for subsequent analysis. Typical dilution factors range between 100 and 1000.

U and Pu are determined – after chemical separation - by conventional Isotopic Dilution (ID) –TIMS technique.
Different fission products including Ce, Nd, Sm, Eu and Gd are determined by the method of ID using IC-ICP-MS technology.

A diluted sample from the dissolution of the spent fuel is transferred into a glove box for further dilution and spiking. For the ID procedure, a mixture of the natural elements (La, Ce, Nd, Sm, Eu, Gd) is used as spike. The sample is mixed with a known amount of these elements and the isotopic abundances of the elements present in the unspiked and spiked solutions are measured by mass spectrometry (MS) using an Inductively

Coupled Plasma (ICP) as the Ion Source and a quadrupole mass spectrometer with pulse counting detection.

To avoid isobaric interferences, the solutions to be analysed are first fed through a mixed-bed Ion Chromatography (IC) column allowing isotopes with the same atomic mass belonging to different elements to be separated depending on their chemical behaviour.

The sample, the spike solution and the spiked sample are, in turn, injected into the chromatographic system and the effluent is sent directly through the nebuliser into the plasma and the ion count rate is measured for the isotopes 140 to 160.

In order to optimize the spike addition, the concentrations of the isotopes present in the fuel are determined semi quantitatively based on the response curve of the instrument. For this purpose, solutions containing In and Tb are added.

The natural element spike solution is measured by IC - ICP- MS to determine the detector dead time and the mass discrimination factor of the instrument. Based on these determinations, all intensities and isotopic ratios measured for the sample, the spike and the spiked sample are corrected accordingly.

After analysis of the isotopic abundances of the elements in the three measured solutions, the element concentration in the stock solution is obtained, considering dilution factors and efficiency of element recovery.

The quality control of the IC – ICP - MS procedure is performed by analysing, in triplicate, a laboratory-prepared U-Ce-Nd-Sm-Eu-Gd standard.

* * *

Chapter 3

Radiochemical results

3.1. General

The operations related to fuel dissolution generate the following data, important for further result processing :

- The weight of the dissolved solid fuel, defined as the difference between the initial total sample weight before dissolution and the cladding weight after dissolution.
- The weight of three liquid solutions, the first collecting most of the actinides and lanthanides (main solution labelled MS), the second trapping the released iodine (named IS) and finally the solution (RS) obtained after residue dissolution.
- The total weight of residue after the first fuel dissolution, and the weight of residue sampled for further dissolution.
- The dilution factor corresponding to the liquid aliquots prepared from MS and RS solutions and sent to companion laboratories.

3.2. Measurement results

Tables 3.1 lists the reported measured isotopes.
The experimental results gathered in Tables 3.2/1 to 3.2/40 consist for each isotope of :

- The isotope content (w/w), at the date of measurement, and relatively to the measured solution (MS, IS, or aliquot solution).
- The date of measurement.
- The measurement method.
- The isotopic composition in at %

The date of separation from precursor, if any, when this date differs significantly from the measurement date is given in Table 3.3.

Several general remarks can be made regarding the obtained results :

- none of the techniques applied by the three laboratories succeeded in measuring a U232 content. On the basis of the techniques detection limit, the U232 content in the analyzed samples is estimated to be $<10^{-5}$ mg/g fuel.
- the HPLC-ICP-MS technique as applied by PSI did not allow the measurement of Pu244 (however not included in the matrix), Cm242 and Cm243.
- the IC-ICP-MS technique as applied by ITU did not allow the measurement of Am242m, Cm242, Cm243 and Sb125. Moreover, due to a background problem, Ag109 was not measurable.

The result normalization to solid fuel weight requires dissolution data relative to measured fuel and residue weights and solution weight. This information, as used in the calculations, is summarized in Table 3.4

The experimental results, normalized to solid fuel weight, are given in Tables 3.5/1 to 3.5/36. One has to note that these normalized results may differ slightly from the results contained in the Laboratory Reports [2.1 to 2.3] just because slightly different solution characteristics may have been used (several re-checks of these solution characteristics occurred in the course of the programme and the last and proper value may have not been used by a laboratory, for the aliquot samples coming from another laboratory).

One important remark must be made regarding the result normalization. All isotopes and elements concentrations refer to original solid fuel weight, after appropriate consideration of dissolution data mentioned above. This data processing requires that the solid fuel weight be correctly measured. To verify this, the mass balance is calculated (see Appendix).

The measured solid fuel weight is compared to the calculated fuel weight, the latter being the sum of actinides (U, Pu, Am, Cm) weights (as measured in main solution) and (positive) weight loss due to burnup (determined from burnup indicator Nd148 measured in main solution).
A mass balance deviating significantly (i.e. more than 3 %) from 1 indicates an error in the solid fuel weighing and/or in the element concentration. The exact origin of unbalanced mass is determined in collaboration with the laboratory. On the basis of these investigations, recommendations are made on the results validity and presentation (see Appendix).
It appears that all the calculated mass balances were within less than 2%, except for two sample (BM3 and GU1) for which a correction was applied, as shown in Table 3.4b.

Tables 3.5/1 to 3.5/36 give also the contents normalized to fuel weight calculated at end of life. Decay corrections are of two types : simple decay of the measured element (e.g. Pu241) and decay correction to evaluate the contribution of a precursor to the measured isotope (e.g. Nd144 content is dependent on decay of Ce144).

Table 3.6 lists the type of decay correction made for each isotope and gives the half-life used for the calculations.
When a parent isotope is not measured (e.g. Pm147, measured in TOP 25 programme only and decaying to Sm147), the isotopic composition is calculated at end of irradiation, after suppression from the composition of the isotope for which the decay correction is not possible.

The input data for decay corrections include constants from Table 3.6, as well as separation and measurement dates (Tables 3.2 and 3.3).

Once again, the EOL contents included in Tables 3.5 may differ slightly from the values contained in the Laboratory Reports [2.1 to 2.3] provided that the laboratory calculations (if any) does not necessarily apply the same correction (for example, the SCK-CEN calculations at EOL do not take into account the U234 precursor chain).

Isotopic contents provided in the ARIANE project are relative to initial solid fuel. Normally, this requires measurements of each isotope in each of three solutions generated by the dissolutions. Practically, this is not necessary, as most of the isotopes are present in one solution only.

Table 3.7 gives the inventory of the presence of the measured isotopes in the different solutions. This table is based on the laboratory's own experience as well as on specific measurements made in the framework of the ARIANE project.

An element is considered as absent from a given solution when its content in that solution is lower than about 1 % of its total content in solid fuel. The actinides (U, Pu, Am, Cm) are present essentially in the main solution MS with fraction of at least 99.9 %. This figure is confirmed by α-metry on the residue and the iodine solutions.

The Pu α activity found in these solutions is negligible compared to the main solution.
As Pu is the most difficult of all actinides of interest to dissolve, this indicates that the other actinides are found essentially in the main solution as well.
A similar demonstration applies to the lanthanides. Gamma activity of Ce and Eu in iodine and residue solutions is negligible. Taking into account the chemical similarity between all lanthanides, one concludes that the other lanthanides of interest are also present in the main solution only.

As regards Cs and Sr, both volatile, the former is not found (gamma spectrometry) in iodine and residue solutions. The latter, being more easy to dissolve and less volatile than Cs, is therefore expected to be found also in MS only. Iodine, volatilized during first dissolution, is trapped with an efficiency > 99 % in the alkaline solution.

The metallic elements Mo, Ru, Tc and Rh as well as Ag and Sb are present in significant amounts in both MS and RS solutions.

Ru 106 was not found to be present in IS (fraction < 0.05 %) ; taking into account their similarity in chemical properties, it is not expected to find the other metallic elements in iodine solution either.

The conclusions reported in Table 3.7 are largely based on SCK•CEN's own experience and measurements. They should apply to ITU and PSI results as well, considering that the dissolution of solid fuel was made under more severe conditions than those applied at SCK•CEN (Chapter 2).

Concentrations of elements found in more than one solution are calculated considering all the measurement results. Radioactive decay corrections are easily made, using individual measurement dates only. Fortunately the elements contained in more than one solution do not need a correction for an eventual precursor.

Tables 3.8/1 to 3.8/7 give the residue analysis results and Tables 3.9/1 to 3.9/4 show the total contents of elements contained partly in the mother and in the residue solutions.

* **

Chapter 4

SIMS Measurements

4.1. Introduction

The SIMS (Secondary Ion Mass Spectrometry) technique has been used to characterize the radial distribution of actinides and fission products across fuel pellets.

The fuel samples and isotopes selected for measurements are described in Tables 1.3 and 1.5 respectively. The fuel samples, named BM1S, BM3S and BM4S were cut close to the fuel pieces BM1, BM3 and BM4-D used for radiochemical analyses. Samples BM1S and BM3S are located at maximum burnup position of rods D3 and B6 respectively (the rods were named E11 and G5 at the very beginning of the programme but renamed later on, according to cask rotation assumption). They have close burnups. Sample BM4S also comes from rod B6. It has been cut lower along the fuel column, adjacent to BM4-D.

SIMS results have been quantified, using the results of the radiochemistry on nearby samples. The data used are summarized at Table 4.1. Note that burnup of BM4S is about 3 % higher than BM4-D. Nevertheless, adjacent radiochemical data were applied without correction.

4.2. Measurement procedure and data processing

4.2.1 Procedure

The samples were prepared for SIMS according to standard procedure, i.e. a 2.5 mm thick slice is first fixed with conductive glue on a steel holder, and embedded in a epoxy resin. It is then ground and polished down to a fuel thickness of 1.0-1.5 mm followed by polishing with diamond paste.

The measurements have been realised with the A-DIDA-SIMS instrument. An oxygen (O_2^-) primary ion beam of 12 keV energy was applied and the atomic masses of uranium, plutonium and some selected fission product nuclides were measured as MO and for Uranium also MO_2.

During one counting cycle, all masses given in Table 4.2 are acquired. The isotope Rh103 has not been measured due to the mass, interference with the molecule (^{87}Rb ^{16}O) which affects the data. Also, the distribution of Pm/Sm147 has not been measured due to an extremely low extraction rate/counting rate. The distribution of the U235 and U238 has been extracted from the ^{235}U $^{16}O_2$ and ^{238}U $^{16}O_2$ count rate respectively because they are systematically higher than the corresponding UO count rate.

The primary beam, about 50 µ in diameter, was scanned over a surface of 100 x 100 µm² in order to average local inhomogeneities. The specimen is moved 0.1 mm along the measurement direction A → B (A and B are diametrally opposite points at sample surface) (Figure 4.1) between two counting cycles. Five parallel traces separated by 0.1 mm were made sequentially, always with the same orientation (A → B).

It must be noted that the sample holder always moves in the same direction during measurement. When a direction BA is measured, it means that the sample is measured from B to A after sample rotation of 180°.

4.2.2. Secondary Effects

The output signal of SIMS should ideally depend on local element concentration and beam intensity only. However, the recorded signals are perturbed by secondary effects due to local fuel conductivity and geometric arrangement of sample in extraction field, as explained hereafter.

Due to the elementary and morphological inhomogeneities of the irradiated fuel and the presence of the pores and cracks, the electrical conductivity of the fuel varies across the pellet cross-section, leading to variations of the secondary ion emission, which are in addition mass dependent. This may lead to difficulties in the data analysis, because it is sometimes difficult to determine if a variation of count rate is a real variation of the isotope content, as it can happen in Pu enriched zone of MIMAS-MOX fuel, or simply a modification of the conductivity of the specimen. However this influence is locally proved to be small in non cracked zones. Also the normalization of the raw data (§ 4.2.3) helped to reduce this factor. Cracks produce large variation of count rate that cannot be removed by the normalization procedure and that are isotope dependent (not the same effect on all measured masses).

In addition, the sample displacement under the steady primary ion beam leads in the present arrangement to extraction field variations called « geometric effect », which exhibits a systematic asymmetry of the recorded data. Although this is greatly corrected by the normalization procedure, there is still residual deficiency which is sample and element dependent.

Due to these secondary effects, each specimen is measured along two perpendicular diameters and a third one along one of the previous diameters but in the reverse

direction. The reproducibility of the measurements is checked by repeated measurements along a same direction.

Parallel but reverse directions of measurements are numbered 1 and 2 for each of the specimens BM4S and BM3S, and 3 and 4 for specimen BM1S.

4.2.3. Data processing

The raw count rate obtained during the SIMS measurement has been processed by PSI. The rate is normalized in order to remove the variation of machine parameters like the primary ion beam intensity or the size of the beam. This is made by dividing the count of the mass of interest by one or the sum of other signals obtained at the same position and time representing an absolute constant.

For example : the sum of all U atoms, Pu atoms and fission events can be considered as constant at all points of the specimen. This value can be obtained by adding the weighted count rate of all U isotopes and the weighted count rate of Pu isotopes to the weighted count rate of the Nd^{148} isotopes which are proportional to the number of fission events at the measured position. Software has been developed by PSI for the evaluation of these weighting factors from the measured raw data using the radiochemical information obtained in a neighbouring specimen as input. The definition of the normalization factors used for the data treatment is given in Table 4.3.

The raw data were processed with the normalization and plotting programme SIPLO. This procedure is referred to as the standard or usual normalization procedure.

The transformation of the evaluated relative count rates into absolute local isotopic compositions has been achieved by comparing the local and average SIMS values with the radiochemically determined compositions of the adjacent samples.
The fission yield for Nd148 is needed for the normalization of the burn-up, relative Pu isotope distribution and relative fission product distribution. A value of 0.0175 has been used in the analysis for the three specimens. The normalization and quantification procedure is not very sensitive to this parameter.

Generally a reduced pellet diameter of 8.8 or 8.9 mm has been taken for processing depending on the individual circumstances. From each given plot, the size of the used diameter can be derived. The removed parts at pellet periphery correspond to zones where the presence of cold gap and cladding markedly modify the signal.
For some nuclides a diameter of up to 9.6 mm, corresponding to the real value, would have been preferable in order to truly follow up the rim concentrations. But there was the danger of misinterpretation due to a higher portion of pellet/cladding information in the count rates.

That excess of information in the end systematically deteriorates the measured data because of the normalization procedure. So the diameter used for the analysis was kept smaller than the real pellet diameter.

The data acquired along the same specimen diameter in reverse direction (Figure 4.1) should be identical and can be compared directly. It was observed that the combination of the « geometrical effect » and the « conductivity effect » is stronger in the first acquired radius of each trace than in the second radius as sketched in Figure 4.1. It means that the secondary ion emission rate is more stable along the second radius (from mid measurement to the end) than in the first one, leading to a better measurement of the nuclide distribution.

Therefore, the data acquired in the second radius of direction 1 and 2 for specimens BM4S and BM3S and direction 3 and 4 for specimen BM1S were combined in order to get the most reliable distribution. It is assumed that the real distributions are rather symmetric so that the following procedure, sketched graphically on Figure 4.2 can be used.

Only the data obtained on the second radius of both directions are taken (step 0 of Figure 4.2). Fully symmetrical data are generated in order to simulate the first radius (Step 1 in Figure 4.2) so that the usual normalization procedure can be used (step 2 in Figure 4.2). Then, only the second radius of the normalized data is used (Figure 4.2). The same procedure is used for the data of both directions and so normalized data are generated for the first radius. The data obtained from the direction 2 represent the isotope content variations from position A to centre and the one obtained from the direction 1, the isotope content variations from centre to position B. Therefore, the distribution of the nuclide content along the full diameter (position A to B) can be plotted by adding the two data sets (step 3 in Figure 4.2).

The two radial data sets have been obtained during two different measurements. Moreover the positioning of the specimen can be slightly different regarding to the rotation angle and the target position. This leads to small changes of the quantified values obtained after normalization. Therefore the data treated in this way have to be re-normalized in order to get a perfectly joined curve in the centre. Twenty points on each side of the centre were taken for the arithmetic mean. This procedure consists simply in adding half of the difference Δh obtained in the centre position to one radius data and subtract it from the other half curve (step 4 in Figure 4.2).

Finally the average value of the new data set is calculated and all values are normalized so that the average is equal to the original value (radio-chemical value or 1.0 for the relative content).

This method is very effective for removing most of the « geometrical effect » and a large part of the «conductivity effect».

Quantification to radiochemical value is made for the :

- ✓ Burnup radial distribution (using Nd148 indicator)
- ✓ Pu/(U + Pu) radial distribution.
- ✓ Isotopic compositions of U, Pu and Nd. All presented compositions sum locally to 100 on measured isotopes.

The other isotopes (individual Pu isotopes and fission products except Nd) are presented each with a radial average equal to 1.0.

4.3. Results

The SIMS data are presented in Figures 4.3 to 4.17. Most results come from measurements on sample BM1S. The other samples show similar behaviour.

Reproducibility.

Tests of reproducibility were made by carrying out repeated measurements in the same direction on sample BM1S. These directions, noted 1 and 2, are perpendicular to directions 3 and 4 mentioned above. Figures 4.3 a to 4.3 d summarize the measurements made along directions 1 and 2 for U235, Pu/(U + Pu), burnup (Nd148) and Cs137. Data have been normalized with the SIPLO procedure. Results show that for each element or isotope, both curves are basically identical. The small differences observed can easily be explained by the measurement positions which were slightly shifted one from the other and therefore the materials analysed are not completely identical. This shift implies that the cracks or local Pu variations in the material thus will influence differently the signals obtained along the two directions. The simultaneity of both curves demonstrates the reliability of the measurements.

U235 Content

U235 content measured along directions 3 and 4 of BM1S is almost flat (Fig. 4.4). No neutronic related effect seems to be present. The same observation is made for the other specimens.

An overall gradient of U235 concentration is noticed on sample BM3S (Fig.4.5). The U235 content increases from about 0.1 % on one side of the pellet (direction 2) to about 1.2 % at the other side (direction 1). This suggests a differential U235 consumption across a pellet during base irradiation.

Pu distribution.

The radial distribution of Pu isotopes (fig. 4.6) is characterized by :

- ✓ A general decrease of Pu239 from centre towards periphery, except at rim where a local enrichment is observed.
- ✓ A general decrease of Pu240 from centre towards periphery, similar to Pu239 drop, with an acceleration of decrease when approaching the rim zone.
- ✓ An almost identical profile for Pu241 and Pu242, increasing progressively from centre towards periphery.

These characteristics, found also in samples BM3S and BM4S, are quite standard and result from Pu neutronic properties :

- ✓ Marked thermal neutron spectrum absorption when entering the fuel, leading to less consumption (fission, capture) of Pu239 at centre.
- ✓ Local and strong breeding on U238 at rim, with production of Pu239.
- ✓ Resonant absorption (1eV) on Pu240 at rim, leading to increase in Pu241 and Pu242.
- ✓ Thermal capture on Pu240, progressively decreasing when entering the pellet, leading to increasing residual Pu240 towards centre, and increase of Pu241 and Pu242 towards periphery.

The absolute content in Pu (Pu/(U + Pu)) (Figure 4.7) varies along pellet radius due local Pu content changes (Pu reduction by fission, Pu enrichment by breeding Pu distribution at fabrication) and due to secondary effects described earlier.

The total Pu content remains almost flat across pellet radius, due to rather small decrease of Pu with burnup, most of Pu isotopes being converted into other Pu isotopes, except when fissioning. Pu239 and Pu240 absolute contents (fig. 4.8 and 4.9) show radial profiles combining effects seen on the absolute Pu content changes to specific neutronic effects, these last ones leading to a relative enhancement of isotopes at centre.

Remarkable on sample BM3S is the asymmetry of Pu distribution across pellet along directions 1-2. More Pu is consumed in direction 2 compared to direction 1.

Neodymium content

The isotopic composition of Nd is almost flat across pellet for all isotopes and all examined samples (Figure 4.10).

Noteworthy is the gradient of concentration of Nd143 and Nd144 across pellet for sample BM3S in directions 1-2 (Figure 4.11). Since thermal neutron absorption leads to significant consumption of Nd143, this observation suggests that direction 1-2 sustained a large neutron gradient during base irradiation.

The Nd148 radial distribution reflects the burnup distribution. It is deeply depressed at pellet centre (Figure 4.12) in all samples, with a burnup at centre of 0.90 times the average burnup.
The local peak burnup at rim reaches about 1.44 times the pellet average for BM1S and about 1.26-1.29 for samples BM3S and BM4S. These values are indicative only, as the pellet periphery is not fully represented in the plots.
Finally, one notes that directions 1 and 2 of BM3S show an asymmetry in Nd148 content, suggesting an increase of thermal neutron flux along direction 2 (Figure 4.13).

Fission product La139 and Ce140.

Lanthanides La139 and Ce140 show identical radial distributions (Figure 4.14).

The concentration profiles closely follow the Nd148 profile. This confirms the linearity of fission product concentration versus burnup and the stability of these elements. This confirms also the good sensitivity and reproducibility of SIMS technique. The asymmetry of Nd distribution noticed on BM3S is present here as well.

Fission product Cs, Ba, Sr and Rb

Isotopes Cs134, Cs135, Cs137 and Ba138 have nearly identical distributions across pellet. They are also very close to lanthanides distribution. This similarity of the various distributions is consistent with low temperature operation of fuel during base irradiation preventing volatile fission product transport.

The stable elements Sr88 and Rb87 show radial distributions (Figure 4.16) similar to the lanthanides, as expected. The isotope Rb85 shows in all samples distributions not consistent with production profile. It looks similar to Rb87 but deviates also from it at several places. No explanation has been found for this unusual behaviour.

Fission products Mo and Tc

The radial distributions of metallic elements Mo97 and Tc99 follow closely the lanthanides and volatile profiles from pellet periphery to relative radius r/ro ~ 0.4-0.5

(Figure 4.17). From about mid-radius up to pellet centre, the apparent Mo97 and Tc99 contents markedly increase.

This increase is attributed to the enhancement of efficiency of secondary ion extraction when metallic elements form precipitates under the influence of larger operating temperature towards pellet centre.

Note on Sample BM3S

Asymmetry of radial distribution is systematically observed along directions 1 and 2 of sample BM3S. A gradient of about 10 % or more over pellet diameter is noted. Analysis of this gradient, isotope by isotope, suggests that it could have for origin the gradient of thermal neutron flux across pellet during base irradiation.

This conclusion supports the assumption that sample BM3S comes from rod B6 irradiated at assembly periphery and not from rod G5 surrounded homogeneously by MOX rods of high Pu content.

This observation is in itself and alone not a proof that rod B6 was used instead of rod G5, as the directions of measurements were selected randomly for all samples examined, and because no gradient of thermal flux has been calculated, not at assembly periphery, not close to water hole, not in a locally homogeneous environment. The present observation is, however, fully compatible with use of peripheral rod B6 instead of G5.

Surprisingly, sample BM1S shows larger burnup at periphery than BM3S and BM4S, suggesting a more thermal environment for the first sample. This is not supported by the positions of rods D3 and B6, but is more in favour of a scenario (E11,G5). The scenario (D3, B6) can however be maintained, knowing that these observations are made along directions randomly selected and not along maximum possible gradient, that measurements at pellet periphery are strongly perturbated by the presence of pellet-cladding gap and that the extreme rim region is absent from present plots.

* * *

Chapter 5

Result analysis

5.1. Introduction

The present chapter summarizes the results of analysis of the experimental data provided by the laboratories.

The uncertainties on the experimental data are first reviewed. The experimental results on isotopic compositions and contents available in two laboratories for the same sample are then compared and recommended values are provided. The burnups inferred from the Nd indicator are analyzed and compared to the calculations.

5.2. Experimental results uncertainty

Uncertainty of the final results is due to the uncertainties in the different steps of the measurement process :

- Efficiency of dissolution and efficiency of element collection.
- Solution handling which includes dilution steps and weighing.
- Quality of the standards and of their use as tracers, spikes, ...
- Appropriate homogeneization of the samples after spiking.
- Quality of the separation of the isobaric elements.
- Quality of the measurements depending on the technique and on the relative abundance of the isotopes.

Each of these steps is characterized by its precision (reproducibility of the results) and accuracy (deviation of the result from the accepted reference value).

The way the three laboratories performed the uncertainty evaluations are extensively described in [2.1] to [2.3].

5.2.1. SCK-CEN

The SCK-CEN general method for uncertainty evaluation consists in determining:

- the uncertainities on each of the sample manipulations and on the used spikes and standards, either as true accuracies (computed on a 2 s (*) basis) or as 2 s uncertainties based on extensive experience and practice (dissolution efficiency, weighings, dilutions, ...)
- the uncertainty on the measurement itself, which depends on the applied method :
    * for the TIMS measurements, the uncertainty on the measurement of the isotopic composition of an element is estimated on the basis of the extensive TIMS experience, at the 95 % confidence level (2 s).
    * for $\alpha\beta\gamma$ -spectometry and ICP-MS, the 2 s uncertainty on the measurement is calculated by combining the uncertainties on each individual source of error (as multiple repeats, standard, counting statistics, specific activity, calibration, spectra analysis, ...) using a spreadsheet technique.

and combining these uncertainties using the "Calculating standard deviations and confidence intervals with a universally applicable spreadsheet technique " developed by J. Kragten and recommended by Eurachem [5.1].

The SCK-CEN experimental results are provided with a 2 s uncertainty, at 95 % confidence level [2.1].

Tables 5.1/1 to 8 gathers all the "as provided" SCK-CEN uncertainties for the measurements performed on the main solution.
The "as provided" uncertainties on the isotopes measured in both the main and the residue solutions are given in Table 5.1/17.

5.2.2. PSI

The PSI general method for the evaluation of the experimental result uncertainty consists in making a step by step evaluation of the random and systematic errors occurring from the sampling up to the sample final preparation (spiking, ...) before measurement.

On the other hand, the analytical result is given as the mean value of a number of repeated measurements with an associated error expressed as a standard deviation (1 s), image of the measurement reproducibility.
The global error on the experimental result is estimated from all these uncertainties through a classical error propagation calculation.

(*) standard deviation

The uncertainty on the PSI experimental results is mainly representative of the measurement standard deviation (the other uncertainties have a minor contribution).
In order to compare these uncertainties to those associated to SCK-CEN results, one has to give them a comparable confidence level. The PSI 1s values [2.2] were thus weighted by a factor (>2) in order to reach a 95 % confidence level taking into account the reduced number of measurements performed (Student distribution).

The weighted uncertainties on PSI results are gathered in Tables 5.1/9 to 12 for the measurements performed on the main solution and in Table 5.1/15 for the isotopes measured in the residue solution. Table 5.1/18 gives the global uncertainty for the isotopes measured both in the main and the residue solutions (quadratic combination of the uncertainties).

5.3.6 ITU

The ITU method for uncertainty evaluation is very close to that of PSI, for what concerns the examinations performed on the main solution : the measurement standard deviation (reproducibility) gives the major contribution to the global result uncertainty.

As for PSI uncertainties, the ITU 1s values were thus weighted in order to reach a 95 % confidence level taking into account the reduced number of measurements performed.

As regards the measurements performed on the residue solution, the major contribution to the global uncertainty comes from the uncertainty on the weighing of the sampled residue. The global uncertainty is no more an image of the measurement standard deviation.

Therefore, for the uncertainties relative to the residue solution and in order to compare them to those of SCK-CEN, the 1s values were weighted by a factor 2, giving a 95 % confidence level with no dependence on the measurement number.

The weighted uncertainties on ITU results are gathered in Tables 5.1/13 and 14 for the measurements performed on the main solution and in Table 5.1/16 for the isotopes measured in the residue solution.

Table 5.1/19 gives the global uncertainty for the isotopes measured in the main and in the residue solutions (quadratic combinaison of the uncertainties).

5.3.Results cross-check and analyses - Recommended values

5.3.6 General

A cross-check analysis was performed on five samples namely BM1, BM5, DM1, DU1 and GU3, each of them being analyzed in two different laboratories.

The samples are referred to as XXX-S, XXX-P or XXX-I depending on the laboratory in which the measurement was performed (**S**CK-CEN, **P**SI or **I**TU).

The first step of the analysis consists in determining the date at which the results cross-check is valid.

The second step defines the basis of the comparison, i.e., defines what makes two results of the same variable compatible or not.

The last step of the analysis justifies the maintaining or not of a result with a view to provide a recommended value.

5.3.2. Cross-check date

The isotopes analyzed in framework of the ARIANE programme are of three types :

- Isotope with no precursor and no decay ;
- Isotope with no precursor and with decay ;
- Isotope with precursor and with decay or not.

Table 3.6 shows the considered build-up and decay for each isotope.

Depending on the type of isotope concerned, the experimental results can be compared :

- either at their respective analysis date, without any correction ;
- or at any post-irradiation date similar for the two results, after build-up/decay correction.

Two types of correction are applied:

* for the isotopes without precursor but with decay, the date chosen for cross-check is the end-of-life (EOL) date. The correction to EOL does not modify the result uncertainty, provided that the isotope half life is either accurately known (< 1 % relative uncertainty) or significanty higher (typically above 100 years) than the time period between EOL and the analysis date.

  Amongst of the isotopes with decay only, two isotopes do not strictly fulfill these requirements : Sm 151 and Eu 155, for which the correction to EOL of the measurement results slightly (a few tenths of percent) increases the associated uncertainty.

* for the isotopes with precursor (with decay or not), the date chosen for cross-check is the analysis date of the last examined sample instead of the EOL date in order to restrict the impact of the correction on the result uncertainty. However, in case the correction brings minor modification to the absolute content, the cross-check date will be the respective analysis dates.

As a matter of fact, for what concerns the isotopes Pu 238 (precursor Cm 242, decay to U 234) and Pu 240 (precursor Cm 244, decay to U 236) the absolute content correction to the date of the last examined sample has a negligible impact (generally < 0.3 % on the absolute content). In these two cases, the cross-check is made at the respective analysis dates, which allows a cross-check for all the sample (not possible for Pu 238 in case corrections are brought since Cm 242 contents could not be determined at PSI and ITU).

One must underline the Sm 147 measurements for sample DM1, which can not be cross-checked at any date because no Pm 147 measurements was performed.

Tables 5.2/1 to 5 gather the absolute contents for all the isotopes of the cross-checked samples at all the possible dates (for example : Sm 147, result as measured at the analysis date; Sm 147 EOL ,result corrected to end-of-life and Sm 147 last date, result corrected to the analysis date of the last examined sample) and for each isotope, the date selected for analysis are highlighted by values in colored pattern.

5.3.6 Cross-check basis

In order to determine if the two measurement results provided by the two concerned laboratories for a given isotope of a given sample at a given selected date are compatible, on must fix a reasonable "compatibility criterion".

It seems reasonable to consider that the 95 % confidence interval centered on the experimental value provides an acceptable probability to include the true isotope content.

Consequently, if the comparison of the two intervals associated to the two experimental results shows an intersection, the two results may be considered as compatible and there is an acceptable probability that the true isotope content is included in the intersection range.

The direct comparison of the 95 % confidence intervals associated to the measured values will thus constitute the cross-check basis.

5.3.4. Cross-check results

The compatibility analysis gives four situations :

Case 1 : the compared experimental values are within uncertainties (*)
Case 2 : the compared experimental values are out of uncertainties
Case 3 : no cross-check because one result is missing
Case 4 : no possible cross-check because no valid date for comparison.

(*) i.e. there is an intersection zone between the two 95% confidence intervals

Depending on the outcome of this compatibility analysis, the following solutions are considered for further data processing :

Case 1 : the results are within uncertainties, they are simply combined to give a unique recommended value.
The combination is performed using a classical formula giving the average value of two experimental results with unequal uncertainties (due to different experimental conditions), as follows :

For the experimental results X_1 and X_2 and their associated uncertainty σ_{X1} and σ_{X2}, the combined, recommended value is calculated as :

$$X_r = \frac{\frac{X_1}{\sigma^2_{X1}} + \frac{X_2}{\sigma^2_{X2}}}{\frac{1}{\sigma^2_{X1}} + \frac{1}{\sigma^2_{X2}}} \quad \text{with} \quad \sigma^2_{Xr} = \frac{1}{\frac{1}{\sigma^2_{X1}} + \frac{1}{\sigma^2_{X2}}}$$

Case 2 : if the results are out of uncertainties, two solutions arise, depending on the issue of an analysis of the laboratory performance. This analysis, performed jointly with the concerned laboratories, takes into account the experience and knowledge of the laboratory as regards the method used, the possible interferences, ...
The two solutions arising from the performance analysis are :

a) one of the two results is rejected for a defined, acceptable, likely reason, discussed and agreed by the concerned laboratory ; the other value is then recommended without further processing,

b) no defined, acceptable reason for the results incompatibility is found and agreed on, and the two results are maintained without further processing and without recommendation.
The analysis of the full set of results for all the analyzed samples for the concerned isotope (and eventually the full vector associated) may help providing a complementary appreciation of the most probably correct value but no decision for recommendation is made on that basis as each sample has its specific power / flux irradiation conditions, not included in the present study.

Case 3 : if only one result is available because the second measurement was either not performed or below detection limit or not measurable (unavoidable interference with another element), the available result is maintained without further processing and without recommendation.

Case 4 : in the only case no cross-check is possible because the results must not be compared at analysis date and can not be corrected to another date (sample DM1, isotope Sm 147, no precursor measurement), a rough estimate of the precursor Pm 147 content (on the basis of the results of measurements on the other measured samples) allows to confirm the compatibility of the two results. Both results are thus maintained, each at its own analysis date, without further processing and without recommendation.

5.3.5 Recommended values

Each isotope of each sample is submitted to the above described analysis and the cross-check conclusions are gathered in Tables 5.2/1 to 5 with the use of colored pattern associated to the compared experimental values as follows :

- a green color means that the value was subjected to a cross-check analysis and validated (accepted, maintained) either for further combination with the other value (the two results are within uncertainties, case 1) or as a unique recommended value (the other result is rejected, case 2a)
- a red color means that the value was subjected to a cross-check analysis and rejected (case 2a)
- a yellow color means that the value was subjected to a cross-check analysis but can neither be rejected nor recommended, either after combination or alone (case 2b)
- a blue color means that only one value is available and thus not subjected to a cross-check analysis (case 3)
- a mauve color means that there is no possibility to cross-check the results (unique case 4), both being however maintained as commented above.

These cross-check conclusions are commented hereafter.

Generally speaking, the three laboratories agree on the high reliability and performance of the TIMS (isotopic dilution/isotopic analysis) measurements performed in the framework of the ARIANE programme.
A second general remark concerns the consistency on a measured vector. The results generated by an isotopic dilution/isotopic analysis must be consistent for all the isotopes of a given element. The non-observation of this consistency may be an indication of an uncertainty under-evaluation.

Tables 5.3/1 to 5.3/53 gather the full set of results and their associated uncertainties for each of the analyzed isotopes (with the exception of U 234 for which no experimental result is available) as well as the recommended values and their associated uncertainties.
The uncertainty calculations at EOL are made according to classical error propagation evaluation, neglecting the uncertainty on half life when < 2%.

The isotopic composition cross-checks are given at figs 5.1/1 to 8 for MOX samples and 5.2/1 to 8 for UO_2 samples. This information will help the general analysis.

Rem : in the isotope cross-check analysis detailed below, the "over-" and "underprediction" terms are used, not as an estimation of the measurement quality, but to give a relative information between the two laboratories. Moreover, the term "vector" means the set of experimental absolute contents of all the isotopes of a given element.

U and Pu vectors

The U and Pu isotopes were measured by TIMS for both SCK-CEN and ITU and their results are highly consistent and accurate. They are all maintained and combined for recommendation.

When comparing SCK-CEN and PSI results for Pu isotopes, one observes a systematic disagreement (results out of uncertainties) : for a given sample, the full vector is either underpredicted (BM1, BM5, DM1) or overpredicted (DM1) by PSI analysis, using ICP-MS technique.
It is agreed to discard the Pu absolute contents measured by PSI, assuming the high quality of the SCK-CEN TIMS results.
Comparison of the isotopic composition for the Pu vectors give however very consistent results, confirming that only the absolute contents from PSI are uncorrectly predicted.

As regards the U isotopes, there is a systematic trend of PSI to overpredict the U 235 content. The overprediction applies to the four cross-checked samples (but the results remain within uncertainties for sample BM1) and appear on the isotopic compositions too.
Once again, assuming the high reliability of the TIMS measurements, the U 235 contents measured by PSI are discarded and SCK-CEN results are recommended.

Am and Cm vectors

The Am isotopes as measured by SCK-CEN (TIMS) and PSI (ICP-MS) show a full agreement. All the cross-checked absolute contents are within uncertainties and combined for recommendation ; the isotopic compositions are consistent as well.

The SCK-CEN comparison with ITU results for the Am isotopes (cross-check on two isotopes only, Am 242m is not measured at ITU) shows a 13 % overprediction at ITU by ICP-MS (the results are out of uncertainties).

This is similar to what is observed between SCK-CEN and PSI for sample BM1 but PSI announces higher uncertainties for its ICP-MS measurement of Am vector than ITU.
Whatever the reason for the Am 243 disagreement between SCK-CEN and ITU, the ITU result on Am 243 is rejected, since SCK-CEN TIMS analysis are considered as highly reliable.

As regards the Cm vector, there is a general observation for Cm 244 absolute content measurements : all the cross-checked results, whatever the compared laboratories, are out of uncertainties without systematic over or underprediction.
The three laboratories announce uncertainties of 2 to 6 %, depending on the analyzed sample and there seems to be a problem of uncertainty under-evaluation, either general or specific to the applied method (α metry at SCK-CEN, ICP-MS at PSI and ITU).
No decision was made on that point and all the Cm 244 results were maintained without recommendation.
One notes however that despite this lack of recommended values for this specific isotope, the provided results allows a satisfactory estimation of the true contents within better than 10% (further analysis of the Cm 244 content versus burnup for all the analyzed samples, see 5.3.6.2, will confirm this) which reaches the target of the programme.

The Cm 245 and Cm 246 absolute contents as measured by TIMS at SCK-CEN and ICP-MS at PSI are all within uncertainties and combined for recommendation.

The SCK-CEN / ITU comparison for Cm 245 (Cm 246 is not measured at ITU) shows results out of uncertainties. No agreed reason is found for this discrepancy and the two results are maintained without recommendation.
One notes that the cross-check on Cm isotopic compositions shows a general good agreement.

Nd vectors

One observes a general agreement between SCK-CEN (TIMS) and PSI (ICP-MS) measurements for absolute contents and isotopic compositions.
All these results are thus combined to give recommended values, except for two isotopes of sample DM1, which are out of uncertainties :

- Nd 142, suspected by SCK-CEN to be overpredicted due to a Nd contamination from the laboratory glass instruments.
  The SCK-CEN result is therefore discarded and the PSI result is recommended.
- Nd 143, for which no satisfactory reason is found. The two results are thus maintained without recommendation.
  Further analysis of all the Nd 143 results versus burnup (see 5.3.6.2.) will give a complementary appreciation on the results.

The SCK-CEN (TIMS) / ITU (ICP-MS) cross-check shows a systematic disagreement for the full Nd vector as regards the absolute contents (systematic underprediction by ITU) and a good agreement of the isotopic composition.

Taking into account the high reliability of the SCK-CEN (TIMS) measurements, it is agreed to discard all the ITU absolute contents.

Sm vector

The cross-check between SCK-CEN (TIMS) and ITU (ICP-MS) gives a good agreement for all the absolute contents as well as for the isotopic compositions. These results are thus all combined for recommendation.

As regards the SCK-CEN / PSI (ICP-MS) comparison, the analysis shows three consistent (i.e. over the total vector) results :

- the absolute contents and isotopic compositions for samples BM1 and DM1 are in good agreement (with the exception of Sm 149 of sample DM1, with a very low content and probably underestimated uncertainties).
  All these results are combined for recommendation, except Sm 149 of sample DM1 for which both values are maintained without recommendation. Further analysis of all the Sm 149 results versus burnup (see 5.3.6.2.) will give a complementary appreciation on the results.

- the absolute contents measured for sample BM5 are systematically overpredicted by PSI.
  It is interesting to underline that depending on the examined sample, the vector is either fully in agreement or fully in disagreement. This indicates a good consistency within a vector but shows that the quality of the measurement is not necessarily reproduced from one sample to another, which indicates an uncontrolled random error.

  Looking at the relative uncertainties announced by PSI for this sample, they are generally significantly lower for sample BM5 (factor ~2) than for the two samples in agreement (BM1 and DM1) and possibly underestimated.

  Whatever it is, no definite answer was given to the disagreement between the two vectors and because the measurement performance (TIMS and ICP-MS) seems to be not the reason for the result discrepancies, they are all maintained without recommendation.
  One notes that the cross-check of the isotopic compositions shows compatible results (only the absolute contents are incorrectly evaluated).

The fourth SCK-CEN / PSI cross-checked sample, DU1, shows no consistency over the vector: for isotopes Sm 147, 148, 151 and 154, the results are within uncertainty; for isotopes Sm 149, 150 and 152, the results are out-of-uncertainty.
Looking at the relative uncertainties announced by PSI for this sample, they appear to be the smallest over their analyses samples, and possibly underestimated (one notes that a 1% relative uncertainty increase would be sufficient to make the Sm 150 and 152 results compatible).
Once again, without definite explanation and without complementary appreciation coming from the analysis of all the results versus burnup, the two laboratory results for Sm 149, 150 and 152 are maintained without recommendation.
One notes the compatibility of the two isotopic compositions.

Eu vector

The isotopes Eu 152 and Eu 153 are measured by TIMS (isotopic dilution/analysis) at SCK-CEN and thus, for these two isotopes, the consistency in the agreement with the comparison laboratory should be observed.
Isotopes Eu 154 and 155 are measured by γ-metry and relatively to each other, they should thus be also consistent in the cross-check analysis.
The two other laboratories, PSI and ITU, used isotopic analysis by ICP-MS for the full Eu vector, thus should show full consistency over the vector.
All this, once again, provided the uncertainties are well estimated.

The SCK-CEN / ITU cross-check shows a full agreement of the results which are thus combined for recommendation.

As regards SCK-CEN / PSI comparison, only sample BM5 shows full agreement and consistency over the Eu vector. These results are thus combined for recommendation.
The three other samples cross-checked between SCK-CEN and PSI must be analyzed case by case :

- sample BM1 : the three isotopes will lower content, i.e. Eu 151, 154 and 155 are overpredicted by PSI; the very high incertainty associated to the PSI measurement of Eu 151 allows, however, the SCK-CEN / PSI results to be within uncertainty.
  A much lower uncertainty is announced for isotopes Eu 154 and 155 and the results are out-of-uncertainty for both isotopes, which is consistent. One of the two laboratories has thus made as uncertainty under-evaluation for theses two isotopes, but no agreement was reached on that point. The two results for both isotopes are thus maintained without recommendation.
  A complementary appreciation on the results validity will be given by the analysis versus burnup (see 5.3.6.2.).

- samples DM1 and DU1 : there is no systematic over- or underprediction observable for the two Eu vectors. Moreover, there is no consistency between the pairs Eu 154 / Eu 155. Conclusions can not be drawn on the basis of the cross-check analysis.
  The analysis versus burnup will not bring determinative indications and information and hardly allows to conclude on the reason for discrepancies and unconsistency.
  Taking into account this lack of explanation, all the results out-of-uncertainty are maintained without recommendation.

Cs vector

The cross-check between SCK-CEN and PSI results shows very consistent observations over the Cs vector : either fully in agreement (samples BM5, DM1, DU1) indicating good measurement performance and uncertainty evaluation, or fully in dis-agreement indicating that a random error was not taken into consideration by one of the two laboratories (sample BM1).

The results of Cs measurements on samples BM5, DM1 and DU1 are all combined for recommendation.
The results on sample BM1 shows a systematic overprediction of the absolute contents by PSI, with no agreed reason. Both laboratory results are thus maintained without recommendation but complementary indications will be given by the analysis versus burnup (see 5.3.6.2.).

One notes that the cross-check of the isotopes compositions shows full agreement for all the samples.

As regards the SCK-CEN / ITU comparison, one observes a good agreement with no systematic over-or underprediction by on of the two laboratories.
The Cs 133 results are out-of-uncertainty but it is probably due to an uncertainty under-evaluation by one of the two laboratories.
The two results are maintained without recommendation and additional information on their validity will be given by the analysis versus burnup.
One notes the satisfactory agreement of the isotopic compositions.

"Isolated" isotopes

Besides the above analyzed vectors, several "isolated" isotopes were measured and cross-checked between two laboratories.

For all the cases indicating that the compared results are within uncertainty, the results are simply combined for recommendation.

In most of the cases for which the results are out of uncertainties, no recommendation is made as it is difficult to reach a definite conclusion on the reasons for discrepancies.
For some of them however, decisions are made to reject one of the two compared values and to recommend the other one provided that a satisfactory and agreed explanation is found.
In some case, the analysis of these isotope absolute contents versus burnup (or power) will give complementary information (as it is the case for Ce144, see 5.3.6.2.)

The review of the results out of uncertainties for which a recommendation is made, is given below :

- Pm 147, sample GU3 (SCK-CEN / ITU comparison) :
  the ITU result is rejected as obviously the absolute content is overestimated and / or the associated uncertainty is under-evaluated.

- Ru 106, sample GU3 (SCK-CEN/ITU comparison) :
  the two results differ by almost a factor 2, which can not result from the measurements performance but probably indicates a spurious error (human failure, instrument malfunction, ...).

The absolute content as measured by ITU is significantly higher than the one measured by SCK-CEN.
Besides the comparison between the absolute contents measured by two laboratories, one has analyzed the chemical behaviour of the Ru element in each laboratory. The Ru solubility at sample dissolution is independent of the isotopic composition, i.e., on the relative Ru 101/Ru 106 contents).
This means that the ratio of the Ru 101 to Ru 106 fractions in residue should be equal to one (both isotopes have the same fraction in residue).
The only reason for a deviation from 1 of this ratio is related to the instability of the isotope Ru 106. As a matter of fact the insoluble metallic precipitates created early in irradiation have a lower Ru 106 to Ru 101 relative content than the soluble fuel matrix, at the time they are examined, just because Ru 106 in the precipitates created early in irradiation had longer decay time.
Consequently, the only possible deviation from 1 must be > 1 (Ru 101 has a higher fraction in residue than Ru 106); a value < 1 is not acceptable (within the measurements uncertainties).
ITU examination on GU3 sample shows a ratio of the fractions in residue significanty lower than one.This means than either Ru 101 content is underpredicted, or Ru 106 content is overpredicted. As the cross-check between SCK-CEN and ITU shows results on Ru 101 within uncertainties, Ru 106 absolute content measured by ITU is rejected, the absolute content measured by SCK-CEN is recommended.

- I 129 , sample BM5 (SCK-CEN / PSI comparison).
  As mentioned in PSI laboratory report [2.2], the overall error on the efficiency of the iodine capturing could not be determined.
  The iodine content as measured by PSI in sample BM5 is more than a factor 2 lower than the one of SCK-CEN.
  It is agreed that the inaccurate evaluation of the iodine recovery at PSI explains the results discrepancy and PSI result is rejected ; SCK-CEN result is recommended.

One notes that the three recommendations described above are corroborated by the analyses of these isotopes contents versus burnup (see 5.3.6.2.).

Generally speaking, the analysis of the isotopes contained in both the main and the residue solutions shows that the different methods used by the three laboratories have satisfactory performance. The results on samples BM1 (SCK-CEN / PSI comparison) and GU3 (SCK-CEN / ITU comparison) show full agreements (with the exception of a probable spurious error for GU3-Ru 106 measurement at ITU, as mentioned above).

The results out-of-uncertainties are indicative of the underestimation or the un-consideration of random error(s) in a given sample analysis.
The examination of the Gd 155 measured contents (very low) shows a general problem of uncertainty under-evaluation (except for sample BM1), with no systematic content over- or underprediction by a given laboratory.

5.3.6 Sample recommended burnup

5.3.6.1. Analysis of the experimental burnups

To the isotopic contents provided by the laboratories, must be associated a sample burnup. The experimental burnup values are determined on the basis of the measured Nd 148 experimental contents, as follows:

$$\text{Burnup} = \left[\frac{\text{Nd 148 atoms}}{\text{yield}} \right] \Big/ \text{inferred initial metal atoms}$$

The inferred initial metal atoms being estimated as the sum of the experimental atomic (U+Pu) contents and the (positive) atomic loss due to the burnup (determined from the Nd148 experimental content). One notes that the minor actinides were not included in the inferred initial metal atoms determination because of neglibible contribution.

Table 5.4 gives the comparison of the calculated burnups with the experimental values as well as the burnup recommended values for each sample.

Recommendation of a burnup for the ARIANE samples is made on the following bases :

- calculated sample burnups are considered for information but are not included in the recommended values (calculations are expected to be less accurate than experiments).

- all the cross-checked SCK-CEN and PSI values are within 3 % and the arithmetic average is recommended.

- the ITU result for sample GU3 is 5 to 6 % lower than the SCK-CEN and the calculated values (SCK-CEN and calculated values are within 1.5 %).
  Considering the high reliability of the U, Pu and Nd measurements at SCK-CEN and considering the systematic underprediction of the Nd isotopes by ITU (see Table 5.2/3), the SCK-CEN experimental burnup is recommended (ITU experimental burnup is rejected).

- for all the uncross-checked burnup, the experimental burnup is recommended, with the following comments :
  * for sample BM6, the experimental value, 8.4 % lower than the calculation, is however confirmed by the BM5 / BM6 Cs 137 activity ratio provided by the gamma scanning analysis of the mother fuel rod.

  * for BWR MOX samples (DM2/3/4), the calculated burnups are 4 to 11 % lower than the experimental values.
    Taking into account the high reliability of the U, Pu and Nd measurements at SCK-CEN, the SCK-CEN experimental values are recommended.

* for sample GU4, despite the rejected ITU measurement for sample GU3, the ITU experimental burnup is fully in accordance with the general (i.e. for all the measured samples) Nd 148 analysis versus burnup (see Table 5.3/26).
ITU experimental value is thus recommended for sample GU4.

5.3.6.2. Isotope contents versus burnup

The evolution of the isotopic contents versus the recommended burnups are included in Tables 5.3/1 to 5.3/53.

One notes that the plotted content values can only be those corresponding to the EOL date, or to the analysis date provided that the isotope has no precursor and no decay. In case the isotope has a precursor or a decay or both, the values at analysis on last date, even if selected for the cross-check analysis, can not give a valuable information versus burnup.

The evolution of the isotope content versus burnup gives an interesting information on the results consistency, on the isotope evolution general trend as well as, in some cases, gives an indication on the respective "quality" of two results maintained without recommendation or on the validity of a result rejection.

Further to the cross-check analysis, several comments and appreciations are given but this complementary analysis of some results validity (not strictly considered as recommendations) is surely not exhaustive :

- isotope Nd 143, sample DM1 : both experimental results were maintained.
  The full Nd vector for sample DM1 as determined by PSI, is underestimated compared to the SCK-CEN analysis ; the results are however within uncertainties for all the isotopes except for Nd 142 (SCK-CEN result is rejected for a glass contamination problem) and Nd 143.
  The analysis versus burnup (Table 5.3/22) shows that the PSI value for Nd 143 seems out-of-trend and that the associated uncertainty should be increased.

- isotope Sm 149 (with very low content) : there is no systematic over- or underprediction of the Sm 149 content by a given laboratory. The examination of samples BM5 and DM1 seems to indicate a problem of uncertainty under-evaluation by SCK-CEN.

- Eu vector : it remains very difficult to conclude on the descrepancies and un-consistencies between the cross-checked results for samples DM1 and DU1.
  Looking at Eu 154 and Eu 155 results for sample BM1, it seems rather clear that PSI underestimates the uncertainty associated to the two isotope contents, both overestimated.

- Cs contents : for sample BM1, the analysis of the full vector versus burnup indicates out-of-trend "contents" from PSI analysis (clear evidence for Cs 137 because of the very linear dependence versus burnup).

For the Cs 133 measurement on sample GU3, the analysis versus burnup shows that ITU underestimates the uncertainty associated to the content measurement, which seems overestimated.

- Ce 144, sample DM1 : both experimental results were maintained.
  The analysis versus burnup is not relevant (Table 5.3/20) but the absolute contents plotted versus the end-of-irradiation average power (considered over a time period corresponding to the Ce 144 half life) is very consistent and gives good indication that the PSI experimental value is most probably underestimated.

- Pm 147, sample GU3
  Ru 106, sample GU3
  I 129, sample BM5 : their respective analysis versus burnup definitely confirms the validity of the SCK-CEN result recommendation and rejection of the cross-checked PSI or ITU value.
  Moreover, as regards the I 129 content measurement at PSI, the analysis confirms that the same problem of accurate evaluation of the iodine recovery occurs for sample BM6 (clear evidence of underestimated content).

- Gd 155 : one notes that the analysis of the Gd 155 contents versus burnup was not possible as the corrections to EOL give negative values (see Table 5.3/40), as a consequence of the unsufficient accuracy on the measurements of both the isotope and its precursor.

Finally, a particular observation allowed by the analysis versus burnup is a severe (at least a factor 3) overestimation of the Cm 242, content of sample DM3.
This unacceptable value, most probably resulting from a spurious error, is rejected.

* * *

Chapter 6

Conclusions

The ARIANE Programme was carried out as an International Programme managed by BELGONUCLEAIRE, with the participation of numerous companies, from Japan, USA and Europe, involved in fuel design, transport cask design, code development, waste management or having an interest for laboratory work or participating as fuel provider to the programme.

The major objectives of the ARIANE Programme are :

- to provide a large set of experimental data on the irradiated fuel inventory : up to 53 isotopes were measured, including major and minor actinides, burnup and burnup credit indicators, long-lived fission products,...
- to confer on these data a minimized and reliable uncertainty level by cross-checking the results obtained on selected samples between different laboratories using similar or different high performance techniques (mainly TIMS and HPLC- or IC-ICP-MS).

UO_2 and MOX fuels irradiated in Beznau-1 PWR (S), Goesgen PWR (S) and Dodewaard BWR (NL) to burnups of 30 to 60 GWd/tM were selected for analysis and the radiochemistry departments of the nuclear centres of SCK•CEN (B), PSI (S) and ITU (D) were selected to perform the experimental work.

The target uncertainties of the programme were mainly :

- 3 to 5 % for the major actinides
- 3 % for the burnup indicators
- < 10 % for the other isotopes

The experimental results were extensively analyzed and recommended values were provided for the samples submitted to cross-ckeck.
For most of the measured isotopes, the target uncertainties have been reached and even exceeded in several cases, as for example :

- the Pu and Nd vectors, generally have associated uncertainties below 1 %
- the Sm and Eu vectors have associated uncertainties below 5 %
- Am241 is measured with an uncertainty of 2 to 5 %

For some of the measured isotopes, the uncertainties are above the target, not systematically, but for a part of the analyzed samples. For example, isotopes as Tc99, Ru101, Ru106 or Rh103 are measured with uncertainties ranging between 2 (or 3) and 20 %, depending on the sample.

For only one of the isotopes included in the programme matrix, none of the techniques applied succeeded in measuring a content : U232, introduced in the programme as an indicator for enriched recycled uranium and for which only a content upper limit could be given (determined as $< 10^{-5}$ mg/g fuel)

Besides the providing of an extended data set, a great interest of the ARIANE Programme is to have allowed three Laboratories of international reputation to directly compare their respective performances, helping them, when necessary, to improve their qualification level and reliability.

* * * *

References

1.1 **ARIANE International Programme**
Minutes of the organizational Meeting. Brussels, September 29, 1994.
Ref. AR 94/03

1.2 **ARIANE International Programme**
Minutes of the 5th Programme Committee Meeting May. 11 – 12, 1998.
Ref. AR 98/10

1.3 **ARIANE International Programme**
Minutes of the 6th Programme Committee Meeting - June 22, 1999
Ref. AR 99/14

1.4 **ARIANE International Programme**
Irradiation Data Report.
Ref. AR 96/05 (Part 1) and Ref. AR 99/13 (Part 2)

1.5 Reassessment of the identity of rods irradiated in assembly M109 and used in the framework of the programmes **M109, ARIANE** and **FIGARO**.
BN ref. 9805422/221 dated July 7, 1998

1.6 **ARIANE International Programme**
Minutes of the 3rd Programme Committee Meeting, December 12 – 13, 1996.
Ref. AR 97/08

1.7 **ARIANE** Project : « **BAMBI** » Report September to December 1998 –
BN ref. 9809811/221 dated December 23, 1998.

2.1 **ARIANE International Programme**
Laboratory Report : SCK-CEN Analyses
.BN ref. 0100291/221 – Jan 2001

2.2 **ARIANE International Programme**
Laboratory Report : PSI Analyses
BN ref. 0100292/221 – Jan 2001

2.3 **ARIANE International Programme**
Laboratory Report : ITU Analyses)
BN ref. 0100293/221 – Jan 2001

5.1. Analyst, 119, 2161-2166 (1994)

Appendix

Mass Balance calculation and result normalization

The mass balance calculation is a powerful tool to control the consistency of the experimental data.

The calculation consists in determining the mass of the fuel sample examined on the basis of the measured individual concentrations of its components. The first step is to sum the (U, Pu, Am, Cm) weights of actinide in the main solution. The (positive) weight loss due to burnup is then added to the previous sum. The burnup is determined using the best estimate burnup indicator (generally Nd148 content measured in the main solution).

This calculated sum, multiplied by the ratio fuel weight / oxygen weight (1.1345 is a good approximation), is then compared to the measured solid fuel weight.

A ratio (calculated mass / measured mass) close to 1.00 is expected. A tolerance of 2 % is allowed considering the measurement accuracies.

This tolerance of 2 % is acceptable for the ARIANE project, considering its objectives of providing most element concentrations with an accuracy of a few percent.

The mass balance calculations described above have been performed in a simplified way at BELGONUCLEAIRE. The method is straightforward and does not require data for minor actinides (Am, Cm). The calculation is detailed hereafter.
The error in using this simplified procedure has been determined by performing mass balance calculations with the help of core physics code (WIMS). The simplified procedure introduces an error << 1 %.

Definitions

- U_o (U) : mass of uranium before (after) irradiation
- Pu_o (Pu) : mass of plutonium before (after) irradiation
- N (U_o) (N (Pu_o)) : number of uranium (plutonium) atoms before irradiation
- A_i : atomic weight of fissile isotope i (i = U235, U238, Pu239, Pu241)

- MA : mass of minor actinides Am and Cm
- N_i (W_i) : number (weight) of atoms of Nd148 issued from fissile isotope I
- Y_i : fission yield of Nd148 for fissile isotope I
- W_f : total fuel weight. :

  - W_f^{inf} :inferred from calculations based on measured individual concentrations
  - W_f^{m} :as measured solid fuel weight.

Formulas :

- $N_i = W_i / A_i$
- $F_i = N_i / Y_i$: number of fissions of fissile atom i
- $\Delta W = \sum_i F_i \times A_i$:weight loss of initial heavy metal atoms by fission
- $U_o + Pu_o = U + Pu + MA + \Delta W$: calculated metal fuel weight
- $BU\ (FIMA) = [(\sum_i F_i) / (N(U_o) + N(Pu_o))]$
- $W_f^{inf} = (U_o + Pu_o) + O_2$ weight : total fuel weight inferred from calculations.

Practical calculations

- MA ~ 0
- A (heavy metal) ~ 238
- A (Nd148) ~ 148
- $\Delta W = (N / \overline{Y}) * 238$

with

- N : measured Nd148 atomic content ([measured weight W of Nd148] / 148)
- $\overline{Y}$: average fission yield of Nd148.

- Mass balance calculations carried out at the end of 1997 and early 1998 were made using yields inferred from Nd isotopic compositions, allowing to determine the contribution of individual isotopes U235, Pu239 and Pu241 to fission process. Weighted yield was then calculated. Fast fission on U238 was taken into account with a contribution of 8 %. Yields were 0.0173 and 0.0178 for UO_2 and MOX respectively.

- Mass balances calculated at the end of 1998 use fission yields obtained from calculations with WIMS-7B code, namely :

- $\overline{Y}$ (UO_2 / BWR) = 0.0173
- $\overline{Y}$ (UO_2 / PWR) = 0.0176
- $\overline{Y}$ (MOX) = 0.0177

- $U_0 + Pu_0 = U + Pu + \Delta W$
- BU (FIMA) = $(N / \overline{Y}) / ([U_o + Pu_o] / 238)$
- $W_f^{inf} = (U_0 + Pu_0) * 1.1345$
- W_f^m = Sample total weight (including cladding) - cladding weight after fuel dissolution
- MBR = W_f^{inf} / W_f^m : mass balance ratio

The calculations use the fuel weight data resulting from the dissolution steps and the measured absolute amounts of individual elements U, Pu and Nd148. The use of experimental results normalized to solution weight is feasible but not necessary, this variable being automatically cancelled out in the calculations. The simplified procedure necessitates neither accurate molar mass nor Avogadro number.

Table A1 summarizes the results of mass balance calculations.
It shows that for all samples, the mass balances are within 2 %, which is satisfactory, with two exceptions : samples BM3 and GU1 (SCK-CEN measurements).
For these two samples, it was found that an erroneous information was given as regards the solution characteristics.
Is was thus agreed to correct the solution characteristics for these two sample by a factor corresponding to the experimental mass balance, i.e. a factor 0.72 for sample BM3 and a factor 1.12 for sample GU1.

* * * *

Table A1 Mass balance calculations

CEN	Sample	BM1	BM3	BM5'	GU1	GU3'	DM1	DM2	DM3	DM4	DU1
U	µg / g sol	3.35E+02	2.38E+02	6.75E+04	4.83E+02	6.13E+04	7.87E+04	7.85E+04	7.72E+04	7.62E+04	6.97E+04
Pu	µg / g sol	1.40E+01	9.87E+00	2.46E+03	5.99E+00	7.63E+02	2.56E+03	3.09E+03	2.82E+03	3.06E+03	6.57E+02
Nd148	µg / g sol	1.84E-01	1.29E-01	4.64E+01	3.47E-01	3.84E+01	5.93E+01	3.53E+01	4.75E+01	3.64E+01	4.64E+01
Yield Nd 148		0.0177	0.0177	0.0177	0.0176	0.0176	0.0177	0.0177	0.0177	0.0177	0.0173
fuel weight	mg / g sol	4.149E-01	2.945E-01	8.418E+01	5.907E-01	7.439E+01	9.830E+01	9.620E+01	9.568E+01	9.367E+01	8.471E+01
Mass balance		**1.00**	**0.72**	**1.00**	**1.12**	**1.00**	**1.00**	**1.00**	**1.00**	**0.98**	**0.99**

PSI	Sample	BM1	BM5	BM6	DM1	DU1
U	µg / g sol	3.47E+02	3.87E+02	3.89E+02	4.87E+02	4.28E+02
Pu	µg / g sol	1.33E+01	1.34E+01	1.55E+01	1.69E+01	3.75E+00
Nd148	µg / g sol	1.95E-01	2.63E-01	1.66E-01	3.58E-01	2.84E-01
Yield Nd 148		0.0177	0.0177	0.0177	0.0177	0.0173
fuel weight	mg / g sol	4.289E-01	4.815E-01	4.756E-01	6.084E-01	5.194E-01
Mass balance		**0.99**	**0.99**	**0.98**	**0.98**	**1.00**

ITU	Sample	GU3	GU4
U	µg / g sol	1.22E+05	1.27E+05
Pu	µg / g sol	1.52E+03	1.11E+03
Nd148	µg / g sol	7.27E+01	4.59E+01
Yield Nd 148		0.0173	0.0173
fuel weight	mg / g sol	1.475E+02	1.506E+02
Mass balance		**1.00**	**1.00**

Table 1.1 - Organizations participating to the ARIANE Programme

• JRI	: Japan
• HITACHI (BWR Jap. utilities)	: Japan
• MITSUBISHI (NFI, PWR Jap. utilities)	: Japan
• NEL	: Japan
• TOSHIBA (BWR Jap. utilities)	: Japan
• GNB	: Germany
• SIEMENS	: Germany
• GKN	: Netherlands
• NOK	: Switzerland
• PSI	: Switzerland
• BNFL	: U.K.
• ORNL	: USA
• TRACTEBEL (ELECTRABEL)	: Belgium
• CEN•SCK	: Belgium
• BELGONUCLEAIRE	: Belgium

Table 1.2 - Main fuel characteristics.

Group	BM						GU				DM				DU
Sample	BM1	BM2-D	BM3	BM4-D	BM5(')	BM6	GU1	GU2	GU3(')	GU4	DM1	DM2	DM3	DM4	DU1
Irradiation	BEZNAU PWR						GOESGEN PWR				DODEWAARD BWR				
Fuel type	MOX						UO2				MOX				UO2
Fuel manufacturer	BELGONUCLEAIRE						SIEMENS				BELGONUCLEAIRE				JNF
Fuel characteristics :															
$^{235}U/U$ (w %)	0.2						3.4		4.1		0.2				4.9
Pu/ U + Pu (w %)	5.9						--		--		6.4				--
Pu fiss/ Pu (w %)	71						--		--		71				--
Assembly of origin	M109				M308						Y014	Y012		Y013	Y013
End of irradiation	04 / 93				06 / 96		06/94	05/92	06/97		01/93	01/92	01/92	01/93	01/93
Fuel rod identification	D3		B6		K7		14H13	14H29	16B05		M09	M05		M07	U004
Calculated sample burnup (GWd/ tM)	47.0	36.8	48.5	37.9	58.9	39.6	59.7	32.5	52.5	29.1	55.6	33.5	46.5	38.1	54.4
Source Laboratory	PSI						ITU				CEN				CEN

Type of document : REPORT

BN reference N° / File - « Rev » - Page 0000253 / 221- "B" – T 2

Other reference : AR 2000 / 15

Table 1.3a Work matrix (valid till May 1998)

Samples	BM1	BM2-D	BM3	BM4-D	GU1	GU2	DM1	DM2	DM3	DM4	DU1
PSI											
Prepare	x	x	x	x							
Base	x	x	x	x	x (ǂ)		x (ǂ)				x (ǂ)
TOP 25	x˙			x˙	x˙						x˙
SIMS	x˙		x˙	x˙							
ITU											
Prepare					x	x					
Base	x (ǂ)		x (ǂ)		x	x	x (ǂ)				x (ǂ)
TOP 25	x˙		x˙		x˙	x˙	x˙				x˙
SCK											
Prepare							x	x	x	x	x
Base	x (ǂ)		x (ǂ)		x (ǂ)		x	x	x˙	x˙	x
TOP 25	x˙				x˙			x˙			x˙

(ǂ) no iodine analysis
˙ extension

Type of document : REPORT

BN reference N° / File - « Rev » - Page 0000253 / 221- "B" – T 3

Other reference : AR 2000 / 15

Table 1.3b Work matrix (valid after May 1998)

Samples	BM1	BM3	BM4-D	BM5(')	BM6	GU1	GU3(')	GU4	DM1	DM2	DM3	DM4	DU1
PSI													
Prepare	x	x	x	x (5)	x								
Base				x	x				x (ł)				x (ł)
TOP 25				x	x								x
SIMS	x	x	x										
ITU													
Prepare						x	x (3)	x					
Base							x	x					
TOP 25							x						
SCK.CEN													
Prepare				x (5')			x (3')		x	x	x	x	x
Base	x (ł)			x		x (ł)	x		x	x	x	x	x
TOP 25	x			x		x	x			x			x

(') analysis performed at PSI (BM5) or TUI (GU3), and SCK.CEN (BM5' and GU3')
(ł) no iodine analysis

Table 1.4 - Isotopes selected for the " Base " Programme

Base actinides

^{234}U , ^{235}U , ^{236}U , ^{238}U
^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu , ^{242}Pu

Minor actinides

^{237}Np
^{241}Am , ^{242m}Am , ^{243}Am
^{242}Cm , ^{243}Cm , ^{244}Cm , ^{245}Cm

Fission Products

Volatile : ^{129}I , ^{133}Cs , ^{134}Cs , ^{135}Cs , ^{137}Cs
Metallic : ^{99}Tc
Lanthanides : ^{144}Ce
^{142}Nd , ^{143}Nd , ^{144}Nd , ^{145}Nd , ^{146}Nd , ^{148}Nd , ^{150}Nd
^{147}Sm , ^{149}Sm , ^{150}Sm , ^{151}Sm , ^{152}Sm
^{153}Eu , ^{154}Eu , ^{155}Eu

Table 1. 5 - Isotopes selected for the " Top 25 " Programme

Base actinides

^{232}U

Fission Products

Metallic : ^{90}Sr , ^{95}Mo , ^{101}Ru , ^{106}Ru , ^{103}Rh , ^{109}Ag , ^{125}Sb
Lanthanides : ^{147}Pm , ^{155}Gd

Table 1.6 - Isotopes selected for the SIMS analysis

Base actinides

^{235}U and ^{238}U / ^{238}Pu
Pu vector (^{239}Pu , ^{240}Pu , ^{241}Pu / ^{241}Am and ^{242}Pu)
Pu content

Fission Products

Volatile : Cs vector (^{133}Cs , ^{134}Cs , ^{135}Cs , ^{137}Cs)
Lanthanides : Nd vector (^{143}Nd , ^{144}Nd / ^{144}Ce , ^{145}Nd , ^{146}Nd / ^{146}Sm , ^{148}Nd / ^{148}Sm , ^{150}Nd / ^{150}Sm)

Others : ^{85}Rb , ^{87}Rb , ^{88}Sr , ^{97}Mo , ^{99}Tc
^{138}Ba , ^{139}La , ^{140}Ce

Table 3.1a - Measurements performed at SCK•CEN

1) Actinides

	Isotope \ Sample	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
X	U232	M				M		M		M			M			M
	U234	M				M		M		M		M	M	M	M	M
	U235	M				M		M		M		M	M	M	M	M
	U236	M				M		M		M		M	M	M	M	M
	U238	M				M		M		M		M	M	M	M	M
	Np237	M				M		M		M		M	M	M	M	M
	Pu238	M				M		M		M		M	M	M	M	M
	Pu239	M				M		M		M		M	M	M	M	M
	Pu240	M				M		M		M		M	M	M	M	M
	Pu241	M				M		M		M		M	M	M	M	M
	Pu242	M				M		M		M		M	M	M	M	M
■	Pu244	M				M		M		M		M	M	M	M	M
	Am241	M				M		M		M		M	M	M	M	M
	Am242m	M				M		M		M		M	M	M	M	M
	Am243	M				M		M		M		M	M	M	M	M
	Cm242	M				M		M		M		M	M	M	M	M
	Cm243	M				M		M		M		M	M	M	M	M
	Cm244	M				M		M		M		M	M	M	M	M
	Cm245	M				M		M		M		M	M	M	M	M
■	Cm246	M				M		M		M		M	M	M	M	M

■ : not contractual

X : TOP 25

not scheduled

M : result from MS
I : IS
R : RS

Table 3.1a - Measurements performed at SCK•CEN

2) Fission products

	Isotope \ Sample	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
■	Ce140															
■	Ce142															
	Ce144	M				M		M		M		M	M	M	M	M
	Nd142	M				M		M		M		M	M	M	M	M
	Nd143	M				M		M		M		M	M	M	M	M
	Nd144	M				M		M		M		M	M	M	M	M
	Nd145	M				M		M		M		M	M	M	M	M
	Nd146	M				M		M		M		M	M	M	M	M
	Nd148	M				M		M		M		M	M	M	M	M
	Nd150	M				M		M		M		M	M	M	M	M
X	Pm147	M				M		M		M			M			M
	Sm147	M				M		M		M		M	M	M	M	M
■	Sm148	M				M		M		M		M	M	M	M	M
	Sm149	M				M		M		M		M	M	M	M	M
	Sm150	M				M		M		M		M	M	M	M	M
	Sm151	M				M		M		M		M	M	M	M	M
	Sm152	M				M		M		M		M	M	M	M	M
■	Sm154	M				M		M		M		M	M	M	M	M
■	Eu151	M				M		M		M		M	M	M	M	M
	Eu153	M				M		M		M		M	M	M	M	M
	Eu154	M				M		M		M		M	M	M	M	M
	Eu155	M				M		M		M		M	M	M	M	M
■	Gd154															
X	Gd155	M				M		M		M		M	M			M
■	Gd156															
■	Gd157															
■	Gd158															
■	Gd160															
X	Sr90	M				M		M		M			M			M
X	Mo95	M+R				M+R		M+R		M+R		M+R	M+R	M	M	M+R
	Tc99	M+R				M+R		M+R		M+R		M+R	M+R	M+R	M+R	M+R
X	Ru101	M+R				M+R		M+R		M+R		M+R	M+R	M	M	M+R
X	Ru106	M+R				M+R		M+R		M+R		M+R	M+R			M+R
X	Rh103	M+R				M+R		M+R		M+R		M+R	M+R	M	M	M+R
X	Ag109	M+R				M+R		M+R		M+R		M+R	M+R	M	M	M+R
X	Sb125	M+R				M+R		M+R		M+R		M+R	M+R			M+R
	I129					I				I		I	I	I	I	I
	Cs133	M				M		M		M		M	M	M	M	M
	Cs134	M				M		M		M		M	M	M	M	M
	Cs135	M				M		M		M		M	M	M	M	M
	Cs137	M				M		M		M		M	M	M	M	M

■ : not contractual

X : TOP 25

not scheduled

M : result from MS
I : IS
R : RS

Table 3.1b - Measurements performed at PSI

1) Actinides

	Isotope \ Sample	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
X	U232				M		M									M
	U234	M	M	M	M		M					M				M
	U235	M	M	M	M		M					M				M
	U236	M	M	M	M		M					M				M
	U238	M	M	M	M		M					M				M
	Np237	M			M		M					M				M
	Pu238	M	M	M	M		M					M				M
	Pu239	M	M	M	M		M					M				M
	Pu240	M	M	M	M		M					M				M
	Pu241	M	M	M	M		M					M				M
	Pu242	M	M	M	M		M					M				M
■	Pu244	M			M		M					M				M
	Am241	M			M		M					M				M
	Am242m	M			M		M					M				M
	Am243	M			M		M					M				M
	Cm242	M			M		M					M				M
	Cm243	M			M		M					M				M
	Cm244	M			M		M					M				M
	Cm245	M			M		M					M				M
■	Cm246	M			M		M					M				M

■ : not contractual

X : TOP 25

not scheduled

M : result from MS
I : IS
R : RS

Table 3.1b - Measurements performed at PSI

2) Fission products

	Isotope \ Sample	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
■	Ce140															
■	Ce142															
	Ce144	M			M		M					M				M
	Nd142	M	M	M	M		M					M				M
	Nd143	M	M	M	M		M					M				M
	Nd144	M	M	M	M		M					M				M
	Nd145	M	M	M	M		M					M				M
	Nd146	M	M	M	M		M					M				M
	Nd148	M	M	M	M		M					M				M
	Nd150	M	M	M	M		M					M				M
X	Pm147				M		M									M
	Sm147	M			M		M					M				M
■	Sm148	M			M		M					M				M
	Sm149	M			M		M					M				M
	Sm150	M			M		M					M				M
	Sm151	M			M		M					M				M
	Sm152	M			M		M					M				M
■	Sm154	M			M		M					M				M
■	Eu151	M			M		M					M				M
	Eu153	M			M		M					M				M
	Eu154	M			M		M					M				M
	Eu155	M			M		M					M				M
■	Gd154	M			M		M					M				M
X	Gd155	M			M		M					M				M
■	Gd156	M			M		M					M				M
■	Gd157	M			M		M					M				M
■	Gd158	M			M		M					M				M
■	Gd160	M			M		M					M				M
X	Sr90	M			M		M									M
X	Mo95	M+R			M+R		M+R									M+R
	Tc99	M+R			M+R		M+R					M+R				M+R
X	Ru101	M+R			M+R		M+R									M+R
X	Ru106	M			M+R		M+R					M+R				M+R
X	Rh103	M			M+R		M+R									M+R
X	Ag109	M+R			M+R		M+R									M+R
X	Sb125	M			M+R		M+R					M+R				M+R
	I129				I		I									
	Cs133	M			M		M					M				M
	Cs134	M			M		M					M				M
	Cs135	M			M		M					M				M
	Cs137	M			M		M					M				M

■ : not contractual

X : TOP 25

not scheduled

M : result from MS
I : IS
R : RS

Table 3.1c - Measurements performed at ITU

1) Actinides

	Sample / Isotope	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
X	U232								M		M					
	U234	M						M	M		M	M				M
	U235	M						M	M		M	M				M
	U236	M						M	M		M	M				M
	U238	M						M	M		M	M				M
	Np237	M						M	M		M	M				M
	Pu238	M						M	M		M	M				M
	Pu239	M						M	M		M	M				M
	Pu240	M						M	M		M	M				M
	Pu241	M						M	M		M	M				M
	Pu242	M						M	M		M	M				M
■	Pu244															
	Am241	M						M	M		M	M				M
	Am242m	M						M	M		M	M				M
	Am243	M						M	M		M	M				M
	Cm242	M						M	M		M	M				M
	Cm243	M						M	M		M	M				M
	Cm244	M						M	M		M	M				M
	Cm245	M						M	M		M					
■	Cm246															

■ : not contractual

X : TOP 25

not scheduled

M : result from MS

I : IS

R : RS

Table 3.1c - Measurements performed at ITU

2) Fission products

	Isotope \ Sample	BM1	BM3	BM4-D	BM5	BM5'	BM6	GU1	GU3	GU3'	GU4	DM1	DM2	DM3	DM4	DU1
	Ce140	M						M				M				M
	Ce142	M						M				M				M
	Ce144	M						M	M		M	M				M
	Nd142	M						M	M		M	M				M
	Nd143	M						M	M		M	M				M
	Nd144	M						M	M		M	M				M
	Nd145	M						M	M		M	M				M
	Nd146	M						M	M		M	M				M
	Nd148	M						M	M		M	M				M
	Nd150	M						M	M		M	M				M
X	Pm147	M							M		M	M				M
	Sm147	M						M	M		M	M				M
■	Sm148	M						M	M		M	M				M
	Sm149	M						M	M		M	M				M
	Sm150	M						M	M		M	M				M
	Sm151	M						M	M		M	M				M
	Sm152	M						M	M		M	M				M
■	Sm154	M						M	M		M	M				M
■	Eu151	M						M				M				M
	Eu153	M						M	M		M	M				M
	Eu154	M						M	M		M	M				M
	Eu155	M						M	M		M	M				M
■	Gd154	M						M				M				M
X	Gd155	M						M	M		M	M				M
■	Gd156	M						M				M				M
■	Gd157	M						M				M				M
■	Gd158	M						M				M				M
■	Gd160	M						M				M				M
X	Sr90	M							M		M	M				M
X	Mo95								M+R		M+R					
	Tc99								M+R		M+R					
X	Ru101								M+R		M+R					
X	Ru106								M+R		M+R					
X	Rh103								M+R		M+R					
X	Ag109								M+R		M+R					
X	Sb125								M+R		M+R					
	I129								I		I					
	Cs133	M						M	M		M	M				M
	Cs134	M						M	M		M	M				M
	Cs135	M						M	M		M	M				M
	Cs137	M						M	M		M	M				M

■ : not contractual

X : TOP 25

not scheduled

M : result from MS
I : IS
R : RS

Table 3.2 / 1 - Results of analysis

Sample reference: BM1
Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	2.66E-02	0.0081	17/03/97	TIMS	
U235	3.43E-01	0.1035	17/03/97	TIMS	
U236	1.06E-01	0.0318	17/03/97	TIMS	
U238	3.35E+02	99.8566	17/03/97	TIMS	
U total	3.35E+02	100.0000	17/03/97		
Np237			17/03/97	gamma	BDL
Pu238	4.60E-01	3.3241	09/04/97	TIMS	
Pu239	4.92E+00	35.3485	09/04/97	TIMS	
Pu240	4.91E+00	35.1348	09/04/97	TIMS	
Pu241	2.07E+00	14.7577	09/04/97	TIMS	
Pu242	1.61E+00	11.4329	09/04/97	TIMS	
Pu244	2.84E-04	0.0020	09/04/97	TIMS	
Pu total	1.40E+01	100.0000	09/04/97		
Am241	6.46E-01	61.139	17/03/97	TIMS	
Am242m	5.87E-03	0.553	17/03/97	TIMS	
Am243	4.08E-01	38.308	17/03/97	TIMS	
Am total	1.06E+00	100.000	17/03/97		
Cm242	1.25E-04	0.049	04/06/97	alpha	
Cm243	3.28E-03	1.294	04/06/97	gamma	
Cm244	2.22E-01	87.088	04/06/97	alpha	
Cm245	2.67E-02	10.436	04/06/97	TIMS	
Cm246	2.91E-03	1.133	04/06/97	TIMS	
Cm Total	2.55E-01	100.000	04/06/97		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 2 - Results of analysis

Sample reference: BM1
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	3.32E-03		28/02/97	gamma	
Ce total					
Nd142	7.47E-03	0.433	17/03/97	TIMS	
Nd143	3.73E-01	21.493	17/03/97	TIMS	
Nd144	4.90E-01	28.029	17/03/97	TIMS	
Nd145	2.91E-01	16.498	17/03/97	TIMS	
Nd146	3.07E-01	17.300	17/03/97	TIMS	
Nd148	1.84E-01	10.226	17/03/97	TIMS	
Nd150	1.10E-01	6.020	17/03/97	TIMS	
Nd total	1.76E+00	100.000	17/03/97		
Pm147	2.66E-02		08/04/97	beta	
Sm147	9.82E-02	22.723	18/04/97	TIMS	
Sm148	7.83E-02	18.009	18/04/97	TIMS	
Sm149	2.09E-03	0.477	18/04/97	TIMS	
Sm150	1.50E-01	34.018	18/04/97	TIMS	
Sm151	9.92E-03	2.237	18/04/97	TIMS	
Sm152	6.81E-02	15.250	18/04/97	TIMS	
Sm154	3.30E-02	7.286	18/04/97	TIMS	
Sm total	4.40E-01	100.000	18/04/97		
Eu151	3.52E-04	0.355	23/04/97	TIMS	
Eu153	8.12E-02	80.690	23/04/97	TIMS	
Eu154	1.53E-02	15.113	23/04/97	gamma	
Eu155	3.92E-03	3.842	23/04/97	gamma	
Eu total	1.01E-01	100.000	23/04/97		
Gd154					NC
Gd155	2.76E-03		04/04/97	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	1.48E-01		24/06/97	beta	
Mo95	2.34E-01		10/04/00	ICP-MS	
Tc99	2.33E-01		10/04/00	ICP-MS	
Ru101	1.30E-01		10/04/00	ICP-MS	
Ru106	2.60E-03		28/02/97	gamma	
Rh103	1.23E-01		10/04/00	ICP-MS	
Ag109	2.99E-02		10/04/00	ICP-MS	
Sb125	1.01E-03		28/02/97	gamma	
I129 (**)					NC
Cs133	5.49E-01	37.646	30/05/97	TIMS	
Cs134	1.55E-02	1.056	30/05/97	TIMS	
Cs135	3.50E-01	23.680	30/05/97	TIMS	
Cs137	5.65E-01	37.618	30/05/97	gamma	
Cs total	1.48E+00	100.000	30/05/97		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 3 - Results of analysis

Sample reference: BM5'
Laboratory : SCK-CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	4.20E+00	0.0063	12/10/99	TIMS	
U235	4.96E+01	0.0744	12/10/99	TIMS	
U236	2.28E+01	0.0340	12/10/99	TIMS	
U238	6.74E+04	99.8853	12/10/99	TIMS	
U total	6.75E+04	100.0000	12/10/99		
Np237	1.55E+01		22/12/99	ICP-MS	
Pu238	8.42E+01	3.4453	11/10/99	TIMS	
Pu239	8.29E+02	33.7901	11/10/99	TIMS	
Pu240	8.51E+02	34.5428	11/10/99	TIMS	
Pu241	3.89E+02	15.7310	11/10/99	TIMS	
Pu242	3.10E+02	12.4873	11/10/99	TIMS	
Pu244	8.47E-02	0.0034	11/10/99	TIMS	
Pu total	2.46E+03	100.0000	11/10/99		
Am241	9.56E+01	54.602	20/12/99	TIMS	
Am242m	8.98E-01	0.511	20/12/99	TIMS	
Am243	7.92E+01	44.887	20/12/99	TIMS	
Am total	1.76E+02	100.000	20/12/99		
Cm242	1.26E-01	0.184	01/07/99	alpha	
Cm243	5.84E-01	0.849	01/07/99	gamma	
Cm244	5.97E+01	86.577	01/07/99	alpha	
Cm245	7.41E+00	10.688	01/07/99	TIMS	
Cm246	1.18E+00	1.702	01/07/99	TIMS	
Cm Total	6.90E+01	100.000	01/07/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 4 - Results of analysis

Sample reference: BM5'
Laboratory: SCK-CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.42E+00		01/07/99	gamma	
Ce total					
Nd142	2.51E+00	0.574	23/11/99	TIMS	
Nd143	8.78E+01	19.919	23/11/99	TIMS	
Nd144	1.31E+02	29.433	23/11/99	TIMS	
Nd145	7.11E+01	15.904	23/11/99	TIMS	
Nd146	8.10E+01	17.996	23/11/99	TIMS	
Nd148	4.64E+01	10.175	23/11/99	TIMS	
Nd150	2.77E+01	5.999	23/11/99	TIMS	
Nd total	4.47E+02	100.000	23/11/99		
Pm147	6.19E+00		03/03/00	beta	
Sm147	1.98E+01	19.640	13/12/99	TIMS	
Sm148	2.29E+01	22.635	13/12/99	TIMS	
Sm149	3.45E-01	0.338	13/12/99	TIMS	
Sm150	3.66E+01	35.622	13/12/99	TIMS	
Sm151	1.85E+00	1.791	13/12/99	TIMS	
Sm152	1.34E+01	12.857	13/12/99	TIMS	
Sm154	7.50E+00	7.117	13/12/99	TIMS	
Sm total	1.02E+02	100.000	13/12/99		
Eu151	6.56E-02	0.265	01/07/99	TIMS	
Eu153	1.97E+01	78.322	01/07/99	TIMS	
Eu154	4.28E+00	16.921	01/07/99	gamma	
Eu155	1.14E+00	4.493	01/07/99	gamma	
Eu total	2.51E+01	100.000	01/07/99		
Gd154					NC
Gd155	6.21E-01		02/12/99	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	2.66E+01		16/05/00	beta	
Mo95	7.29E+01		10/04/00	ICP-MS	
Tc99	7.95E+01		10/04/00	ICP-MS	
Ru101	6.53E+01		10/04/00	ICP-MS	
Ru106	1.77E+00		01/07/99	gamma	
Rh103	5.12E+01		10/04/00	ICP-MS	
Ag109	1.27E+01		10/04/00	ICP-MS	
Sb125	2.36E-01		01/07/99	gamma	
I129 (**)	8.08E+01		24/12/99	ICP-MS	
Cs133	1.29E+02	35.912	01/07/99	TIMS	
Cs134	6.26E+00	1.734	01/07/99	TIMS	
Cs135	8.77E+01	24.120	01/07/99	TIMS	
Cs137	1.41E+02	38.235	01/07/99	gamma	
Cs total	3.64E+02	100.000	01/07/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 5 - Results of analysis

Sample reference: GU1
Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	6.26E-02	0.0132	09/04/97	TIMS	
U235	1.10E+00	0.2302	09/04/97	TIMS	
U236	2.52E+00	0.5261	09/04/97	TIMS	
U238	4.79E+02	99.2305	09/04/97	TIMS	
U total	4.83E+02	100.0000	09/04/97		
Np237			09/04/97	gamma	BDL
Pu238	2.36E-01	3.9760	22/04/97	TIMS	
Pu239	2.54E+00	42.6120	22/04/97	TIMS	
Pu240	1.65E+00	27.5649	22/04/97	TIMS	
Pu241	7.53E-01	12.5072	22/04/97	TIMS	
Pu242	8.06E-01	13.3375	22/04/97	TIMS	
Pu244	1.52E-04	0.0025	22/04/97	TIMS	
Pu total	5.99E+00	100.0000	22/04/97		
Am241	1.29E-01	38.309	09/04/97	TIMS	
Am242m	3.57E-04	0.105	09/04/97	TIMS	
Am243	2.10E-01	61.586	09/04/97	TIMS	
Am total	3.40E-01	100.000	09/04/97		
Cm242	1.60E-04	0.116	04/06/97	alpha	
Cm243	1.76E-04	0.127	04/06/97	gamma	
Cm244	1.27E-01	91.288	04/06/97	alpha	
Cm245	9.07E-03	6.501	04/06/97	TIMS	
Cm246	2.76E-03	1.967	04/06/97	TIMS	
Cm Total	1.39E-01	100.000	04/06/97		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 6 - Results of analysis

Sample reference: GU1
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.75E-02		28/02/97	gamma	
Ce total					
Nd142	3.52E-02	0.986	09/04/97	TIMS	
Nd143	4.86E-01	13.498	09/04/97	TIMS	
Nd144	1.37E+00	37.887	09/04/97	TIMS	
Nd145	5.43E-01	14.866	09/04/97	TIMS	
Nd146	6.90E-01	18.766	09/04/97	TIMS	
Nd148	3.47E-01	9.316	09/04/97	TIMS	
Nd150	1.77E-01	4.681	09/04/97	TIMS	
Nd total	3.65E+00	100.000	09/04/97		
Pm147	3.31E-02		29/04/97	beta	
Sm147	1.16E-01	17.161	23/04/97	TIMS	
Sm148	1.69E-01	24.847	23/04/97	TIMS	
Sm149	1.71E-03	0.250	23/04/97	TIMS	
Sm150	2.64E-01	38.433	23/04/97	TIMS	
Sm151	6.79E-03	0.980	23/04/97	TIMS	
Sm152	8.65E-02	12.398	23/04/97	TIMS	
Sm154	4.19E-02	5.930	23/04/97	TIMS	
Sm total	6.86E-01	100.000	23/04/97		
Eu151	3.74E-04	0.287	23/04/97	TIMS	
Eu153	1.09E-01	82.659	23/04/97	TIMS	
Eu154	1.68E-02	12.654	23/04/97	gamma	
Eu155	5.88E-03	4.400	23/04/97	gamma	
Eu total	1.32E-01	100.000	23/04/97		
Gd154					NC
Gd155	2.93E-03		20/04/97	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	5.06E-01		24/06/97	beta	
Mo95	4.22E-01		10/04/00	ICP-MS	
Tc99	3.61E-01		10/04/00	ICP-MS	
Ru101	2.06E-01		10/04/00	ICP-MS	
Ru106	7.58E-03		28/02/97	gamma	
Rh103	1.21E-01		10/04/00	ICP-MS	
Ag109	5.83E-03		10/04/00	ICP-MS	
Sb125	1.95E-03		28/02/97	gamma	
I129 (**)					NC
Cs133	8.95E-01	39.958	30/05/97	TIMS	
Cs134	5.65E-02	2.502	30/05/97	TIMS	
Cs135	2.69E-01	11.813	30/05/97	TIMS	
Cs137	1.06E+00	45.727	30/05/97	gamma	
Cs total	2.28E+00	100.000	30/05/97		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 7 - Results of analysis

Sample reference: GU3'
Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	9.19E+00	0.0152	12/10/99	TIMS	
U235	3.96E+02	0.6532	12/10/99	TIMS	
U236	3.69E+02	0.6072	12/10/99	TIMS	
U238	6.05E+04	98.7243	12/10/99	TIMS	
U total	6.13E+04	100.0000	12/10/99		
Np237	5.26E+01		22/12/99	ICP-MS	
Pu238	2.47E+01	3.2560	11/10/99	TIMS	
Pu239	3.80E+02	50.0084	11/10/99	TIMS	
Pu240	1.85E+02	24.2636	11/10/99	TIMS	
Pu241	1.06E+02	13.8700	11/10/99	TIMS	
Pu242	6.62E+01	8.6005	11/10/99	TIMS	
Pu244	1.21E-02	0.0016	11/10/99	TIMS	
Pu total	7.63E+02	100.0000	11/10/99		
Am241	1.46E+01	48.538	21/12/99	TIMS	
Am242m	6.01E-02	0.199	21/12/99	TIMS	
Am243	1.55E+01	51.263	21/12/99	TIMS	
Am total	3.02E+01	100.000	21/12/99		
Cm242	7.29E-02	0.792	01/07/99	alpha	
Cm243	3.88E-02	0.420	01/07/99	gamma	
Cm244	8.44E+00	90.977	01/07/99	alpha	
Cm245	6.34E-01	6.805	01/07/99	TIMS	
Cm246	9.41E-02	1.006	01/07/99	TIMS	
Cm Total	9.28E+00	100.000	01/07/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 8 - Results of analysis

Sample reference: GU3'
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	4.69E+00		01/07/99	gamma	
Ce total					
Nd142	2.77E+00	0.689	24/11/99	TIMS	
Nd143	7.01E+01	17.330	24/11/99	TIMS	
Nd144	1.41E+02	34.519	24/11/99	TIMS	
Nd145	6.47E+01	15.780	24/11/99	TIMS	
Nd146	7.48E+01	18.111	24/11/99	TIMS	
Nd148	3.84E+01	9.168	24/11/99	TIMS	
Nd150	1.87E+01	4.403	24/11/99	TIMS	
Nd total	4.10E+02	100.000	24/11/99		
Pm147	6.12E+00		03/03/00	beta	
Sm147	1.28E+01	18.042	13/12/99	TIMS	
Sm148	1.66E+01	23.207	13/12/99	TIMS	
Sm149	2.20E-01	0.305	13/12/99	TIMS	
Sm150	2.92E+01	40.232	13/12/99	TIMS	
Sm151	9.46E-01	1.295	13/12/99	TIMS	
Sm152	8.74E+00	11.884	13/12/99	TIMS	
Sm154	3.75E+00	5.035	13/12/99	TIMS	
Sm total	7.23E+01	100.000	13/12/99		
Eu151	2.75E-02	0.185	01/07/99	TIMS	
Eu153	1.21E+01	80.010	01/07/99	TIMS	
Eu154	2.27E+00	14.958	01/07/99	gamma	
Eu155	7.40E-01	4.847	01/07/99	gamma	
Eu total	1.51E+01	100.000	01/07/99		
Gd154					NC
Gd155	2.53E-01		01/12/99	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	4.68E+01		16/05/00	beta	
Mo95	7.19E+01		10/04/00	ICP-MS	
Tc99	7.39E+01		10/04/00	ICP-MS	
Ru101	6.30E+01		10/04/00	ICP-MS	
Ru106	3.35E+00		01/07/99	gamma	
Rh103	3.43E+01		10/04/00	ICP-MS	
Ag109	5.65E+00		10/04/00	ICP-MS	
Sb125	2.75E-01		01/07/99	gamma	
I129 (**)	5.81E+01		24/12/99	ICP-MS	
Cs133	1.03E+02	40.332	01/07/99	TIMS	
Cs134	8.11E+00	3.158	01/07/99	TIMS	
Cs135	3.01E+01	11.623	01/07/99	TIMS	
Cs137	1.18E+02	44.887	01/07/99	gamma	
Cs total	2.59E+02	100.000	01/07/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 9 - Results of analysis

Sample reference: DM1

Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	6.30E+00	0.0081	06/05/96	TIMS	
U235	4.41E+01	0.0568	06/05/96	TIMS	
U236	2.90E+01	0.0371	06/05/96	TIMS	
U238	7.87E+04	99.8980	06/05/96	TIMS	
U total	7.87E+04	100.0000	06/05/96		
Np237	1.26E+01		18/02/97	gamma	
Pu238	1.05E+02	4.1286	03/05/96	TIMS	
Pu239	5.36E+02	21.0083	03/05/96	TIMS	
Pu240	1.00E+03	39.0524	03/05/96	TIMS	
Pu241	3.51E+02	13.6399	03/05/96	TIMS	
Pu242	5.72E+02	22.1670	03/05/96	TIMS	
Pu244	9.89E-02	0.0038	03/05/96	TIMS	
Pu total	2.56E+03	100.0000	03/05/96		
Am241	8.54E+01	39.319	18/06/96	TIMS	
Am242m	5.73E-01	0.263	18/06/96	TIMS	
Am243	1.32E+02	60.418	18/06/96	TIMS	
Am total	2.18E+02	100.000	18/06/96		
Cm242	7.41E-02	0.081	17/06/96	alpha	
Cm243	5.52E-01	0.600	17/06/96	gamma	
Cm244	8.38E+01	90.703	17/06/96	alpha	
Cm245	6.40E+00	6.902	17/06/96	TIMS	
Cm246	1.60E+00	1.714	17/06/96	TIMS	
Cm Total	9.24E+01	100.000	17/06/96		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 10 - Results of analysis

Sample reference: DM1
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.67E+00		13/03/96	gamma	
Ce total					
Nd142	5.04E+00	0.899	18/10/96	TIMS	
Nd143	9.87E+01	17.464	18/10/96	TIMS	
Nd144	1.81E+02	31.905	18/10/96	TIMS	
Nd145	9.10E+01	15.879	18/10/96	TIMS	
Nd146	1.02E+02	17.755	18/10/96	TIMS	
Nd148	5.93E+01	10.135	18/10/96	TIMS	
Nd150	3.53E+01	5.963	18/10/96	TIMS	
Nd total	5.73E+02	100.000	18/10/96		
Pm147					NC
Sm147	2.85E+01	21.800	02/12/96	TIMS	
Sm148	2.54E+01	19.263	02/12/96	TIMS	
Sm149	4.58E-01	0.345	02/12/96	TIMS	
Sm150	4.70E+01	35.208	02/12/96	TIMS	
Sm151	1.48E+00	1.104	02/12/96	TIMS	
Sm152	2.03E+01	15.014	02/12/96	TIMS	
Sm154	9.96E+00	7.267	02/12/96	TIMS	
Sm total	1.33E+02	100.000	02/12/96		
Eu151	8.46E-02	0.289	03/12/96	TIMS	
Eu153	2.45E+01	82.694	03/12/96	TIMS	
Eu154	3.75E+00	12.583	03/12/96	gamma	
Eu155	1.33E+00	4.434	03/12/96	gamma	
Eu total	2.97E+01	100.000	03/12/96		
Gd154					NC
Gd155	1.02E+00		24/06/96	TIMS	(not scheduled)
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90					NC
Mo95	6.63E+01		10/04/00	ICP-MS	(not scheduled)
Tc99	4.94E+01		10/04/00	ICP-MS	
Ru101	3.78E+01		10/04/00	ICP-MS	(not scheduled)
Ru106	1.37E+00		13/03/96	gamma	(not scheduled)
Rh103	3.06E+01		10/04/00	ICP-MS	(not scheduled)
Ag109	9.15E+00		10/04/00	ICP-MS	(not scheduled)
Sb125	3.76E-01		13/03/96	gamma	(not scheduled)
I129 (**)	9.26E+01		01/11/96	gamma	
Cs133	1.66E+02	39.187	30/09/96	TIMS	
Cs134	5.64E+00	1.318	30/09/96	TIMS	
Cs135	8.05E+01	18.661	30/09/96	TIMS	
Cs137	1.79E+02	40.834	30/09/96	gamma	
Cs total	4.31E+02	100.000	30/09/96		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 11 - Results of analysis

Sample reference: DM2
Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	7.17E+00	0.0093	06/05/96	TIMS	
U235	8.65E+01	0.1117	06/05/96	TIMS	
U236	2.04E+01	0.0262	06/05/96	TIMS	
U238	7.83E+04	99.8529	06/05/96	TIMS	
U total	7.85E+04	100.0000	06/05/96		
Np237	8.33E+00		06/02/97	gamma	
Pu238	9.80E+01	3.1928	14/05/96	TIMS	
Pu239	7.99E+02	25.9395	14/05/96	TIMS	
Pu240	1.40E+03	45.1373	14/05/96	TIMS	
Pu241	3.65E+02	11.7503	14/05/96	TIMS	
Pu242	4.36E+02	13.9789	14/05/96	TIMS	
Pu244	3.77E-02	0.0012	14/05/96	TIMS	
Pu total	3.09E+03	100.0000	14/05/96		
Am241	1.36E+02	67.571	18/06/96	TIMS	
Am242m	9.09E-01	0.449	18/06/96	TIMS	
Am243	6.51E+01	31.980	18/06/96	TIMS	
Am total	2.02E+02	100.000	18/06/96		
Cm242	1.52E-02	0.083	17/06/96	alpha	
Cm243	3.37E-01	1.844	17/06/96	gamma	
Cm244	1.71E+01	93.119	17/06/96	alpha	
Cm245	8.11E-01	4.395	17/06/96	TIMS	
Cm246	1.03E-01	0.559	17/06/96	TIMS	
Cm Total	1.84E+01	100.000	17/06/96		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 12 - Results of analysis

Sample reference: DM2
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	4.20E-01		13/03/96	gamma	
Ce total					
Nd142	1.07E+00	0.322	18/11/96	TIMS	
Nd143	7.22E+01	21.477	18/11/96	TIMS	
Nd144	9.63E+01	28.455	18/11/96	TIMS	
Nd145	5.90E+01	17.304	18/11/96	TIMS	
Nd146	5.61E+01	16.353	18/11/96	TIMS	
Nd148	3.53E+01	10.155	18/11/96	TIMS	
Nd150	2.09E+01	5.934	18/11/96	TIMS	
Nd total	3.41E+02	100.000	18/11/96		
Pm147	4.68E+00		31/01/97	beta	
Sm147	2.59E+01	30.000	11/12/96	TIMS	
Sm148	8.96E+00	10.327	11/12/96	TIMS	
Sm149	2.67E-01	0.306	11/12/96	TIMS	
Sm150	2.73E+01	31.020	11/12/96	TIMS	
Sm151	1.32E+00	1.490	11/12/96	TIMS	
Sm152	1.82E+01	20.408	11/12/96	TIMS	
Sm154	5.82E+00	6.449	11/12/96	TIMS	
Sm total	8.77E+01	100.000	11/12/96		
Eu151	7.49E-02	0.453	15/01/97	TIMS	
Eu153	1.47E+01	87.576	15/01/97	TIMS	
Eu154	1.45E+00	8.579	15/01/97	gamma	
Eu155	5.76E-01	3.392	15/01/97	gamma	
Eu total	1.68E+01	100.000	15/01/97		
Gd154					NC
Gd155	4.90E-01		24/06/96	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	2.71E+01		24/06/97	beta	
Mo95	5.15E+01		10/04/00	ICP-MS	
Tc99	4.68E+01		10/04/00	ICP-MS	
Ru101	3.81E+01		10/04/00	ICP-MS	
Ru106	5.56E-01		13/03/96	gamma	
Rh103	3.31E+01		10/04/00	ICP-MS	
Ag109	1.05E+01		10/04/00	ICP-MS	
Sb125	2.55E-01		13/03/96	gamma	
I129 (**)	4.91E+01		01/11/96	gamma	
Cs133	1.14E+02	41.876	30/09/96	TIMS	
Cs134	1.24E+00	0.451	30/09/96	TIMS	
Cs135	5.41E+01	19.585	30/09/96	TIMS	
Cs137	1.07E+02	38.088	30/09/96	gamma	
Cs total	2.76E+02	100.000	30/09/96		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 13 - Results of analysis

Sample reference: DM3

Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	8.40E+00	0.0111	23/12/97	TIMS	
U235	6.51E+01	0.0854	23/12/97	TIMS	
U236	2.58E+01	0.0337	23/12/97	TIMS	
U238	7.71E+04	99.8699	23/12/97	TIMS	
U total	7.72E+04	100.0000	23/12/97		
Np237	1.13E+01		01/08/98	gamma	
Pu238	1.04E+02	3.7073	16/12/97	TIMS	
Pu239	6.97E+02	24.8124	16/12/97	TIMS	
Pu240	1.17E+03	41.5306	16/12/97	TIMS	
Pu241	3.63E+02	12.8112	16/12/97	TIMS	
Pu242	4.88E+02	17.1352	16/12/97	TIMS	
Pu244	9.47E-02	0.0033	16/12/97	TIMS	
Pu total	2.82E+03	100.0000	16/12/97		
Am241	1.51E+02	58.427	03/12/97	TIMS	
Am242m	6.84E-01	0.264	03/12/97	TIMS	
Am243	1.07E+02	41.309	03/12/97	TIMS	
Am total	2.59E+02	100.000	03/12/97		
Cm242	7.23E-03	0.013	06/12/97	alpha	
Cm243	6.24E-01	1.112	06/12/97	gamma	
Cm244	5.07E+01	90.022	06/12/97	alpha	
Cm245	4.32E+00	7.632	06/12/97	TIMS	
Cm246	6.94E-01	1.220	06/12/97	TIMS	
Cm Total	5.64E+01	100.000	06/12/97		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 14 - Results of analysis

Sample reference: DM3

Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.72E-01		14/11/97	gamma	
Ce total					
Nd142	2.06E+00	0.463	11/02/98	TIMS	
Nd143	8.90E+01	19.853	11/02/98	TIMS	
Nd144	1.35E+02	29.848	11/02/98	TIMS	
Nd145	7.49E+01	16.476	11/02/98	TIMS	
Nd146	7.85E+01	17.144	11/02/98	TIMS	
Nd148	4.75E+01	10.242	11/02/98	TIMS	
Nd150	2.81E+01	5.974	11/02/98	TIMS	
Nd total	4.55E+02	100.000	11/02/98		
Pm147					NC
Sm147	2.88E+01	25.862	05/02/98	TIMS	
Sm148	1.75E+01	15.615	05/02/98	TIMS	
Sm149	3.31E-01	0.294	05/02/98	TIMS	
Sm150	3.86E+01	34.003	05/02/98	TIMS	
Sm151	1.57E+00	1.371	05/02/98	TIMS	
Sm152	1.84E+01	15.994	05/02/98	TIMS	
Sm154	8.00E+00	6.861	05/02/98	TIMS	
Sm total	1.13E+02	100.000	05/02/98		
Eu151	7.74E-02	0.327	03/02/98	TIMS	
Eu153	2.06E+01	86.081	03/02/98	TIMS	
Eu154	2.57E+00	10.659	03/02/98	gamma	
Eu155	7.12E-01	2.933	03/02/98	gamma	
Eu total	2.40E+01	100.000	03/02/98		
Gd154					NC
Gd155					NC
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90					NC
Mo95	6.01E+01		10/04/00	ICP-MS	(not scheduled)
Tc99	4.51E+01		10/04/00	ICP-MS	
Ru101	3.42E+01		10/04/00	ICP-MS	(not scheduled)
Ru106					NC
Rh103	2.84E+01		10/04/00	ICP-MS	(not scheduled)
Ag109	1.31E+01		10/04/00	ICP-MS	(not scheduled)
Sb125					NC
I129 (**)	8.98E+01		24/12/99	ICP-MS	
Cs133	1.42E+02	40.861	14/11/97	TIMS	
Cs134	2.07E+00	0.594	14/11/97	TIMS	
Cs135	6.84E+01	19.431	14/11/97	TIMS	
Cs137	1.40E+02	39.114	14/11/97	gamma	
Cs total	3.52E+02	100.000	14/11/97		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 15 - Results of analysis

Sample reference: DM4

Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	8.50E+00	0.0114	23/12/97	TIMS	
U235	8.31E+01	0.1105	23/12/97	TIMS	
U236	2.20E+01	0.0291	23/12/97	TIMS	
U238	7.61E+04	99.8490	23/12/97	TIMS	
U total	7.62E+04	100.0000	23/12/97		
Np237	9.03E+00		01/08/98	gamma	
Pu238	1.10E+02	3.6102	16/12/97	TIMS	
Pu239	8.70E+02	28.5356	16/12/97	TIMS	
Pu240	1.28E+03	41.8780	16/12/97	TIMS	
Pu241	3.84E+02	12.4862	16/12/97	TIMS	
Pu242	4.16E+02	13.4866	16/12/97	TIMS	
Pu244	1.03E-01	0.0033	16/12/97	TIMS	
Pu total	3.06E+03	100.0000	16/12/97		
Am241	1.56E+02	65.520	03/12/97	TIMS	
Am242m	1.14E+00	0.476	03/12/97	TIMS	
Am243	8.16E+01	34.004	03/12/97	TIMS	
Am total	2.39E+02	100.000	03/12/97		
Cm242	1.21E-02	0.037	06/12/97	alpha	
Cm243	4.25E-01	1.293	06/12/97	gamma	
Cm244	3.02E+01	91.356	06/12/97	alpha	
Cm245	2.19E+00	6.622	06/12/97	TIMS	
Cm246	2.30E-01	0.692	06/12/97	TIMS	
Cm Total	3.30E+01	100.000	06/12/97		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 16 - Results of analysis

Sample reference: DM4

Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	2.59E-01		14/11/97	gamma	
Ce total					
Nd142	1.40E+00	0.402	17/02/98	TIMS	
Nd143	7.52E+01	21.505	17/02/98	TIMS	
Nd144	1.00E+02	28.479	17/02/98	TIMS	
Nd145	6.05E+01	17.050	17/02/98	TIMS	
Nd146	5.98E+01	16.742	17/02/98	TIMS	
Nd148	3.64E+01	10.045	17/02/98	TIMS	
Nd150	2.12E+01	5.776	17/02/98	TIMS	
Nd total	3.55E+02	100.000	17/02/98		
Pm147					NC
Sm147	2.52E+01	27.815	09/02/98	TIMS	
Sm148	1.19E+01	13.080	09/02/98	TIMS	
Sm149	3.19E-01	0.347	09/02/98	TIMS	
Sm150	2.95E+01	31.914	09/02/98	TIMS	
Sm151	1.60E+00	1.715	09/02/98	TIMS	
Sm152	1.70E+01	18.154	09/02/98	TIMS	
Sm154	6.63E+00	6.976	09/02/98	TIMS	
Sm total	9.23E+01	100.000	09/02/98		
Eu151	8.03E-02	0.435	03/02/98	TIMS	
Eu153	1.61E+01	86.003	03/02/98	TIMS	
Eu154	1.96E+00	10.412	03/02/98	gamma	
Eu155	5.97E-01	3.150	03/02/98	gamma	
Eu total	1.87E+01	100.000	03/02/98		
Gd154					NC
Gd155					NC
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90					NC
Mo95	5.41E+01		10/04/00	ICP-MS	(not scheduled)
Tc99	5.80E+01		10/04/00	ICP-MS	
Ru101	4.45E+01		10/04/00	ICP-MS	(not scheduled)
Ru106					NC
Rh103	3.90E+01		10/04/00	ICP-MS	(not scheduled)
Ag109	1.22E+01		10/04/00	ICP-MS	(not scheduled)
Sb125					NC
I129 (**)	6.54E+01		24/12/99	ICP-MS	
Cs133	1.17E+02	39.690	14/11/97	TIMS	
Cs134	1.62E+00	0.548	14/11/97	TIMS	
Cs135	6.91E+01	23.173	14/11/97	TIMS	
Cs137	1.11E+02	36.589	14/11/97	gamma	
Cs total	2.98E+02	100.000	14/11/97		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 17 - Results of analysis

Sample reference: DU1

Laboratory: SCK - CEN Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232				ICP-MS	BDL
U234	1.06E+01	0.0155	06/05/96	TIMS	
U235	4.33E+02	0.6295	06/05/96	TIMS	
U236	5.35E+02	0.7734	06/05/96	TIMS	
U238	6.87E+04	98.5816	06/05/96	TIMS	
U total	6.97E+04	100.0000	06/05/96		
Np237	5.32E+01		13/02/97	gamma	
Pu238	2.29E+01	3.5195	12/04/96	TIMS	
Pu239	2.92E+02	44.5397	12/04/96	TIMS	
Pu240	2.04E+02	31.0455	12/04/96	TIMS	
Pu241	7.39E+01	11.2034	12/04/96	TIMS	
Pu242	6.42E+01	9.6910	12/04/96	TIMS	
Pu244	6.01E-03	0.0009	12/04/96	TIMS	
Pu total	6.57E+02	100.0000	12/04/96		
Am241	1.55E+01	54.448	18/06/96	TIMS	
Am242m	5.12E-02	0.180	18/06/96	TIMS	
Am243	1.30E+01	45.372	18/06/96	TIMS	
Am total	2.85E+01	100.000	18/06/96		
Cm242	7.92E-03	0.149	17/06/96	alpha	
Cm243	3.76E-02	0.705	17/06/96	gamma	
Cm244	5.01E+00	93.446	17/06/96	alpha	
Cm245	2.52E-01	4.672	17/06/96	TIMS	
Cm246	5.56E-02	1.028	17/06/96	TIMS	
Cm Total	5.37E+00	100.000	17/06/96		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 18 - Results of analysis

Sample reference: DU1
Laboratory: SCK - CEN Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.60E+00		13/03/96	gamma	
Ce total					
Nd142	4.22E+00	0.834	16/10/96	TIMS	
Nd143	7.90E+01	15.488	16/10/96	TIMS	
Nd144	1.91E+02	37.239	16/10/96	TIMS	
Nd145	8.21E+01	15.880	16/10/96	TIMS	
Nd146	9.16E+01	17.601	16/10/96	TIMS	
Nd148	4.64E+01	8.801	16/10/96	TIMS	
Nd150	2.22E+01	4.157	16/10/96	TIMS	
Nd total	5.17E+02	100.000	16/10/96		
Pm147	5.82E+00		31/01/97	beta	
Sm147	2.33E+01	25.214	27/11/96	TIMS	
Sm148	1.98E+01	21.318	27/11/96	TIMS	
Sm149	2.26E-01	0.241	27/11/96	TIMS	
Sm150	3.32E+01	35.213	27/11/96	TIMS	
Sm151	8.10E-01	0.853	27/11/96	TIMS	
Sm152	1.21E+01	12.689	27/11/96	TIMS	
Sm154	4.33E+00	4.473	27/11/96	TIMS	
Sm total	9.39E+01	100.000	27/11/96		
Eu151	5.15E-02	0.334	28/11/96	TIMS	
Eu153	1.32E+01	84.871	28/11/96	TIMS	
Eu154	1.67E+00	10.661	28/11/96	gamma	
Eu155	6.54E-01	4.134	28/11/96	gamma	
Eu total	1.56E+01	100.000	28/11/96		
Gd154					NC
Gd155	4.24E-01		24/06/96	TIMS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	7.72E+01		24/06/97	beta	
Mo95	1.03E+02		10/04/00	ICP-MS	
Tc99	9.69E+01		10/04/00	ICP-MS	
Ru101	8.54E+01		10/04/00	ICP-MS	
Ru106	1.29E+00		13/03/96	gamma	
Rh103	4.30E+01		10/04/00	ICP-MS	
Ag109	3.99E+00		10/04/00	ICP-MS	
Sb125	2.50E-01		13/03/96	gamma	
I129 (**)	5.20E+01		01/11/96	gamma	
Cs133	1.28E+02	41.914	01/10/96	TIMS	
Cs134	4.21E+00	1.369	01/10/96	TIMS	
Cs135	4.33E+01	13.992	01/10/96	TIMS	
Cs137	1.34E+02	42.725	01/10/96	gamma	
Cs total	3.10E+02	100.000	01/10/96		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 19 - Results of analysis

Sample reference: BM1

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	3.24E-02	0.0095	30/10/98	HPLC-ICP-MS	
U235	3.74E-01	0.1092	30/10/98	HPLC-ICP-MS	
U236	1.12E-01	0.0324	30/10/98	HPLC-ICP-MS	
U238	3.47E+02	99.8489	30/10/98	HPLC-ICP-MS	
U total	3.47E+02	100.0000	30/10/98		
Np237	6.52E-02		15-09-99	ICP-MS	(not scheduled)
Pu238	4.31E-01	3.2701	17/11/98	HPLC-ICP-MS	
Pu239	4.76E+00	36.0211	17/11/98	HPLC-ICP-MS	
Pu240	4.70E+00	35.4161	17/11/98	HPLC-ICP-MS	
Pu241	1.87E+00	14.0024	17/11/98	HPLC-ICP-MS	
Pu242	1.51E+00	11.2903	17/11/98	HPLC-ICP-MS	
Pu244			17/11/98	HPLC-ICP-MS	BDL
Pu total	1.33E+01	100.0000	17/11/98		
Am241	1.04E+00	68.020	02/12/99	HPLC-ICP-MS	(not scheduled)
Am242m	6.99E-03	0.455	02/12/99	HPLC-ICP-MS	(not scheduled)
Am243	4.86E-01	31.524	02/12/99	HPLC-ICP-MS	(not scheduled)
Am total	1.53E+00	100.000	02/12/99		
Cm242			02/12/99	HPLC-ICP-MS	BDL
Cm243			02/12/99	HPLC-ICP-MS	BDL
Cm244	1.99E-01	87.556	02/12/99	HPLC-ICP-MS	(not scheduled)
Cm245	2.55E-02	11.209	02/12/99	HPLC-ICP-MS	(not scheduled)
Cm246	2.82E-03	1.235	02/12/99	HPLC-ICP-MS	(not scheduled)
Cm Total	2.27E-01	100.000	02/12/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 20 - Results of analysis

Sample reference: BM1
Laboratory: PSI Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	3.26E-04		25/09/99	Gamma	(not scheduled)
Ce total					
Nd142	7.16E-03	0.400	20/11/98	HPLC-ICP-MS	
Nd143	3.81E-01	21.113	20/11/98	HPLC-ICP-MS	
Nd144	5.04E-01	27.739	20/11/98	HPLC-ICP-MS	
Nd145	3.03E-01	16.565	20/11/98	HPLC-ICP-MS	
Nd146	3.23E-01	17.524	20/11/98	HPLC-ICP-MS	
Nd148	1.95E-01	10.463	20/11/98	HPLC-ICP-MS	
Nd150	1.17E-01	6.196	20/11/98	HPLC-ICP-MS	
Nd total	1.83E+00	100.000	20/11/98		
Pm147					NC
Sm147	1.12E-01	24.158	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm148	8.37E-02	17.868	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm149	2.18E-03	0.462	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm150	1.60E-01	33.721	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm151	1.03E-02	2.153	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm152	6.96E-02	14.460	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm154	3.50E-02	7.178	02/08/99	HPLC-ICP-MS	(not scheduled)
Sm total	4.73E-01	100.000	02/08/99		
Eu151	6.90E-04	0.672	02/08/99	HPLC-ICP-MS	(not scheduled)
Eu153	8.41E-02	80.873	02/08/99	HPLC-ICP-MS	(not scheduled)
Eu154	1.60E-02	15.238	02/08/99	HPLC-ICP-MS	(not scheduled)
Eu155	3.39E-03	3.216	02/08/99	HPLC-ICP-MS	(not scheduled)
Eu total	1.04E-01	100.000	02/08/99		
Gd154	1.18E-02	11.711	02/08/99	HPLC-ICP-MS	(not scheduled)
Gd155	4.06E-03	4.021	02/08/99	HPLC-ICP-MS	(not scheduled)
Gd156	6.65E-02	65.410	02/08/99	HPLC-ICP-MS	(not scheduled)
Gd157			02/08/99	HPLC-ICP-MS	BDL
Gd158	1.80E-02	17.460	02/08/99	HPLC-ICP-MS	(not scheduled)
Gd160	1.46E-03	1.398	02/08/99	HPLC-ICP-MS	(not scheduled)
Gd total	1.02E-01	100.000	02/08/99		
Sr90	1.22E-01		05/10/99	HPLC-ICP-MS	(not scheduled)
Mo95	2.52E-01		11/01/00	ICP-MS	(not scheduled)
Tc99	2.29E-01		20/01/00	ICP-MS	(not scheduled)
Ru101	1.40E-01		11/01/00	ICP-MS	(not scheduled)
Ru106	4.37E-04		25/09/99	Gamma	(not scheduled)
Rh103	1.42E-01		08/12/99	ICP-MS	(not scheduled)
Ag109	2.99E-02		11/01/00	ICP-MS	(not scheduled)
Sb125	5.64E-04		25/09/99	Gamma	(not scheduled)
I129 (**)					NC
Cs133	6.15E-01	38.074	03/09/99	HPLC-ICP-MS	(not scheduled)
Cs134	8.22E-03	0.505	03/09/99	HPLC-ICP-MS	(not scheduled)
Cs135	4.03E-01	24.537	03/09/99	HPLC-ICP-MS	(not scheduled)
Cs137	6.14E-01	36.884	03/09/99	HPLC-ICP-MS	(not scheduled)
Cs total	1.64E+00	100.000	03/09/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 21 - Results of analysis

Sample reference: BM3

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	2.68E-02	0.0110	30/10/98	HPLC-ICP-MS	
U235	2.76E-01	0.1129	30/10/98	HPLC-ICP-MS	
U236	8.17E-02	0.0333	30/10/98	HPLC-ICP-MS	
U238	2.47E+02	99.8428	30/10/98	HPLC-ICP-MS	
U total	2.48E+02	100.0000	30/10/98		
Np237					NC
Pu238	3.61E-01	3.3646	17/11/98	HPLC-ICP-MS	
Pu239	3.84E+00	35.6487	17/11/98	HPLC-ICP-MS	
Pu240	3.87E+00	35.7679	17/11/98	HPLC-ICP-MS	
Pu241	1.49E+00	13.7125	17/11/98	HPLC-ICP-MS	
Pu242	1.25E+00	11.5064	17/11/98	HPLC-ICP-MS	
Pu244			17/11/98	HPLC-ICP-MS	BDL
Pu total	1.08E+01	100.0000	17/11/98		
Am241					NC
Am242m					NC
Am243					NC
Am total					
Cm242					NC
Cm243					NC
Cm244					NC
Cm245					NC
Cm246					NC
Cm Total					

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 22 - Results of analysis

Sample reference: BM3
Laboratory: PSI — Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144					NC
Ce total					
Nd142	5.53E-03	0.401	20/11/98	HPLC-ICP-MS	
Nd143	2.99E-01	21.557	20/11/98	HPLC-ICP-MS	
Nd144	3.93E-01	28.132	20/11/98	HPLC-ICP-MS	
Nd145	2.31E-01	16.416	20/11/98	HPLC-ICP-MS	
Nd146	2.48E-01	17.464	20/11/98	HPLC-ICP-MS	
Nd148	1.42E-01	9.894	20/11/98	HPLC-ICP-MS	
Nd150	8.94E-02	6.136	20/11/98	HPLC-ICP-MS	
Nd total	1.41E+00	100.000	20/11/98		
Pm147					NC
Sm147					NC
Sm148					NC
Sm149					NC
Sm150					NC
Sm151					NC
Sm152					NC
Sm154					NC
Sm total					
Eu151					NC
Eu153					NC
Eu154					NC
Eu155					NC
Eu total					
Gd154					NC
Gd155					NC
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90					NC
Mo95					NC
Tc99					NC
Ru101					NC
Ru106					NC
Rh103					NC
Ag109					NC
Sb125					NC
I129 (**)					NC
Cs133					NC
Cs134					NC
Cs135					NC
Cs137					NC
Cs total					

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 23 - Results of analysis

Sample reference: BM4-D

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	3.84E-02	0.0106	30/10/98	HPLC-ICP-MS	
U235	5.02E-01	0.1382	30/10/98	HPLC-ICP-MS	
U236	1.05E-01	0.0288	30/10/98	HPLC-ICP-MS	
U238	3.68E+02	99.8224	30/10/98	HPLC-ICP-MS	
U total	3.68E+02	100.0000	30/10/98		
Np237					NC
Pu238	5.02E-01	2.9461	17/11/98	HPLC-ICP-MS	
Pu239	6.72E+00	39.2089	17/11/98	HPLC-ICP-MS	
Pu240	6.09E+00	35.4103	17/11/98	HPLC-ICP-MS	
Pu241	2.23E+00	12.9305	17/11/98	HPLC-ICP-MS	
Pu242	1.65E+00	9.5041	17/11/98	HPLC-ICP-MS	
Pu244			17/11/98	HPLC-ICP-MS	BDL
Pu total	1.72E+01	100.0000	17/11/98		
Am241					NC
Am242m					NC
Am243					NC
Am total					
Cm242					NC
Cm243					NC
Cm244					NC
Cm245					NC
Cm246					NC
Cm Total					

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 24 - Results of analysis

Sample reference: BM4-D
Laboratory: PSI Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144					NC
Ce total					
Nd142	8.93E-03	0.471	20/11/98	HPLC-ICP-MS	
Nd143	4.34E-01	22.749	20/11/98	HPLC-ICP-MS	
Nd144	5.22E-01	27.141	20/11/98	HPLC-ICP-MS	
Nd145	3.28E-01	16.950	20/11/98	HPLC-ICP-MS	
Nd146	3.31E-01	16.971	20/11/98	HPLC-ICP-MS	
Nd148	1.90E-01	9.635	20/11/98	HPLC-ICP-MS	
Nd150	1.22E-01	6.083	20/11/98	HPLC-ICP-MS	
Nd total	1.94E+00	100.000	20/11/98		
Pm147					NC
Sm147					NC
Sm148					NC
Sm149					NC
Sm150					NC
Sm151					NC
Sm152					NC
Sm154					NC
Sm total					
Eu151					NC
Eu153					NC
Eu154					NC
Eu155					NC
Eu total					
Gd154					NC
Gd155					NC
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90					NC
Mo95					NC
Tc99					NC
Ru101					NC
Ru106					NC
Rh103					NC
Ag109					NC
Sb125					NC
I129 (**)					NC
Cs133					NC
Cs134					NC
Cs135					NC
Cs137					NC
Cs total					

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 25 - Results of analysis

Sample reference: BM5

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					not measurable
U234	2.17E-02	0.0057	20/04/99	HPLC-ICP-MS	
U235	3.58E-01	0.0937	20/04/99	HPLC-ICP-MS	
U236	1.30E-01	0.0339	20/04/99	HPLC-ICP-MS	
U238	3.87E+02	99.8668	20/04/99	HPLC-ICP-MS	
U total	3.87E+02	100.0000	20/04/99		
Np237	8.48E-02		15-09-99	ICP-MS	
Pu238	4.19E-01	3.1488	04/05/99	HPLC-ICP-MS	
Pu239	4.48E+00	33.5558	04/05/99	HPLC-ICP-MS	
Pu240	4.65E+00	34.6380	04/05/99	HPLC-ICP-MS	
Pu241	2.16E+00	16.0640	04/05/99	HPLC-ICP-MS	
Pu242	1.70E+00	12.5934	04/05/99	HPLC-ICP-MS	
Pu244			04/05/99	HPLC-ICP-MS	BDL
Pu total	1.34E+01	100.0000	04/05/99		
Am241	5.23E-01	55.406	26/11/99	HPLC-ICP-MS	
Am242m	5.06E-03	0.534	26/11/99	HPLC-ICP-MS	
Am243	4.20E-01	44.060	26/11/99	HPLC-ICP-MS	
Am total	9.48E-01	100.000	26/11/99		
Cm242			26/11/99	HPLC-ICP-MS	BDL
Cm243			26/11/99	HPLC-ICP-MS	BDL
Cm244	3.63E-01	87.623	26/11/99	HPLC-ICP-MS	
Cm245	4.43E-02	10.645	26/11/99	HPLC-ICP-MS	
Cm246	7.24E-03	1.731	26/11/99	HPLC-ICP-MS	
Cm Total	4.15E-01	100.000	26/11/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 26 - Results of analysis

Sample reference: BM5
Laboratory: PSI — Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	6.04E-03		28/09/99	gamma	
Ce total					
Nd142	1.38E-02	0.576	31/05/99	HPLC-ICP-MS	
Nd143	4.65E-01	19.257	31/05/99	HPLC-ICP-MS	
Nd144	7.06E-01	29.034	31/05/99	HPLC-ICP-MS	
Nd145	3.92E-01	15.989	31/05/99	HPLC-ICP-MS	
Nd146	4.56E-01	18.495	31/05/99	HPLC-ICP-MS	
Nd148	2.63E-01	10.535	31/05/99	HPLC-ICP-MS	
Nd150	1.55E-01	6.115	31/05/99	HPLC-ICP-MS	
Nd total	2.45E+00	100.000			
Pm147	3.23E-02		23/12/99	HPLC-ICP-MS	
Sm147	1.19E-01	18.907	09/08/99	HPLC-ICP-MS	
Sm148	1.41E-01	22.274	09/08/99	HPLC-ICP-MS	
Sm149	2.50E-03	0.393	09/08/99	HPLC-ICP-MS	
Sm150	2.28E-01	35.620	09/08/99	HPLC-ICP-MS	
Sm151	1.18E-02	1.837	09/08/99	HPLC-ICP-MS	
Sm152	8.54E-02	13.166	09/08/99	HPLC-ICP-MS	
Sm154	5.13E-02	7.804	09/08/99	HPLC-ICP-MS	
Sm total	6.39E-01	100.000	09/08/99		
Eu151	3.66E-04	0.258	09/08/99	HPLC-ICP-MS	
Eu153	1.12E-01	78.017	09/08/99	HPLC-ICP-MS	
Eu154	2.56E-02	17.682	09/08/99	HPLC-ICP-MS	
Eu155	5.90E-03	4.044	09/08/99	HPLC-ICP-MS	
Eu total	1.44E-01	100.000	09/08/99		
Gd154	1.34E-02	7.819	09/08/99	HPLC-ICP-MS	
Gd155	3.96E-03	2.302	09/08/99	HPLC-ICP-MS	
Gd156	1.26E-01	72.798	09/08/99	HPLC-ICP-MS	
Gd157			09/08/99	HPLC-ICP-MS	BDL
Gd158	2.79E-02	15.904	09/08/99	HPLC-ICP-MS	
Gd160	2.09E-03	1.177	09/08/99	HPLC-ICP-MS	
Gd total	1.73E-01	100.000	09/08/99		
Sr90	1.95E-01		06/10/99	HPLC-ICP-MS	
Mo95	3.79E-01		11/01/00	ICP-MS	
Tc99	3.08E-01		20/01/00	ICP-MS	
Ru101	2.03E-01		11/01/00	ICP-MS	
Ru106	4.69E-03		28/09/99	gamma	
Rh103	1.77E-01		08/12/99	ICP-MS	
Ag109	1.47E-02		11/01/00	ICP-MS	
Sb125	1.24E-03		28/09/99	gamma	
I129 (**)	see Table 3.5/26		06/01/00	gamma	
Cs133	7.67E-01	36.032	02/09/99	HPLC-ICP-MS	
Cs134	3.52E-02	1.640	02/09/99	HPLC-ICP-MS	
Cs135	5.20E-01	24.060	02/09/99	HPLC-ICP-MS	
Cs137	8.39E-01	38.268	02/09/99	HPLC-ICP-MS	
Cs total	2.16E+00	100.000	02/09/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 27 - Results of analysis

Sample reference: BM6

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					not measurable
U234	2.41E-02	0.0063	08/02/00	HPLC-ICP-MS	
U235	4.65E-01	0.1211	08/02/00	HPLC-ICP-MS	
U236	1.02E-01	0.0264	08/02/00	HPLC-ICP-MS	
U238	3.88E+02	99.8463	08/02/00	HPLC-ICP-MS	
U total	3.89E+02	100.0000	08/02/00		
Np237	6.07E-02		15-09-99	ICP-MS	
Pu238	3.80E-01	2.4730	05/05/99	HPLC-ICP-MS	
Pu239	6.45E+00	41.7996	05/05/99	HPLC-ICP-MS	
Pu240	5.28E+00	34.0746	05/05/99	HPLC-ICP-MS	
Pu241	2.22E+00	14.2351	05/05/99	HPLC-ICP-MS	
Pu242	1.16E+00	7.4177	05/05/99	HPLC-ICP-MS	
Pu244				HPLC-ICP-MS	BDL
Pu total	1.55E+01	100.0000	05/05/99		
Am241	8.20E-01	69.389	29/11/99	HPLC-ICP-MS	
Am242m	1.07E-02	0.902	29/11/99	HPLC-ICP-MS	
Am243	3.54E-01	29.709	29/11/99	HPLC-ICP-MS	
Am total	1.18E+00	100.000	29/11/99		
Cm242			29/11/99	HPLC-ICP-MS	BDL
Cm243			29/11/99	HPLC-ICP-MS	BDL
Cm244	1.35E-01	89.685	29/11/99	HPLC-ICP-MS	
Cm245	1.45E-02	9.545	29/11/99	HPLC-ICP-MS	
Cm246	1.17E-03	0.770	29/11/99	HPLC-ICP-MS	
Cm Total	1.51E-01	100.000	29/11/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 28 - Results of analysis

Sample reference: BM6
Laboratory: PSI Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	4.20E-03		26/09/99	gamma	
Ce total					
Nd142	4.54E-03	0.303	27/05/99	HPLC-ICP-MS	
Nd143	3.32E-01	22.022	27/05/99	HPLC-ICP-MS	
Nd144	4.03E-01	26.538	27/05/99	HPLC-ICP-MS	
Nd145	2.60E-01	17.022	27/05/99	HPLC-ICP-MS	
Nd146	2.68E-01	17.425	27/05/99	HPLC-ICP-MS	
Nd148	1.66E-01	10.616	27/05/99	HPLC-ICP-MS	
Nd150	9.61E-02	6.074	27/05/99	HPLC-ICP-MS	
Nd total	1.53E+00	100.000	27/05/99		
Pm147	2.59E-02		23/12/99	HPLC-ICP-MS	
Sm147	9.82E-02	23.907	11/08/99	HPLC-ICP-MS	
Sm148	7.08E-02	17.126	11/08/99	HPLC-ICP-MS	
Sm149	2.27E-03	0.544	11/08/99	HPLC-ICP-MS	
Sm150	1.37E-01	32.668	11/08/99	HPLC-ICP-MS	
Sm151	1.18E-02	2.802	11/08/99	HPLC-ICP-MS	
Sm152	6.74E-02	15.878	11/08/99	HPLC-ICP-MS	
Sm154	3.04E-02	7.075	11/08/99	HPLC-ICP-MS	
Sm total	4.18E-01	100.000	11/08/99		
Eu151	4.03E-04	0.438	11/08/99	HPLC-ICP-MS	
Eu153	7.38E-02	79.082	11/08/99	HPLC-ICP-MS	
Eu154	1.56E-02	16.603	11/08/99	HPLC-ICP-MS	
Eu155	3.67E-03	3.877	11/08/99	HPLC-ICP-MS	
Eu total	9.35E-02	100.000	11/08/99		
Gd154	6.95E-03	9.687	11/08/99	HPLC-ICP-MS	
Gd155	2.13E-03	2.953	11/08/99	HPLC-ICP-MS	
Gd156	4.77E-02	65.662	11/08/99	HPLC-ICP-MS	
Gd157			11/08/99	HPLC-ICP-MS	BDL
Gd158	1.47E-02	20.030	11/08/99	HPLC-ICP-MS	
Gd160	1.24E-03	1.667	11/08/99	HPLC-ICP-MS	
Gd total	7.28E-02	100.000	11/08/99		
Sr90	1.14E-01		07/10/99	HPLC-ICP-MS	
Mo95	2.68E-01		11/01/00	ICP-MS	
Tc99	2.30E-01		20/01/00	ICP-MS	
Ru101	1.56E-01		11/01/00	ICP-MS	
Ru106	3.80E-03		26/09/99	gamma	
Rh103	1.67E-01		08/12/99	ICP-MS	
Ag109	6.81E-03		11/01/00	ICP-MS	
Sb125	1.05E-03		26/09/99	gamma	
I129 (**)	3.53E-02		06/01/00	gamma	
Cs133	5.26E-01	35.706	03/09/99	HPLC-ICP-MS	
Cs134	1.57E-02	1.058	03/09/99	HPLC-ICP-MS	
Cs135	4.17E-01	27.908	03/09/99	HPLC-ICP-MS	
Cs137	5.36E-01	35.328	03/09/99	HPLC-ICP-MS	
Cs total	1.49E+00	100.000	03/09/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 29 - Results of analysis

Sample reference: DM1

Laboratory : PSI

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234	5.51E-02	0.0115	27/04/99	HPLC-ICP-MS	
U235	3.02E-01	0.0628	27/04/99	HPLC-ICP-MS	
U236	1.74E-01	0.0361	27/04/99	HPLC-ICP-MS	
U238	4.86E+02	99.8896	27/04/99	HPLC-ICP-MS	
U total	4.87E+02	100.0000	27/04/99		
Np237	8.08E-02		15-09-99	ICP-MS	
Pu238	6.39E-01	3.8233	07/05/99	HPLC-ICP-MS	
Pu239	3.57E+00	21.2707	07/05/99	HPLC-ICP-MS	
Pu240	6.78E+00	40.2280	07/05/99	HPLC-ICP-MS	
Pu241	2.03E+00	11.9827	07/05/99	HPLC-ICP-MS	
Pu242	3.86E+00	22.6953	07/05/99	HPLC-ICP-MS	
Pu244				HPLC-ICP-MS	BDL
Pu total	1.69E+01	100.0000	07/05/99		
Am241	8.21E-01	48.583	06/12/99	HPLC-ICP-MS	
Am242m	3.09E-03	0.182	06/12/99	HPLC-ICP-MS	
Am243	8.73E-01	51.235	06/12/99	HPLC-ICP-MS	
Am total	1.70E+00	100.000	06/12/99		
Cm242		0.000	06/12/99	HPLC-ICP-MS	BDL
Cm243		0.000	06/12/99	HPLC-ICP-MS	BDL
Cm244	3.90E-01	89.099	06/12/99	HPLC-ICP-MS	
Cm245	3.82E-02	8.685	06/12/99	HPLC-ICP-MS	
Cm246	9.78E-03	2.216	06/12/99	HPLC-ICP-MS	
Cm Total	4.38E-01	100.000	06/12/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 30 - Results of analysis

Sample reference: DM1
Laboratory: PSI Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	4.26E-04		23/09/99	gamma	
Ce total					
Nd142	2.13E-02	0.656	01/06/99	HPLC-ICP-MS	
Nd143	5.42E-01	16.618	01/06/99	HPLC-ICP-MS	
Nd144	1.04E+00	31.543	01/06/99	HPLC-ICP-MS	
Nd145	5.32E-01	16.085	01/06/99	HPLC-ICP-MS	
Nd146	6.11E-01	18.347	01/06/99	HPLC-ICP-MS	
Nd148	3.58E-01	10.590	01/06/99	HPLC-ICP-MS	
Nd150	2.11E-01	6.161	01/06/99	HPLC-ICP-MS	
Nd total	3.31E+00	100.000			
Pm147					NC
Sm147	2.05E-01	23.852	17/08/99	HPLC-ICP-MS	
Sm148	1.61E-01	18.640	17/08/99	HPLC-ICP-MS	
Sm149	1.91E-03	0.220	17/08/99	HPLC-ICP-MS	
Sm150	3.02E-01	34.565	17/08/99	HPLC-ICP-MS	
Sm151	9.43E-03	1.071	17/08/99	HPLC-ICP-MS	
Sm152	1.28E-01	14.415	17/08/99	HPLC-ICP-MS	
Sm154	6.50E-02	7.236	17/08/99	HPLC-ICP-MS	
Sm total	8.72E-01	100.000	17/08/99		
Eu151	6.21E-04	0.330	17/08/99	HPLC-ICP-MS	
Eu153	1.62E-01	84.837	17/08/99	HPLC-ICP-MS	
Eu154	2.25E-02	11.722	17/08/99	HPLC-ICP-MS	
Eu155	6.02E-03	3.112	17/08/99	HPLC-ICP-MS	
Eu total	1.91E-01	100.000	17/08/99		
Gd154	1.84E-02	7.607	17/08/99	HPLC-ICP-MS	(not scheduled)
Gd155	7.59E-03	3.125	17/08/99	HPLC-ICP-MS	(not scheduled)
Gd156	1.79E-01	73.432	17/08/99	HPLC-ICP-MS	(not scheduled)
Gd157			17/08/99	HPLC-ICP-MS	BDL
Gd158	3.64E-02	14.715	17/08/99	HPLC-ICP-MS	(not scheduled)
Gd160	2.81E-03	1.121	17/08/99	HPLC-ICP-MS	(not scheduled)
Gd total	2.45E-01	100.000	17/08/99		
Sr90					NC
Mo95					NC
Tc99	2.85E-01		20/01/00	ICP-MS	
Ru101					NC
Ru106	6.52E-04		23/09/99	gamma	(not scheduled)
Rh103					NC
Ag109					NC
Sb125	8.60E-04		23/09/99	gamma	(not scheduled)
I129 (**)					NC
Cs133	1.07E+00	40.579	07/09/99	HPLC-ICP-MS	
Cs134	1.34E-02	0.507	07/09/99	HPLC-ICP-MS	
Cs135	5.17E-01	19.337	07/09/99	HPLC-ICP-MS	
Cs137	1.07E+00	39.577	07/09/99	HPLC-ICP-MS	
Cs total	2.67E+00	100.000			

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 31 - Results of analysis

Sample reference: DU1
Laboratory : PSI — Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					not measurable
U234	6.81E-02	0.0162	22/04/99	HPLC-ICP-MS	
U235	2.81E+00	0.6642	22/04/99	HPLC-ICP-MS	
U236	3.29E+00	0.7745	22/04/99	HPLC-ICP-MS	
U238	4.22E+02	98.5451	22/04/99	HPLC-ICP-MS	
U total	4.28E+02	100.0000	22/04/99		
Np237	3.09E-01		15-09-99	ICP-MS	
Pu238	1.23E-01	3.3070	17/05/99	HPLC-ICP-MS	
Pu239	1.72E+00	45.9581	17/05/99	HPLC-ICP-MS	
Pu240	1.18E+00	31.3503	17/05/99	HPLC-ICP-MS	
Pu241	3.66E-01	9.7124	17/05/99	HPLC-ICP-MS	
Pu242	3.66E-01	9.6722	17/05/99	HPLC-ICP-MS	
Pu244			17/05/99	HPLC-ICP-MS	BDL
Pu total	3.74E+00	100.0000	17/05/99		
Am241	1.69E-01	67.187	01/12/99	HPLC-ICP-MS	
Am242m	3.24E-04	0.128	01/12/99	HPLC-ICP-MS	
Am243	8.28E-02	32.685	01/12/99	HPLC-ICP-MS	
Am total	2.52E-01	100.000	01/12/99		
Cm242			01/12/99	HPLC-ICP-MS	BDL
Cm243			01/12/99	HPLC-ICP-MS	BDL
Cm244	2.43E-02	93.348	01/12/99	HPLC-ICP-MS	
Cm245	1.44E-03	5.507	01/12/99	HPLC-ICP-MS	
Cm246	3.00E-04	1.145	01/12/99	HPLC-ICP-MS	
Cm Total	2.60E-02	100.000	01/12/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 32 - Results of analysis

Sample reference: DU1

Laboratory: PSI Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					
Ce142					
Ce144	4.15E-04		19/09/99	gamma	
Ce total					
Nd142	2.30E-02	0.764	28/05/99	HPLC-ICP-MS	
Nd143	4.49E-01	14.836	28/05/99	HPLC-ICP-MS	
Nd144	1.13E+00	36.947	28/05/99	HPLC-ICP-MS	
Nd145	4.94E-01	16.097	28/05/99	HPLC-ICP-MS	
Nd146	5.63E-01	18.220	28/05/99	HPLC-ICP-MS	
Nd148	2.84E-01	9.079	28/05/99	HPLC-ICP-MS	
Nd150	1.29E-01	4.057	28/05/99	HPLC-ICP-MS	
Nd total	3.07E+00	100.000			
Pm147	1.41E-02		23/12/99	HPLC-ICP-MS	
Sm147	1.64E-01	27.470	13/08/99	HPLC-ICP-MS	
Sm148	1.24E-01	20.534	13/08/99	HPLC-ICP-MS	
Sm149	1.12E-03	0.185	13/08/99	HPLC-ICP-MS	
Sm150	2.09E-01	34.292	13/08/99	HPLC-ICP-MS	
Sm151	4.95E-03	0.806	13/08/99	HPLC-ICP-MS	
Sm152	7.65E-02	12.378	13/08/99	HPLC-ICP-MS	
Sm154	2.71E-02	4.335	13/08/99	HPLC-ICP-MS	
Sm total	6.06E-01	100.000	13/08/99		
Eu151	2.85E-04	0.320	13/08/99	HPLC-ICP-MS	
Eu153	7.84E-02	86.877	13/08/99	HPLC-ICP-MS	
Eu154	8.90E-03	9.796	13/08/99	HPLC-ICP-MS	
Eu155	2.75E-03	3.007	13/08/99	HPLC-ICP-MS	
Eu total	9.04E-02	100.000	13/08/99		
Gd154	7.62E-03	6.977	13/08/99	HPLC-ICP-MS	
Gd155	3.73E-03	3.394	13/08/99	HPLC-ICP-MS	
Gd156	8.70E-02	78.652	13/08/99	HPLC-ICP-MS	
Gd157			13/08/99	HPLC-ICP-MS	BDL
Gd158	1.15E-02	10.290	13/08/99	HPLC-ICP-MS	
Gd160	7.80E-04	0.687	13/08/99	HPLC-ICP-MS	
Gd total	1.11E-01	100.000	13/08/99		
Sr90	3.90E-01		08/10/99	HPLC-ICP-MS	
Mo95	5.02E-01		11/01/00	ICP-MS	
Tc99	4.54E-01		20/01/00	ICP-MS	
Ru101	3.99E-01		11/01/00	ICP-MS	
Ru106	6.36E-04		19/09/99	gamma	
Rh103	2.39E-01		13/12/99	ICP-MS	
Ag109	2.08E-02		11/01/00	ICP-MS	
Sb125	5.65E-04		19/09/99	gamma	
I129 (**)					
Cs133	7.90E-01	43.471	06/09/99	HPLC-ICP-MS	
Cs134	9.66E-03	0.528	06/09/99	HPLC-ICP-MS	
Cs135	2.66E-01	14.431	06/09/99	HPLC-ICP-MS	
Cs137	7.78E-01	41.570	06/09/99	HPLC-ICP-MS	
Cs total	1.84E+00	100.000			

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 33 - Results of analysis

Sample reference: BM1

Laboratory: ITU

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234		0.0090	08/10/97	TIMS	
U235		0.1014	08/10/97	TIMS	
U236		0.0306	08/10/97	TIMS	
U238		99.8590	08/10/97	TIMS	
U total		100.0000			
Np237			20/08/97	IC-ICP-MS	
Pu238		3.1556	24/09/97	TIMS	
Pu239		35.1648	24/09/97	TIMS	
Pu240		35.0180	24/09/97	TIMS	
Pu241		14.8393	24/09/97	TIMS	
Pu242		11.8223	24/09/97	TIMS	
Pu244					NC
Pu total		100.000			
Am241		64.194	20/08/97	IC-ICP-MS	
Am242m			20/08/97	IC-ICP-MS	BDL
Am243		35.806	20/08/97	IC-ICP-MS	
Am total		100.000			
Cm242				IC-ICP-MS	BDL
Cm243				IC-ICP-MS	BDL
Cm244			20/08/97	IC-ICP-MS	
Cm245				IC-ICP-MS	BDL
Cm246					NC
Cm Total					

Absolute contents rejected

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 34 - Results of analysis

Sample reference: BM1
Laboratory: ITU — Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140		52.571	22/08/97	IC-ICP-MS	
Ce142		47.229	22/08/97	IC-ICP-MS	
Ce144		0.200	22/08/97	IC-ICP-MS	
Ce total		100.000			
Nd142		0.521	22/08/97	IC-ICP MS	
Nd143		20.749	22/08/97	IC-ICP-MS	
Nd144		27.232	22/08/97	IC-ICP-MS	
Nd145		16.607	22/08/97	IC-ICP-MS	
Nd146		17.685	22/08/97	IC-ICP-MS	
Nd148		10.678	22/08/97	IC-ICP-MS	
Nd150		6.528	22/08/97	IC-ICP-MS	
Nd total		100.000			
Pm147			22/08/97	IC-ICP-MS	
Sm147		22.395	22/08/97	IC-ICP-MS	
Sm148		18.250	22/08/97	IC-ICP-MS	
Sm149		0.564	22/08/97	IC-ICP-MS	
Sm150		33.797	22/08/97	IC-ICP-MS	
Sm151		2.152	22/08/97	IC-ICP-MS	
Sm152		15.384	22/08/97	IC-ICP-MS	
Sm154		7.459	22/08/97	IC-ICP-MS	
Sm total		100.000			
Eu151		0.924	22/08/97	IC-ICP-MS	
Eu153		81.113	22/08/97	IC-ICP-MS	
Eu154		14.792	22/08/97	IC-ICP-MS	
Eu155		3.171	22/08/97	IC-ICP-MS	
Eu total		100.000			
Gd154		9.033	22/08/97	IC-ICP-MS	
Gd155		2.777	22/08/97	IC-ICP-MS	
Gd156		67.939	22/08/97	IC-ICP-MS	
Gd157			22/08/97	IC-ICP-MS	BDL
Gd158		18.261	22/08/97	IC-ICP-MS	
Gd160		1.990	22/08/97	IC-ICP-MS	
Gd total		100.000			
Sr90			22/08/97	IC-ICP-MS	
Mo95					NC
Tc99					NC
Ru101					NC
Ru106					NC
Rh103					NC
Ag109					NC
Sb125					NC
I129 (**)					NC
Cs133		38.940	21/08/97	IC-ICP-MS	
Cs134		1.105	21/08/97	IC-ICP-MS	
Cs135		24.260	21/08/97	IC-ICP-MS	
Cs137		35.694	21/08/97	IC-ICP-MS	
Cs total		100.000			

Absolute contents rejected

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 35 - Results of analysis

Sample reference: GU1

Laboratory: ITU

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232					NC
U234		0.0133	06/12/96	TIMS	
U235		0.2313	06/12/96	TIMS	
U236		0.5279	06/12/96	TIMS	
U238		99.2275	06/12/96	TIMS	
U total		100.0000			
Np237			20/08/97	IC-ICP-MS	
Pu238		3.8430	06/12/96	TIMS	
Pu239		42.4787	06/12/96	TIMS	
Pu240		27.5477	06/12/96	TIMS	
Pu241		12.7948	06/12/96	TIMS	
Pu242		13.3358	06/12/96	TIMS	
Pu244					NC
Pu total		100.0000			
Am241		42.639	20/08/97	IC-ICP-MS	
Am242m			20/08/97	IC-ICP-MS	BDL
Am243		57.361	20/08/97	IC-ICP-MS	
Am total		100.000			
Cm242			20/08/97	IC-ICP-MS	BDL
Cm243			20/08/97	IC-ICP-MS	BDL
Cm244			20/08/97	IC-ICP-MS	
Cm245			20/08/97	IC-ICP-MS	BDL
Cm246					NC
Cm Total					

Absolute contents rejected

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 36 - Results of analysis

Sample reference: GU1
Laboratory: ITU Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140		53.893	11/12/96	IC-ICP-MS	
Ce142		45.289	11/12/96	IC-ICP-MS	
Ce144		0.818	11/12/96	IC-ICP-MS	
Ce total		100.000			
Nd142		0.975	11/12/96	IC-ICP MS	
Nd143		13.646	11/12/96	IC-ICP-MS	
Nd144		37.961	11/12/96	IC-ICP-MS	
Nd145		14.970	11/12/96	IC-ICP-MS	
Nd146		18.844	11/12/96	IC-ICP-MS	
Nd148		9.202	11/12/96	IC-ICP-MS	
Nd150		4.401	11/12/96	IC-ICP-MS	
Nd total		100.000			
Pm147					NC
Sm147		16.992	11/12/96	IC-ICP-MS	
Sm148		24.654	11/12/96	IC-ICP-MS	
Sm149		0.648	11/12/96	IC-ICP-MS	
Sm150		38.383	11/12/96	IC-ICP-MS	
Sm151		0.757	11/12/96	IC-ICP-MS	
Sm152		11.758	11/12/96	IC-ICP-MS	
Sm154		6.808	11/12/96	IC-ICP-MS	
Sm total		100.000			
Eu151			11/12/96	IC-ICP-MS	BDL
Eu153		83.173	11/12/96	IC-ICP-MS	
Eu154		10.144	11/12/96	IC-ICP-MS	
Eu155		6.684	11/12/96	IC-ICP-MS	
Eu total		100.000			
Gd154		5.205	11/12/96	IC-ICP-MS	
Gd155		2.806	11/12/96	IC-ICP-MS	
Gd156		80.378	11/12/96	IC-ICP-MS	
Gd157			11/12/96	IC-ICP-MS	BDL
Gd158		10.228	11/12/96	IC-ICP-MS	
Gd160		1.382	11/12/96	IC-ICP-MS	
Gd total		100.000			
Sr90					NC
Mo95					NC
Tc99					NC
Ru101					NC
Ru106					NC
Rh103					NC
Ag109					NC
Sb125					NC
I129 (**)					NC
Cs133		42.021	11/12/96	IC-ICP-MS	
Cs134		3.051	11/12/96	IC-ICP-MS	
Cs135		11.597	11/12/96	IC-ICP-MS	
Cs137		43.331	11/12/96	IC-ICP-MS	
Cs total		100.000			

Absolute contents rejected

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 37 - Results of analysis

Sample reference: GU3

Laboratory: ITU

Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232			28/01/99	TIMS	BDL
U234	1.82E+01	0.0152	28/01/99	TIMS	
U235	7.83E+02	0.6502	28/01/99	TIMS	
U236	7.35E+02	0.6084	28/01/99	TIMS	
U238	1.20E+05	98.7262	28/01/99	TIMS	
U total	1.22E+05	100.0000	28/01/99		
Np237	1.07E+02		16/06/99	IC-ICP-MS	
Pu238	4.83E+01	3.2041	28/01/99	TIMS	
Pu239	7.53E+02	49.7286	28/01/99	TIMS	
Pu240	3.68E+02	24.1974	28/01/99	TIMS	
Pu241	2.18E+02	14.2731	28/01/99	TIMS	
Pu242	1.32E+02	8.5968	28/01/99	TIMS	
Pu244					NC
Pu total	1.52E+03	100.0000	28/01/99		
Am241	2.46E+01	41.615	16/06/99	IC-ICP-MS	
Am242m			16/06/99	IC-ICP-MS	BDL
Am243	3.48E+01	58.385	16/06/99	IC-ICP-MS	
Am total	5.94E+01	100.000	16/06/99		
Cm242			16/06/99	IC-ICP-MS	BDL
Cm243			16/06/99	IC-ICP-MS	BDL
Cm244	2.00E+01	93.050	16/06/99	IC-ICP-MS	
Cm245	1.50E+00	6.950	16/06/99	IC-ICP-MS	
Cm246					NC
Cm Total	2.15E+01	100.000	16/06/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 38 - Results of analysis

Sample reference: GU3

Laboratory: ITU Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	1.05E+01		03/05/99	IC-ICP-MS	
Ce total					
Nd142	4.70E+00	0.629	26/03/99	IC-ICP MS	
Nd143	1.29E+02	17.148	26/03/99	IC-ICP-MS	
Nd144	2.57E+02	33.926	26/03/99	IC-ICP-MS	
Nd145	1.21E+02	15.863	26/03/99	IC-ICP-MS	
Nd146	1.41E+02	18.358	26/03/99	IC-ICP-MS	
Nd148	7.27E+01	9.337	26/03/99	IC-ICP-MS	
Nd150	3.74E+01	4.739	26/03/99	IC-ICP-MS	
Nd total	7.63E+02	100.000	26/03/99		
Pm147	2.07E+01		04/05/99	IC-ICP-MS	
Sm147	2.40E+01	17.134	04/05/99	IC-ICP-MS	
Sm148	3.40E+01	24.108	04/05/99	IC-ICP-MS	
Sm149	6.00E-01	0.423	04/05/99	IC-ICP-MS	
Sm150	5.80E+01	40.577	04/05/99	IC-ICP-MS	
Sm151	1.90E+00	1.320	04/05/99	IC-ICP-MS	
Sm152	1.70E+01	11.736	04/05/99	IC-ICP-MS	
Sm154	6.90E+00	4.702	04/05/99	IC-ICP-MS	
Sm total	1.42E+02	100.000	04/05/99		
Eu151					NC
Eu153	2.43E+01	79.261	04/05/99	IC-ICP-MS	
Eu154	4.81E+00	15.587	04/05/99	IC-ICP-MS	
Eu155	1.60E+00	5.151	04/05/99	IC-ICP-MS	
Eu total	3.07E+01	100.000	04/05/99		
Gd154					NC
Gd155	5.40E-01		06/10/99	IC-ICP-MS	
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	9.50E+01		07/10/99	IC-ICP-MS	
Mo95	1.02E+02		07/10/99	IC-ICP-MS	
Tc99	8.28E+01		07/10/99	IC-ICP-MS	
Ru101	9.80E+01		07/10/99	IC-ICP-MS	
Ru106	4.30E+00		07/10/99	IC-ICP-MS	
Rh103	3.54E+01		07/10/99	IC-ICP-MS	
Ag109			07/10/99	IC-ICP-MS	not measurable
Sb125			07/10/99	IC-ICP-MS	BDL
I129 (**)	3.40E+01		11/03/99	ICP-MS	
Cs133	2.17E+02	41.466	04/05/99	IC-ICP-MS	
Cs134	1.88E+01	3.566	04/05/99	IC-ICP-MS	
Cs135	6.24E+01	11.747	04/05/99	IC-ICP-MS	
Cs137	2.33E+02	43.222	04/05/99	IC-ICP-MS	
Cs total	5.31E+02	100.000			

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.2 / 39 - Results of analysis

Sample reference: GU4

Laboratory: ITU Main solution - Actinides

Isotope	Concentration µg/g solution	at %	Date of analysis	Method of analysis	Comment (*)
U232			20/05/99	TIMS	BDL
U234	2.58E+01	0.0206	20/05/99	TIMS	
U235	1.93E+03	1.5306	20/05/99	TIMS	
U236	6.08E+02	0.4810	20/05/99	TIMS	
U238	1.25E+05	97.9678	20/05/99	TIMS	
U total	1.27E+05	100.0000	20/05/99		
Np237	6.95E+01		16/06/99	IC-ICP-MS	
Pu238	1.47E+01	1.3316	17/08/99	TIMS	
Pu239	6.83E+02	61.5436	17/08/99	TIMS	
Pu240	2.43E+02	21.7947	17/08/99	TIMS	
Pu241	1.31E+02	11.6771	17/08/99	TIMS	
Pu242	4.11E+01	3.6529	17/08/99	TIMS	
Pu244					NC
Pu total	1.11E+03	100.0000	17/08/99		
Am241	1.95E+01	77.212	16/06/99	IC-ICP-MS	
Am242m			16/06/99	IC-ICP-MS	BDL
Am243	5.80E+00	22.788	16/06/99	IC-ICP-MS	
Am total	2.53E+01	100.000	16/06/99		
Cm242			16/06/99	IC-ICP-MS	BDL
Cm243			16/06/99	IC-ICP-MS	BDL
Cm244	1.64E+00	95.591	16/06/99	IC-ICP-MS	
Cm245	7.60E-02	4.409	16/06/99	IC-ICP-MS	
Cm246					NC
Cm Total	1.72E+00	100.000	16/06/99		

(*) NC = not considered
BDL = below detection limit

Table 3.2 / 40 - Results of analysis

Sample reference: GU4
Laboratory: ITU Main solution - Fission Products

Isotope	Concentration µg/g sol.	at %	Date of analysis	Method of analysis	Comment (*)
Ce140					NC
Ce142					NC
Ce144	4.81E+00		30/09/99	IC-ICP-MS	
Ce total					
Nd142	1.59E+00	0.313	30/09/99	IC-ICP MS	
Nd143	1.14E+02	22.253	30/09/99	IC-ICP-MS	
Nd144	1.62E+02	31.290	30/09/99	IC-ICP-MS	
Nd145	8.95E+01	17.203	30/09/99	IC-ICP-MS	
Nd146	8.60E+01	16.429	30/09/99	IC-ICP-MS	
Nd148	4.59E+01	8.645	30/09/99	IC-ICP-MS	
Nd150	2.08E+01	3.868	30/09/99	IC-ICP-MS	
Nd total	5.20E+02	100.000	30/09/99		
Pm147	1.45E+01		01/10/99	IC-ICP-MS	(not scheduled)
Sm147	2.13E+01	25.209	01/10/99	IC-ICP-MS	
Sm148	1.46E+01	17.166	01/10/99	IC-ICP-MS	
Sm149	4.00E-01	0.466	01/10/99	IC-ICP-MS	
Sm150	3.21E+01	37.190	01/10/99	IC-ICP-MS	
Sm151	1.49E+00	1.717	01/10/99	IC-ICP-MS	
Sm152	1.25E+01	14.303	01/10/99	IC-ICP-MS	
Sm154	3.50E+00	3.949	01/10/99	IC-ICP-MS	
Sm total	8.60E+01	100.000	01/10/99		
Eu151					NC
Eu153	1.24E+01	83.864	04/10/99	IC-ICP-MS	
Eu154	1.83E+00	12.258	04/10/99	IC-ICP-MS	
Eu155	5.82E-01	3.877	04/10/99	IC-ICP-MS	
Eu total	1.48E+01	100.000	04/10/99		
Gd154					NC
Gd155	3.49E-01		04/10/99	IC-ICP-MS	(not scheduled)
Gd156					NC
Gd157					NC
Gd158					NC
Gd160					NC
Gd total					
Sr90	6.69E+01		15/11/99	IC-ICP-MS	(not scheduled)
Mo95	5.84E+01		15/11/99	IC-ICP-MS	(not scheduled)
Tc99	5.77E+01		15/11/99	IC-ICP-MS	
Ru101	4.11E+01		15/11/99	IC-ICP-MS	(not scheduled)
Ru106	1.57E+00		15/11/99	IC-ICP-MS	(not scheduled)
Rh103	2.13E+01		15/11/99	IC-ICP-MS	(not scheduled)
Ag109			15/11/99	IC-ICP-MS	not measurable
Sb125			15/11/99	IC-ICP-MS	BDL
I129 (**)	2.20E+01		09/12/99	ICP-MS	
Cs133	1.43E+02	44.051	06/10/99	IC-ICP-MS	
Cs134	5.48E+00	1.671	06/10/99	IC-ICP-MS	
Cs135	4.94E+01	14.970	06/10/99	IC-ICP-MS	
Cs137	1.32E+02	39.308	06/10/99	IC-ICP-MS	
Cs total	3.30E+02	100.000	06/10/99		

(*) NC = not considered - BDL = below detection limit (**) Iodine solution

Table 3.3 - Separation dates needed for EOL calculations of SCK•CEN results -

Sample / Separation	BM1	BM5'	GU1	GU3'	DM1	DM2	DM3	DM4	DU1
Pu / Cm	17-03-97	04-10-99	09-04-97	04-10-99	24-04-96	30-04-96	03-12-97	03-12-97	02-04-96
Pu / Am	17-03-97	04-10-99	09-04-97	04-10-99	24-04-96	30-04-96	03-12-97	03-12-97	02-04-96
Ce / Nd	19-03-97	13-10-99	11-04-97	13-10-99	18-06-96	18-06-96	08-12-97	08-12-97	18-06-96
Pm / Sm	02-04-97	14-10-99	18-04-97	14-10-99	--	22-06-96	--	--	22-06-96
Sm / Eu	03-04-97	14-10-99	19-04-97	14-10-99	23-06-96	23-06-96	12-12-97	12-12-97	23-06-96

Table 3.4a - Dissolution characteristics

Sample	Weights (g) dissolved fuel (g)	total residue (mg)	Dissolved residue (mg)	Residue solution characteristic mg res. / g sol
SCK-CEN				
BM1	26.1750	595.0	11.6	0.09690
BM5'	26.4677	203.83	203.83	
GU1	23.2020	205.0	6.0	0.10652
GU3'	22.7411	39.32	39.32	
DM1	31.3628	260.0	260.0	
DM2	30.8393	133.0	133.0	
DM3	29.9238	345.03	345.03	
DM4	30.0562	109.18	109.18	
DU1	26.7659	73.5	73.5	
PSI				
BM1	26.1750	595.0	11.6	0.09738
BM5	23.5660	222.0	93.2	0.07895
BM6	25.7890	290.0	59.0	0.09890
DM1	31.3628	260.0	260.0	0.08881
DU1	26.7659	73.5	73.5	0.11390
ITU				
GU3	21.0970	52.0	23.8	0.89075
GU4	21.7660	141.0	31.0	0.94449

Table 3.4b - Characteristics of the Mother Solutions

Sample	Laboratory	mg fuel / g solution (as reported by the laboratory)	mg fuel / g solution (corrected for mass balance deviation)
BM1	PSI	0.43275 (1)	
		0.43386 (2)	
	CEN	0.41475	
BM3	PSI	0.42650	0.42650 / 1.39 = 0.30683
BM4-D	PSI	0.46666	
BM5	PSI	0.48450 (4)	
		0.48550 (2)	
BM5'	CEN	84.56147	
BM6	PSI	0.48610 (4)	
		0.48667 (2)	
GU1	CEN	0.52576	0.52576 / 0.89 = 0.59074
GU3	TUI	147.25138	
GU3'	CEN	74.22027	
GU4	TUI	150.17249	
DM1	CEN	98.70875	
	PSI	0.61852 (3)	
		0.62001 (2)	
DM2	CEN	96.58772	
DM3	CEN	95.87901	
DM4	CEN	95.32563	
DU1	CEN	85.25081	
	PSI	0.51910 (3)	
		0.52171 (2)	

(1) For U , Pu , Nd only
(2) Averaged value
(3) For U , Pu , Nd , Cs , Np only
(4) For U , Pu , Nd , Cs , Np , Sm , Eu , Gd only

Table 3.5 / 1 - Results normalized to solid fuel

Sample reference: BM1

Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	6.42E-02	0.0081	7.94E-02	2.95E-02	0.0037	3.65E-02
U235	8.26E-01	0.1035	1.02E+00	8.26E-01	0.1035	1.02E+00
U236	2.55E-01	0.0318	3.16E-01	2.55E-01	0.0318	3.16E-01
U238	8.08E+02	99.8566	9.99E+02	8.08E+02	99.8609	9.99E+02
U total	8.09E+02	100.0000	1.00E+03	8.09E+02	100.0000	1.00E+03
Np237						
Pu238	1.11E+00	3.3241	1.37E+00	9.65E-01	2.8193	1.19E+00
Pu239	1.19E+01	35.3485	1.47E+01	1.19E+01	34.4976	1.47E+01
Pu240	1.18E+01	35.1348	1.46E+01	1.17E+01	34.0478	1.45E+01
Pu241	4.99E+00	14.7577	6.17E+00	6.06E+00	17.4769	7.49E+00
Pu242	3.88E+00	11.4329	4.80E+00	3.88E+00	11.1565	4.80E+00
Pu244	6.85E-04	0.0020	8.47E-04	6.85E-04	0.0020	8.47E-04
Pu total	3.37E+01	100.0000	4.16E+01	3.45E+01	100.0000	4.27E+01
Am241	1.56E+00	61.139	1.93E+00	5.14E-01	34.146	6.35E-01
Am242m	1.41E-02	0.553	1.75E-02	1.44E-02	0.954	1.78E-02
Am243	9.84E-01	38.308	1.22E+00	9.85E-01	64.899	1.22E+00
Am total	2.56E+00	100.000	3.16E+00	1.51E+00	100.000	1.87E+00
Cm242	3.01E-04	0.049	3.73E-04	1.70E-01	19.460	2.10E-01
Cm243	7.91E-03	1.294	9.79E-03	8.74E-03	0.999	1.08E-02
Cm244	5.35E-01	87.088	6.62E-01	6.28E-01	71.449	7.76E-01
Cm245	6.44E-02	10.436	7.96E-02	6.44E-02	7.300	7.96E-02
Cm246	7.02E-03	1.133	8.68E-03	7.02E-03	0.793	8.68E-03
Cm Total	6.15E-01	100.000	7.60E-01	8.77E-01	100.000	1.09E+00

Build - up (+ decay if any) correction

Table 3.5 / 2 - Results normalized to solid fuel

Sample reference : BM1

Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	8.02E-03		9.91E-03	2.59E-01		3.20E-01
Ce total						
Nd142	1.80E-02	0.433	2.23E-02	1.80E-02	0.461	2.23E-02
Nd143	9.00E-01	21.493	1.11E+00	9.00E-01	22.855	1.11E+00
Nd144	1.18E+00	28.029	1.46E+00	9.31E-01	23.469	1.15E+00
Nd145	7.01E-01	16.498	8.67E-01	7.01E-01	17.544	8.67E-01
Nd146	7.40E-01	17.300	9.15E-01	7.40E-01	18.396	9.15E-01
Nd148	4.43E-01	10.226	5.48E-01	4.43E-01	10.874	5.48E-01
Nd150	2.65E-01	6.020	3.27E-01	2.65E-01	6.401	3.27E-01
Nd total	4.25E+00	100.000	5.25E+00	4.00E+00	100.000	4.94E+00
Pm147	6.41E-02		7.93E-02	1.85E-01		2.29E-01
Sm147	2.37E-01	22.723	2.93E-01	1.16E-01	12.554	1.43E-01
Sm148	1.89E-01	18.009	2.34E-01	1.89E-01	20.360	2.34E-01
Sm149	5.03E-03	0.477	6.23E-03	5.03E-03	0.539	6.23E-03
Sm150	3.62E-01	34.018	4.47E-01	3.62E-01	38.459	4.47E-01
Sm151	2.39E-02	2.237	2.96E-02	2.47E-02	2.609	3.05E-02
Sm152	1.64E-01	15.250	2.03E-01	1.64E-01	17.241	2.03E-01
Sm154	7.95E-02	7.286	9.83E-02	7.95E-02	8.237	9.83E-02
Sm total	1.06E+00	100.000	1.31E+00	9.39E-01	100.000	1.16E+00
Eu151	8.50E-04	0.355	1.05E-03	1.00E-04	0.039	1.24E-04
Eu153	1.96E-01	80.690	2.42E-01	1.96E-01	74.305	2.42E-01
Eu154	3.69E-02	15.113	4.56E-02	5.13E-02	19.336	6.34E-02
Eu155	9.44E-03	3.842	1.17E-02	1.69E-02	6.320	2.09E-02
Eu total	2.43E-01	100.000	3.00E-01	2.64E-01	100.000	3.26E-01
Gd154						
Gd155	6.65E-03		8.23E-03	!(-6.92E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	3.56E-01		4.40E-01	3.94E-01		4.87E-01
Mo95	5.64E-01		6.97E-01	5.64E-01		6.97E-01
Tc99	5.61E-01		6.94E-01	5.61E-01		6.94E-01
Ru101	3.14E-01		3.88E-01	3.14E-01		3.88E-01
Ru106	6.28E-03		7.76E-03	8.96E-02		1.11E-01
Rh103	2.96E-01		3.66E-01	2.96E-01		3.66E-01
Ag109	7.21E-02		8.92E-02	7.21E-02		8.92E-02
Sb125	2.44E-03		3.02E-03	6.52E-03		8.07E-03
I129 (*)						
Cs133	1.32E+00	37.646	1.64E+00	1.32E+00	35.192	1.64E+00
Cs134	3.74E-02	1.056	4.62E-02	1.51E-01	3.989	1.87E-01
Cs135	8.45E-01	23.680	1.04E+00	8.45E-01	22.136	1.04E+00
Cs137	1.36E+00	37.618	1.68E+00	1.50E+00	38.684	1.85E+00
Cs total	3.57E+00	100.000	4.41E+00	3.82E+00	100.000	4.72E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 3 - Results normalized to solid fuel

Sample reference: BM5'

Laboratory: SCK-CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	4.97E-02	0.0063	6.22E-02	2.41E-02	0.0031	3.01E-02
U235	5.86E-01	0.0744	7.34E-01	5.86E-01	0.0744	7.34E-01
U236	2.69E-01	0.0340	3.37E-01	2.69E-01	0.0340	3.37E-01
U238	7.98E+02	99.8853	9.99E+02	7.98E+02	99.8886	9.99E+02
U total	7.98E+02	100.0000	1.00E+03	7.98E+02	100.0000	1.00E+03
Np237	1.84E-01		2.30E-01	1.84E-01		2.30E-01
Pu238	9.95E-01	3.4453	1.25E+00	8.66E-01	2.9412	1.08E+00
Pu239	9.80E+00	33.7901	1.23E+01	9.80E+00	33.1473	1.23E+01
Pu240	1.01E+01	34.5428	1.26E+01	9.97E+00	33.5855	1.25E+01
Pu241	4.60E+00	15.7310	5.76E+00	5.39E+00	18.0741	6.75E+00
Pu242	3.67E+00	12.4873	4.59E+00	3.67E+00	12.2486	4.59E+00
Pu244	1.00E-03	0.0034	1.25E-03	1.00E-03	0.0033	1.25E-03
Pu total	2.91E+01	100.0000	3.65E+01	2.97E+01	100.0000	3.72E+01
Am241	1.13E+00	54.602	1.42E+00	3.50E-01	27.147	4.39E-01
Am242m	1.06E-02	0.511	1.33E-02	1.08E-02	0.834	1.35E-02
Am243	9.37E-01	44.887	1.17E+00	9.37E-01	72.019	1.17E+00
Am total	2.08E+00	100.000	2.60E+00	1.30E+00	100.000	1.63E+00
Cm242	1.49E-03	0.184	1.86E-03	1.56E-01	14.868	1.96E-01
Cm243	6.90E-03	0.849	8.65E-03	7.42E-03	0.703	9.29E-03
Cm244	7.07E-01	86.577	8.85E-01	7.93E-01	74.876	9.93E-01
Cm245	8.76E-02	10.688	1.10E-01	8.76E-02	8.241	1.10E-01
Cm246	1.40E-02	1.702	1.75E-02	1.40E-02	1.312	1.75E-02
Cm Total	8.16E-01	100.000	1.02E+00	1.06E+00	100.000	1.32E+00

Build - up (+ decay if any) correction

Table 3.5 / 4 - Results normalized to solid fuel

Sample reference : BM5'

Laboratory: SCK-CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	1.68E-02		2.11E-02	2.43E-01		3.05E-01
Ce total						
Nd142	2.97E-02	0.574	3.72E-02	2.97E-02	0.601	3.72E-02
Nd143	1.04E+00	19.919	1.30E+00	1.04E+00	20.832	1.30E+00
Nd144	1.55E+00	29.433	1.94E+00	1.31E+00	26.197	1.65E+00
Nd145	8.41E-01	15.904	1.05E+00	8.41E-01	16.634	1.05E+00
Nd146	9.58E-01	17.996	1.20E+00	9.58E-01	18.821	1.20E+00
Nd148	5.49E-01	10.175	6.88E-01	5.49E-01	10.642	6.88E-01
Nd150	3.28E-01	5.999	4.11E-01	3.28E-01	6.274	4.11E-01
Nd total	5.29E+00	100.000	6.62E+00	5.06E+00	100.000	6.34E+00
Pm147	7.32E-02		9.17E-02	1.94E-01		2.42E-01
Sm147	2.34E-01	19.640	2.93E-01	1.21E-01	11.247	1.52E-01
Sm148	2.71E-01	22.635	3.40E-01	2.71E-01	24.984	3.40E-01
Sm149	4.08E-03	0.338	5.11E-03	4.08E-03	0.373	5.11E-03
Sm150	4.33E-01	35.622	5.42E-01	4.33E-01	39.319	5.42E-01
Sm151	2.19E-02	1.791	2.74E-02	2.25E-02	2.030	2.82E-02
Sm152	1.58E-01	12.857	1.98E-01	1.58E-01	14.191	1.98E-01
Sm154	8.87E-02	7.117	1.11E-01	8.87E-02	7.856	1.11E-01
Sm total	1.21E+00	100.000	1.52E+00	1.10E+00	100.000	1.38E+00
Eu151	7.76E-04	0.265	9.72E-04	2.13E-04	0.068	2.66E-04
Eu153	2.33E-01	78.322	2.91E-01	2.33E-01	73.278	2.91E-01
Eu154	5.06E-02	16.921	6.33E-02	6.45E-02	20.195	8.08E-02
Eu155	1.35E-02	4.493	1.69E-02	2.08E-02	6.459	2.60E-02
Eu total	2.97E-01	100.000	3.72E-01	3.18E-01	100.000	3.98E-01
Gd154						
Gd155	7.34E-03		9.19E-03	! (-4.57E-04) !		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	3.14E-01		3.93E-01	3.45E-01		4.32E-01
Mo95	8.62E-01		1.08E+00	8.62E-01		1.08E+00
Tc99	9.40E-01		1.18E+00	9.41E-01		1.18E+00
Ru101	7.72E-01		9.67E-01	7.72E-01		9.67E-01
Ru106	2.09E-02		2.62E-02	1.61E-01		2.02E-01
Rh103	6.05E-01		7.58E-01	6.05E-01		7.58E-01
Ag109	1.50E-01		1.88E-01	1.50E-01		1.88E-01
Sb125	2.79E-03		3.49E-03	5.93E-03		7.42E-03
I129 (*)	2.24E-01		2.81E-01	2.24E-01		2.81E-01
Cs133	1.52E+00	35.912	1.91E+00	1.52E+00	33.959	1.91E+00
Cs134	7.40E-02	1.734	9.27E-02	2.03E-01	4.498	2.54E-01
Cs135	1.04E+00	24.120	1.30E+00	1.04E+00	22.808	1.30E+00
Cs137	1.67E+00	38.235	2.09E+00	1.79E+00	38.734	2.24E+00
Cs total	4.30E+00	100.000	5.39E+00	4.55E+00	100.000	5.70E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 5 - Results normalized to solid fuel

Sample reference: GU1
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 04 / 06 / 94		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.06E-01	0.0132	1.30E-01	9.71E-02	0.0121	1.19E-01
U235	1.86E+00	0.2302	2.27E+00	1.86E+00	0.2302	2.27E+00
U236	4.26E+00	0.5261	5.22E+00	4.26E+00	0.5261	5.22E+00
U238	8.11E+02	99.2305	9.92E+02	8.11E+02	99.2316	9.92E+02
U total	8.17E+02	100.0000	1.00E+03	8.17E+02	100.0000	1.00E+03
Np237						
Pu238	4.00E-01	3.9760	4.90E-01	3.81E-01	3.7345	4.67E-01
Pu239	4.31E+00	42.6120	5.27E+00	4.31E+00	42.0084	5.27E+00
Pu240	2.80E+00	27.5649	3.43E+00	2.77E+00	26.9428	3.40E+00
Pu241	1.27E+00	12.5072	1.56E+00	1.46E+00	14.1643	1.79E+00
Pu242	1.37E+00	13.3375	1.67E+00	1.37E+00	13.1475	1.67E+00
Pu244	2.58E-04	0.0025	3.16E-04	2.58E-04	0.0025	3.16E-04
Pu total	1.01E+01	100.0000	1.24E+01	1.03E+01	100.0000	1.26E+01
Am241	2.19E-01	38.309	2.68E-01	3.21E-02	8.341	3.93E-02
Am242m	6.04E-04	0.105	7.40E-04	6.13E-04	0.158	7.50E-04
Am243	3.55E-01	61.586	4.35E-01	3.55E-01	91.500	4.35E-01
Am total	5.75E-01	100.000	7.04E-01	3.88E-01	100.000	4.75E-01
Cm242	2.72E-04	0.116	3.33E-04	2.87E-02	9.973	3.51E-02
Cm243	2.98E-04	0.127	3.65E-04	3.21E-04	0.111	3.92E-04
Cm244	2.15E-01	91.288	2.63E-01	2.41E-01	83.047	2.95E-01
Cm245	1.54E-02	6.501	1.88E-02	1.54E-02	5.273	1.88E-02
Cm246	4.66E-03	1.967	5.71E-03	4.67E-03	1.596	5.71E-03
Cm Total	2.35E-01	100.000	2.88E-01	2.90E-01	100.000	3.55E-01

Build - up (+ decay if any) correction

Table 3.5 / 6 - Results normalized to solid fuel

Sample reference : GU1
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 04 / 06 / 94		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	2.97E-02		3.63E-02	3.38E-01		4.13E-01
Ce total						
Nd142	5.97E-02	0.986	7.30E-02	5.97E-02	1.039	7.30E-02
Nd143	8.22E-01	13.498	1.01E+00	8.22E-01	14.218	1.01E+00
Nd144	2.32E+00	37.887	2.85E+00	2.01E+00	34.571	2.46E+00
Nd145	9.18E-01	14.866	1.12E+00	9.18E-01	15.660	1.12E+00
Nd146	1.17E+00	18.766	1.43E+00	1.17E+00	19.767	1.43E+00
Nd148	5.87E-01	9.316	7.19E-01	5.87E-01	9.814	7.19E-01
Nd150	2.99E-01	4.681	3.66E-01	2.99E-01	4.931	3.66E-01
Nd total	6.18E+00	100.000	7.56E+00	5.87E+00	100.000	7.18E+00
Pm147	5.61E-02		6.87E-02	1.21E-01		1.48E-01
Sm147	1.96E-01	17.161	2.40E-01	1.32E-01	12.220	1.61E-01
Sm148	2.86E-01	24.847	3.50E-01	2.86E-01	26.322	3.50E-01
Sm149	2.89E-03	0.250	3.54E-03	2.89E-03	0.265	3.54E-03
Sm150	4.48E-01	38.433	5.48E-01	4.48E-01	40.715	5.48E-01
Sm151	1.15E-02	0.980	1.41E-02	1.18E-02	1.062	1.44E-02
Sm152	1.46E-01	12.398	1.79E-01	1.46E-01	13.134	1.79E-01
Sm154	7.09E-02	5.930	8.68E-02	7.09E-02	6.282	8.68E-02
Sm total	1.16E+00	100.000	1.42E+00	1.10E+00	100.000	1.34E+00
Eu151	6.33E-04	0.287	7.75E-04	3.76E-04	0.162	4.60E-04
Eu153	1.85E-01	82.659	2.26E-01	1.85E-01	78.378	2.26E-01
Eu154	2.84E-02	12.654	3.48E-02	3.59E-02	15.158	4.40E-02
Eu155	9.95E-03	4.400	1.22E-02	1.50E-02	6.302	1.84E-02
Eu total	2.24E-01	100.000	2.74E-01	2.36E-01	100.000	2.89E-01
Gd154						
Gd155	4.96E-03		6.07E-03	!(-1.01E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	8.57E-01		1.05E+00	9.22E-01		1.13E+00
Mo95	7.14E-01		8.74E-01	7.14E-01		8.74E-01
Tc99	6.10E-01		7.47E-01	6.10E-01		7.47E-01
Ru101	3.49E-01		4.28E-01	3.49E-01		4.28E-01
Ru106	1.28E-02		1.57E-02	8.24E-02		1.01E-01
Rh103	2.04E-01		2.50E-01	2.04E-01		2.50E-01
Ag109	9.87E-03		1.21E-02	9.87E-03		1.21E-02
Sb125	3.29E-03		4.03E-03	6.55E-03		8.02E-03
I129 (*)						
Cs133	1.52E+00	39.958	1.86E+00	1.52E+00	37.151	1.86E+00
Cs134	9.56E-02	2.502	1.17E-01	2.61E-01	6.339	3.19E-01
Cs135	4.55E-01	11.813	5.57E-01	4.55E-01	10.983	5.57E-01
Cs137	1.79E+00	45.727	2.19E+00	1.91E+00	45.527	2.34E+00
Cs total	3.85E+00	100.000	4.72E+00	4.14E+00	100.000	5.07E+00

(*) Iodine solution Build - up correction

Table 3.5 / 7 - Results normalized to solid fuel

Sample reference: GU3'
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 06 / 97		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.24E-01	0.0152	1.50E-01	1.18E-01	0.0145	1.43E-01
U235	5.33E+00	0.6532	6.45E+00	5.33E+00	0.6532	6.45E+00
U236	4.97E+00	0.6072	6.02E+00	4.97E+00	0.6072	6.02E+00
U238	8.16E+02	98.7243	9.87E+02	8.16E+02	98.7250	9.87E+02
U total	8.26E+02	100.0000	1.00E+03	8.26E+02	100.0000	1.00E+03
Np237	7.09E-01		8.58E-01	7.09E-01		8.58E-01
Pu238	3.32E-01	3.2560	4.02E-01	3.15E-01	3.0451	3.81E-01
Pu239	5.13E+00	50.0084	6.20E+00	5.13E+00	49.3225	6.20E+00
Pu240	2.50E+00	24.2636	3.02E+00	2.49E+00	23.8364	3.01E+00
Pu241	1.43E+00	13.8700	1.74E+00	1.60E+00	15.3124	1.94E+00
Pu242	8.93E-01	8.6005	1.08E+00	8.93E-01	8.4820	1.08E+00
Pu244	1.63E-04	0.0016	1.97E-04	1.63E-04	0.0015	1.97E-04
Pu total	1.03E+01	100.0000	1.24E+01	1.04E+01	100.0000	1.26E+01
Am241	1.97E-01	48.538	2.38E-01	2.74E-02	11.594	3.31E-02
Am242m	8.10E-04	0.199	9.80E-04	8.20E-04	0.346	9.93E-04
Am243	2.10E-01	51.263	2.54E-01	2.10E-01	88.060	2.54E-01
Am total	4.07E-01	100.000	4.93E-01	2.38E-01	100.000	2.88E-01
Cm242	9.82E-04	0.792	1.19E-03	2.43E-02	15.509	2.94E-02
Cm243	5.23E-04	0.420	6.33E-04	5.50E-04	0.349	6.65E-04
Cm244	1.14E-01	90.977	1.38E-01	1.23E-01	77.956	1.49E-01
Cm245	8.54E-03	6.805	1.03E-02	8.55E-03	5.389	1.03E-02
Cm246	1.27E-03	1.006	1.53E-03	1.27E-03	0.796	1.54E-03
Cm Total	1.25E-01	100.000	1.51E-01	1.58E-01	100.000	1.91E-01

Build - up (+ decay if any) correction

Table 3.5 / 8 - Results normalized to solid fuel

Sample reference : GU3'

Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 06 / 97		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	6.32E-02		7.65E-02	3.95E-01		4.79E-01
Ce total						
Nd142	3.73E-02	0.689	4.52E-02	3.73E-02	0.736	4.52E-02
Nd143	9.45E-01	17.330	1.14E+00	9.45E-01	18.497	1.14E+00
Nd144	1.89E+00	34.519	2.29E+00	1.55E+00	30.110	1.87E+00
Nd145	8.72E-01	15.780	1.06E+00	8.72E-01	16.842	1.06E+00
Nd146	1.01E+00	18.111	1.22E+00	1.01E+00	19.330	1.22E+00
Nd148	5.17E-01	9.168	6.26E-01	5.17E-01	9.785	6.26E-01
Nd150	2.52E-01	4.403	3.05E-01	2.52E-01	4.700	3.05E-01
Nd total	5.53E+00	100.000	6.69E+00	5.18E+00	100.000	6.27E+00
Pm147	8.25E-02		9.98E-02	1.70E-01		2.06E-01
Sm147	1.73E-01	18.042	2.09E-01	9.42E-02	14.519	1.14E-01
Sm148	2.24E-01	23.207	2.71E-01	2.24E-01	24.197	2.71E-01
Sm149	2.96E-03	0.305	3.59E-03	2.96E-03	0.318	3.59E-03
Sm150	3.93E-01	40.232	4.76E-01	3.93E-01	41.949	4.76E-01
Sm151	1.27E-02	1.295	1.54E-02	1.30E-02	1.377	1.57E-02
Sm152	1.18E-01	11.884	1.43E-01	1.18E-01	12.391	1.43E-01
Sm154	5.06E-02	5.035	6.12E-02	5.06E-02	5.250	6.12E-02
Sm total	9.74E-01	100.000	1.18E+00	8.96E-01	100.000	1.08E+00
Eu151	3.70E-04	0.185	4.48E-04	1.37E-04	0.065	1.66E-04
Eu153	1.62E-01	80.010	1.97E-01	1.62E-01	76.734	1.97E-01
Eu154	3.06E-02	14.958	3.70E-02	3.61E-02	16.956	4.37E-02
Eu155	9.97E-03	4.847	1.21E-02	1.34E-02	6.244	1.62E-02
Eu total	2.03E-01	100.000	2.46E-01	2.12E-01	100.000	2.57E-01
Gd154						
Gd155	3.41E-03		4.13E-03	!(-4.10E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	6.30E-01		7.63E-01	6.76E-01		8.19E-01
Mo95	9.68E-01		1.17E+00	9.68E-01		1.17E+00
Tc99	9.96E-01		1.21E+00	9.96E-01		1.21E+00
Ru101	8.49E-01		1.03E+00	8.49E-01		1.03E+00
Ru106	4.51E-02		5.46E-02	1.84E-01		2.22E-01
Rh103	4.62E-01		5.60E-01	4.62E-01		5.60E-01
Ag109	7.62E-02		9.22E-02	7.62E-02		9.22E-02
Sb125	3.71E-03		4.49E-03	6.23E-03		7.55E-03
I129 (*)	2.39E-01		2.90E-01	2.39E-01		2.90E-01
Cs133	1.39E+00	40.332	1.68E+00	1.39E+00	38.291	1.68E+00
Cs134	1.09E-01	3.158	1.32E-01	2.18E-01	5.994	2.64E-01
Cs135	4.05E-01	11.623	4.90E-01	4.05E-01	11.035	4.90E-01
Cs137	1.59E+00	44.887	1.92E+00	1.66E+00	44.680	2.02E+00
Cs total	3.49E+00	100.000	4.22E+00	3.67E+00	100.000	4.45E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 9 - Results normalized to solid fuel

Sample reference: DM1
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	6.38E-02	0.0081	8.00E-02	3.63E-02	0.0046	4.55E-02
U235	4.47E-01	0.0568	5.61E-01	4.47E-01	0.0568	5.61E-01
U236	2.94E-01	0.0371	3.68E-01	2.94E-01	0.0371	3.68E-01
U238	7.97E+02	99.8980	9.99E+02	7.97E+02	99.9015	9.99E+02
U total	7.98E+02	100.0000	1.00E+03	7.98E+02	100.0000	1.00E+03
Np237	1.27E-01		1.59E-01	1.27E-01		1.59E-01
Pu238	1.06E+00	4.1286	1.33E+00	9.37E-01	3.5888	1.17E+00
Pu239	5.43E+00	21.0083	6.80E+00	5.43E+00	20.7089	6.80E+00
Pu240	1.01E+01	39.0524	1.27E+01	1.00E+01	38.0767	1.26E+01
Pu241	3.55E+00	13.6399	4.45E+00	4.17E+00	15.7727	5.23E+00
Pu242	5.80E+00	22.1670	7.27E+00	5.80E+00	21.8492	7.27E+00
Pu244	1.00E-03	0.0038	1.26E-03	1.00E-03	0.0037	1.26E-03
Pu total	2.60E+01	100.0000	3.26E+01	2.64E+01	100.0000	3.30E+01
Am241	8.65E-01	39.319	1.08E+00	2.57E-01	16.135	3.22E-01
Am242m	5.80E-03	0.263	7.27E-03	5.90E-03	0.369	7.40E-03
Am243	1.34E+00	60.418	1.68E+00	1.34E+00	83.495	1.68E+00
Am total	2.21E+00	100.000	2.77E+00	1.60E+00	100.000	2.01E+00
Cm242	7.51E-04	0.081	9.41E-04	1.55E-01	12.868	1.94E-01
Cm243	5.59E-03	0.600	7.01E-03	6.07E-03	0.503	7.61E-03
Cm244	8.49E-01	90.703	1.06E+00	9.69E-01	79.968	1.21E+00
Cm245	6.49E-02	6.902	8.13E-02	6.49E-02	5.336	8.13E-02
Cm246	1.62E-02	1.714	2.03E-02	1.62E-02	1.325	2.03E-02
Cm Total	9.36E-01	100.000	1.17E+00	1.21E+00	100.000	1.52E+00

Build - up (+ decay if any) correction

Table 3.5 / 10 - Results normalized to solid fuel

Sample reference : DM1
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	1.69E-02		2.12E-02	2.84E-01		3.56E-01
Ce total						
Nd142	5.11E-02	0.899	6.40E-02	5.11E-02	0.943	6.40E-02
Nd143	9.99E-01	17.464	1.25E+00	9.99E-01	18.325	1.25E+00
Nd144	1.84E+00	31.905	2.30E+00	1.57E+00	28.548	1.97E+00
Nd145	9.21E-01	15.879	1.16E+00	9.21E-01	16.662	1.16E+00
Nd146	1.04E+00	17.755	1.30E+00	1.04E+00	18.630	1.30E+00
Nd148	6.00E-01	10.135	7.53E-01	6.00E-01	10.635	7.53E-01
Nd150	3.58E-01	5.963	4.49E-01	3.58E-01	6.257	4.49E-01
Nd total	5.81E+00	100.000	7.28E+00	5.54E+00	100.000	6.94E+00
Pm147						
Sm147	2.89E-01	21.800	3.62E-01			
Sm148	2.57E-01	19.263	3.22E-01	2.57E-01	24.622	3.22E-01
Sm149	4.64E-03	0.345	5.81E-03	4.64E-03	0.441	5.81E-03
Sm150	4.76E-01	35.208	5.97E-01	4.76E-01	45.003	5.97E-01
Sm151	1.50E-02	1.104	1.88E-02	1.55E-02	1.454	1.94E-02
Sm152	2.06E-01	15.014	2.58E-01	2.06E-01	19.191	2.58E-01
Sm154	1.01E-01	7.267	1.26E-01	1.01E-01	9.288	1.26E-01
Sm total	1.35E+00	100.000	1.69E+00		100.000	
Eu151	8.57E-04	0.289	1.07E-03	4.51E-04	0.141	5.65E-04
Eu153	2.48E-01	82.694	3.11E-01	2.48E-01	76.671	3.11E-01
Eu154	3.80E-02	12.583	4.77E-02	5.22E-02	16.005	6.54E-02
Eu155	1.35E-02	4.434	1.69E-02	2.36E-02	7.182	2.95E-02
Eu total	3.01E-01	100.000	3.77E-01	3.24E-01	100.000	4.07E-01
Gd154						
Gd155	1.04E-02		1.30E-02	1.17E-03		1.46E-03
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90						
Mo95	6.72E-01		8.42E-01	6.72E-01		8.42E-01
Tc99	5.00E-01		6.27E-01	5.00E-01		6.27E-01
Ru101	3.83E-01		4.80E-01	3.83E-01		4.80E-01
Ru106	1.38E-02		1.73E-02	1.20E-01		1.50E-01
Rh103	3.10E-01		3.89E-01	3.10E-01		3.89E-01
Ag109	9.27E-02		1.16E-01	9.27E-02		1.16E-01
Sb125	3.81E-03		4.78E-03	8.47E-03		1.06E-02
I129 (*)	2.78E-01		3.48E-01	2.78E-01		3.48E-01
Cs133	1.69E+00	39.187	2.11E+00	1.69E+00	36.646	2.11E+00
Cs134	5.71E-02	1.318	7.16E-02	2.00E-01	4.308	2.50E-01
Cs135	8.15E-01	18.661	1.02E+00	8.15E-01	17.452	1.02E+00
Cs137	1.81E+00	40.834	2.27E+00	1.97E+00	41.594	2.47E+00
Cs total	4.37E+00	100.000	5.48E+00	4.67E+00	100.000	5.86E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 11 - Results normalized to solid fuel

Sample reference: DM2
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 10 / 01 / 92		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	7.42E-02	0.0093	9.13E-02	3.97E-02	0.0050	4.89E-02
U235	8.96E-01	0.1117	1.10E+00	8.96E-01	0.1117	1.10E+00
U236	2.11E-01	0.0262	2.60E-01	2.11E-01	0.0262	2.60E-01
U238	8.11E+02	99.8529	9.99E+02	8.11E+02	99.8572	9.99E+02
U total	8.12E+02	100.0000	1.00E+03	8.12E+02	100.0000	1.00E+03
Np237	8.63E-02		1.06E-01	8.63E-02		1.06E-01
Pu238	1.01E+00	3.1928	1.25E+00	9.11E-01	2.8033	1.12E+00
Pu239	8.27E+00	25.9395	1.02E+01	8.28E+00	25.3512	1.02E+01
Pu240	1.45E+01	45.1373	1.78E+01	1.44E+01	44.0325	1.78E+01
Pu241	3.78E+00	11.7503	4.65E+00	4.66E+00	14.1516	5.73E+00
Pu242	4.52E+00	13.9789	5.56E+00	4.52E+00	13.6602	5.56E+00
Pu244	3.91E-04	0.0012	4.81E-04	3.91E-04	0.0012	4.81E-04
Pu total	3.20E+01	100.0000	3.94E+01	3.28E+01	100.0000	4.04E+01
Am241	1.41E+00	67.571	1.74E+00	5.47E-01	44.658	6.73E-01
Am242m	9.41E-03	0.449	1.16E-02	9.62E-03	0.782	1.18E-02
Am243	6.74E-01	31.980	8.29E-01	6.74E-01	54.560	8.30E-01
Am total	2.09E+00	100.000	2.58E+00	1.23E+00	100.000	1.51E+00
Cm242	1.57E-04	0.083	1.93E-04	1.26E-01	36.237	1.55E-01
Cm243	3.49E-03	1.844	4.30E-03	3.88E-03	1.114	4.78E-03
Cm244	1.77E-01	93.119	2.18E-01	2.10E-01	59.957	2.58E-01
Cm245	8.39E-03	4.395	1.03E-02	8.40E-03	2.389	1.03E-02
Cm246	1.07E-03	0.559	1.32E-03	1.07E-03	0.304	1.32E-03
Cm Total	1.90E-01	100.000	2.34E-01	3.49E-01	100.000	4.30E-01

Build - up (+ decay if any) correction

Table 3.5 / 12 - Results normalized to solid fuel

Sample reference : DM2
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 10 / 01 / 92		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	4.35E-03		5.36E-03	1.77E-01		2.18E-01
Ce total						
Nd142	1.11E-02	0.322	1.37E-02	1.11E-02	0.339	1.37E-02
Nd143	7.47E-01	21.477	9.20E-01	7.47E-01	22.598	9.20E-01
Nd144	9.97E-01	28.455	1.23E+00	8.24E-01	24.722	1.01E+00
Nd145	6.11E-01	17.304	7.52E-01	6.11E-01	18.207	7.52E-01
Nd146	5.81E-01	16.353	7.15E-01	5.81E-01	17.206	7.15E-01
Nd148	3.66E-01	10.155	4.50E-01	3.66E-01	10.685	4.50E-01
Nd150	2.17E-01	5.934	2.67E-01	2.17E-01	6.244	2.67E-01
Nd total	3.53E+00	100.000	4.35E+00	3.36E+00	100.000	4.13E+00
Pm147	4.85E-02		5.97E-02	1.85E-01		2.27E-01
Sm147	2.68E-01	30.000	3.30E-01	1.40E-01	18.306	1.72E-01
Sm148	9.28E-02	10.327	1.14E-01	9.28E-02	12.042	1.14E-01
Sm149	2.77E-03	0.306	3.41E-03	2.77E-03	0.357	3.41E-03
Sm150	2.82E-01	31.020	3.48E-01	2.82E-01	36.173	3.48E-01
Sm151	1.37E-02	1.490	1.68E-02	1.42E-02	1.804	1.75E-02
Sm152	1.88E-01	20.408	2.32E-01	1.88E-01	23.798	2.32E-01
Sm154	6.03E-02	6.449	7.42E-02	6.03E-02	7.520	7.42E-02
Sm total	9.08E-01	100.000	1.12E+00	7.81E-01	100.000	9.61E-01
Eu151	7.75E-04	0.453	9.55E-04	2.97E-04	0.161	3.66E-04
Eu153	1.52E-01	87.576	1.87E-01	1.52E-01	81.409	1.87E-01
Eu154	1.50E-02	8.579	1.84E-02	2.25E-02	11.972	2.77E-02
Eu155	5.96E-03	3.392	7.34E-03	1.22E-02	6.458	1.50E-02
Eu total	1.74E-01	100.000	2.14E-01	1.87E-01	100.000	2.30E-01
Gd154						
Gd155	5.07E-03		6.24E-03	!(-6.78E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	2.80E-01		3.45E-01	3.19E-01		3.93E-01
Mo95	5.33E-01		6.56E-01	5.33E-01		6.56E-01
Tc99	4.84E-01		5.96E-01	4.84E-01		5.96E-01
Ru101	3.95E-01		4.86E-01	3.95E-01		4.86E-01
Ru106	5.76E-03		7.09E-03	9.81E-02		1.21E-01
Rh103	3.43E-01		4.22E-01	3.43E-01		4.22E-01
Ag109	1.09E-01		1.34E-01	1.09E-01		1.34E-01
Sb125	2.64E-03		3.25E-03	7.54E-03		9.28E-03
I129 (*)	1.97E-01		2.42E-01	1.97E-01		2.42E-01
Cs133	1.18E+00	41.876	1.45E+00	1.18E+00	39.467	1.45E+00
Cs134	1.28E-02	0.451	1.58E-02	6.25E-02	2.076	7.69E-02
Cs135	5.60E-01	19.585	6.89E-01	5.60E-01	18.458	6.89E-01
Cs137	1.10E+00	38.088	1.36E+00	1.23E+00	39.999	1.52E+00
Cs total	2.86E+00	100.000	3.52E+00	3.03E+00	100.000	3.73E+00

(*) Iodine solution Build - up correction

Table 3.5 / 13 - Results normalized to solid fuel

Sample reference: DM3
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 10 / 01 / 92		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	8.76E-02	0.0111	1.09E-01	3.68E-02	0.0046	4.57E-02
U235	6.79E-01	0.0854	8.43E-01	6.79E-01	0.0854	8.43E-01
U236	2.69E-01	0.0337	3.34E-01	2.69E-01	0.0337	3.34E-01
U238	8.05E+02	99.8699	9.99E+02	8.05E+02	99.8763	9.99E+02
U total	8.06E+02	100.0000	1.00E+03	8.06E+02	100.0000	1.00E+03
Np237	1.17E-01		1.46E-01	1.17E-01		1.46E-01
Pu238	1.08E+00	3.7073	1.34E+00	5.17E-01	1.7389	6.42E-01
Pu239	7.27E+00	24.8124	9.03E+00	7.28E+00	24.3584	9.03E+00
Pu240	1.22E+01	41.5306	1.52E+01	1.21E+01	40.3493	1.50E+01
Pu241	3.79E+00	12.8112	4.70E+00	5.04E+00	16.7311	6.26E+00
Pu242	5.09E+00	17.1352	6.31E+00	5.09E+00	16.8190	6.32E+00
Pu244	9.88E-04	0.0033	1.23E-03	9.88E-04	0.0032	1.23E-03
Pu total	2.95E+01	100.0000	3.66E+01	3.00E+01	100.0000	3.73E+01
Am241	1.57E+00	58.427	1.95E+00	3.35E-01	23.049	4.16E-01
Am242m	7.13E-03	0.264	8.85E-03	7.34E-03	0.503	9.11E-03
Am243	1.12E+00	41.309	1.39E+00	1.12E+00	76.448	1.39E+00
Am total	2.70E+00	100.000	3.35E+00	1.46E+00	100.000	1.82E+00
Cm242	7.54E-05	0.013	9.36E-05	5.14E-01	41.767	6.39E-01
Cm243	6.51E-03	1.112	8.08E-03	7.49E-03	0.606	9.30E-03
Cm244	5.29E-01	90.022	6.57E-01	6.64E-01	53.434	8.24E-01
Cm245	4.51E-02	7.632	5.59E-02	4.51E-02	3.615	5.60E-02
Cm246	7.23E-03	1.220	8.98E-03	7.24E-03	0.578	8.99E-03
Cm Total	5.88E-01	100.000	7.30E-01	1.24E+00	100.000	1.54E+00

Build - up (+ decay if any) correction

Table 3.5 / 14 - Results normalized to solid fuel

Sample reference : DM3
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 10 / 01 / 92		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	1.79E-03		2.22E-03	3.22E-01		4.00E-01
Ce total						
Nd142	2.15E-02	0.463	2.67E-02	2.15E-02	0.497	2.67E-02
Nd143	9.28E-01	19.853	1.15E+00	9.28E-01	21.304	1.15E+00
Nd144	1.41E+00	29.848	1.74E+00	1.08E+00	24.721	1.35E+00
Nd145	7.81E-01	16.476	9.70E-01	7.81E-01	17.680	9.70E-01
Nd146	8.19E-01	17.144	1.02E+00	8.19E-01	18.397	1.02E+00
Nd148	4.96E-01	10.242	6.15E-01	4.96E-01	10.990	6.15E-01
Nd150	2.93E-01	5.974	3.64E-01	2.93E-01	6.411	3.64E-01
Nd total	4.74E+00	100.000	5.89E+00	4.42E+00	100.000	5.49E+00
Pm147						
Sm147	3.00E-01	25.862	3.72E-01			
Sm148	1.82E-01	15.615	2.26E-01	1.82E-01	21.043	2.26E-01
Sm149	3.46E-03	0.294	4.29E-03	3.46E-03	0.396	4.29E-03
Sm150	4.03E-01	34.003	5.00E-01	4.03E-01	45.824	5.00E-01
Sm151	1.63E-02	1.371	2.03E-02	1.71E-02	1.936	2.13E-02
Sm152	1.92E-01	15.994	2.38E-01	1.92E-01	21.554	2.38E-01
Sm154	8.34E-02	6.861	1.04E-01	8.34E-02	9.246	1.04E-01
Sm total	1.18E+00	100.000	1.46E+00	8.81E-01	100.000	1.09E+00
Eu151	8.07E-04	0.327	1.00E-03	4.34E-05	0.016	5.39E-05
Eu153	2.15E-01	86.081	2.67E-01	2.15E-01	77.900	2.67E-01
Eu154	2.68E-02	10.659	3.33E-02	4.38E-02	15.767	5.44E-02
Eu155	7.42E-03	2.933	9.22E-03	1.77E-02	6.317	2.19E-02
Eu total	2.50E-01	100.000	3.11E-01	2.77E-01	100.000	3.43E-01
Gd154						
Gd155						
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90						
Mo95	6.27E-01		7.78E-01	6.27E-01		7.78E-01
Tc99	4.70E-01		5.83E-01	4.70E-01		5.83E-01
Ru101	3.57E-01		4.43E-01	3.57E-01		4.43E-01
Ru106						
Rh103	2.96E-01		3.68E-01	2.96E-01		3.68E-01
Ag109	1.37E-01		1.70E-01	1.37E-01		1.70E-01
Sb125						
I129 (*)	3.04E-01		3.78E-01	3.04E-01		3.78E-01
Cs133	1.48E+00	40.861	1.83E+00	1.48E+00	37.406	1.83E+00
Cs134	2.16E-02	0.594	2.68E-02	1.54E-01	3.866	1.91E-01
Cs135	7.13E-01	19.431	8.85E-01	7.13E-01	17.788	8.85E-01
Cs137	1.46E+00	39.114	1.81E+00	1.67E+00	40.939	2.07E+00
Cs total	3.67E+00	100.000	4.55E+00	4.01E+00	100.000	4.98E+00

(*) Iodine solution Build - up correction

Table 3.5 / 15 - Results normalized to solid fuel

Sample reference: DM4
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	8.92E-02	0.0114	1.12E-01	4.45E-02	0.0057	5.57E-02
U235	8.72E-01	0.1105	1.09E+00	8.72E-01	0.1105	1.09E+00
U236	2.31E-01	0.0291	2.89E-01	2.31E-01	0.0291	2.89E-01
U238	7.98E+02	99.8490	9.99E+02	7.98E+02	99.8547	9.99E+02
U total	7.99E+02	100.0000	1.00E+03	7.99E+02	100.0000	1.00E+03
Np237	9.47E-02		1.19E-01	9.47E-02		1.19E-01
Pu238	1.15E+00	3.6102	1.44E+00	9.73E-01	2.9787	1.22E+00
Pu239	9.13E+00	28.5356	1.14E+01	9.13E+00	27.8101	1.14E+01
Pu240	1.34E+01	41.8780	1.68E+01	1.34E+01	40.6336	1.68E+01
Pu241	4.03E+00	12.4862	5.04E+00	5.11E+00	15.4325	6.39E+00
Pu242	4.37E+00	13.4866	5.46E+00	4.37E+00	13.1419	5.47E+00
Pu244	1.08E-03	0.0033	1.35E-03	1.08E-03	0.0032	1.35E-03
Pu total	3.21E+01	100.0000	4.02E+01	3.30E+01	100.0000	4.13E+01
Am241	1.64E+00	65.520	2.05E+00	5.70E-01	39.841	7.14E-01
Am242m	1.19E-02	0.476	1.49E-02	1.22E-02	0.850	1.53E-02
Am243	8.56E-01	34.004	1.07E+00	8.56E-01	59.309	1.07E+00
Am total	2.50E+00	100.000	3.13E+00	1.44E+00	100.000	1.80E+00
Cm242	1.27E-04	0.037	1.59E-04	1.85E-01	31.211	2.32E-01
Cm243	4.46E-03	1.293	5.58E-03	5.01E-03	0.840	6.27E-03
Cm244	3.16E-01	91.356	3.96E-01	3.82E-01	63.720	4.78E-01
Cm245	2.30E-02	6.622	2.88E-02	2.30E-02	3.828	2.88E-02
Cm246	2.42E-03	0.692	3.02E-03	2.42E-03	0.400	3.03E-03
Cm Total	3.46E-01	100.000	4.33E-01	5.98E-01	100.000	7.48E-01

Build - up (+ decay if any) correction

Table 3.5 / 16 - Results normalized to solid fuel

Sample reference : DM4
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	2.72E-03		3.40E-03	2.02E-01		2.53E-01
Ce total						
Nd142	1.46E-02	0.402	1.83E-02	1.46E-02	0.425	1.83E-02
Nd143	7.89E-01	21.505	9.88E-01	7.89E-01	22.733	9.88E-01
Nd144	1.05E+00	28.479	1.32E+00	8.53E-01	24.398	1.07E+00
Nd145	6.35E-01	17.050	7.94E-01	6.35E-01	18.023	7.94E-01
Nd146	6.27E-01	16.742	7.85E-01	6.27E-01	17.698	7.85E-01
Nd148	3.82E-01	10.045	4.78E-01	3.82E-01	10.619	4.78E-01
Nd150	2.22E-01	5.776	2.78E-01	2.22E-01	6.106	2.78E-01
Nd total	3.72E+00	100.000	4.66E+00	3.52E+00	100.000	4.41E+00
Pm147						
Sm147	2.65E-01	27.815	3.31E-01			
Sm148	1.25E-01	13.080	1.57E-01	1.25E-01	18.103	1.57E-01
Sm149	3.35E-03	0.347	4.19E-03	3.35E-03	0.480	4.19E-03
Sm150	3.10E-01	31.914	3.88E-01	3.10E-01	44.169	3.88E-01
Sm151	1.68E-02	1.715	2.10E-02	1.74E-02	2.468	2.18E-02
Sm152	1.79E-01	18.154	2.23E-01	1.79E-01	25.125	2.24E-01
Sm154	6.95E-02	6.976	8.70E-02	6.95E-02	9.655	8.70E-02
Sm total	9.68E-01	100.000	1.21E+00		100.000	
Eu151	8.43E-04	0.435	1.05E-03	1.94E-04	0.092	2.42E-04
Eu153	1.69E-01	86.003	2.11E-01	1.69E-01	79.404	2.11E-01
Eu154	2.06E-02	10.412	2.57E-02	3.10E-02	14.498	3.88E-02
Eu155	6.27E-03	3.150	7.84E-03	1.29E-02	6.006	1.62E-02
Eu total	1.97E-01	100.000	2.46E-01	2.13E-01	100.000	2.67E-01
Gd154						
Gd155						
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90						
Mo95	5.68E-01		7.10E-01	5.68E-01		7.10E-01
Tc99	6.08E-01		7.61E-01	6.08E-01		7.61E-01
Ru101	4.67E-01		5.84E-01	4.67E-01		5.84E-01
Ru106						
Rh103	4.09E-01		5.12E-01	4.09E-01		5.12E-01
Ag109	1.27E-01		1.59E-01	1.27E-01		1.60E-01
Sb125						
I129 (*)	2.33E-01		2.92E-01	2.33E-01		2.92E-01
Cs133	1.22E+00	39.690	1.53E+00	1.22E+00	37.251	1.53E+00
Cs134	1.70E-02	0.548	2.13E-02	8.66E-02	2.620	1.08E-01
Cs135	7.24E-01	23.173	9.07E-01	7.24E-01	21.750	9.07E-01
Cs137	1.16E+00	36.589	1.45E+00	1.30E+00	38.379	1.62E+00
Cs total	3.12E+00	100.000	3.91E+00	3.33E+00	100.000	4.17E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 17 - Results normalized to solid fuel

Sample reference: DU1
Laboratory: SCK - CEN Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.24E-01	0.0155	1.52E-01	1.18E-01	0.0146	1.44E-01
U235	5.08E+00	0.6295	6.22E+00	5.08E+00	0.6295	6.22E+00
U236	6.27E+00	0.7734	7.67E+00	6.27E+00	0.7734	7.67E+00
U238	8.06E+02	98.5816	9.86E+02	8.06E+02	98.5824	9.86E+02
U total	8.18E+02	100.0000	1.00E+03	8.18E+02	100.0000	1.00E+03
Np237	6.24E-01		7.63E-01	6.24E-01		7.63E-01
Pu238	2.69E-01	3.5195	3.29E-01	2.57E-01	3.3073	3.14E-01
Pu239	3.42E+00	44.5397	4.18E+00	3.42E+00	43.8157	4.18E+00
Pu240	2.39E+00	31.0455	2.93E+00	2.39E+00	30.4504	2.92E+00
Pu241	8.67E-01	11.2034	1.06E+00	1.01E+00	12.8931	1.24E+00
Pu242	7.53E-01	9.6910	9.21E-01	7.53E-01	9.5326	9.21E-01
Pu244	7.05E-05	0.0009	8.63E-05	7.05E-05	0.0009	8.63E-05
Pu total	7.70E+00	100.0000	9.42E+00	7.83E+00	100.0000	9.58E+00
Am241	1.81E-01	54.448	2.22E-01	3.56E-02	19.014	4.36E-02
Am242m	6.01E-04	0.180	7.34E-04	6.11E-04	0.325	7.47E-04
Am243	1.52E-01	45.372	1.86E-01	1.52E-01	80.661	1.86E-01
Am total	3.34E-01	100.000	4.09E-01	1.89E-01	100.000	2.31E-01
Cm242	9.29E-05	0.149	1.14E-04	1.92E-02	21.398	2.35E-02
Cm243	4.41E-04	0.705	5.40E-04	4.79E-04	0.532	5.86E-04
Cm244	5.88E-02	93.446	7.19E-02	6.71E-02	74.107	8.20E-02
Cm245	2.95E-03	4.672	3.61E-03	2.95E-03	3.249	3.61E-03
Cm246	6.52E-04	1.028	7.97E-04	6.52E-04	0.715	7.98E-04
Cm Total	6.29E-02	100.000	7.70E-02	9.04E-02	100.000	1.11E-01

Build - up (+ decay if any) correction

Table 3.5 / 18 - Results normalized to solid fuel

Sample reference : DU1
Laboratory: SCK - CEN Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	1.87E-02		2.29E-02	3.15E-01		3.86E-01
Ce total						
Nd142	4.95E-02	0.834	6.06E-02	4.95E-02	0.878	6.06E-02
Nd143	9.26E-01	15.488	1.13E+00	9.26E-01	16.302	1.13E+00
Nd144	2.24E+00	37.239	2.74E+00	1.94E+00	33.941	2.37E+00
Nd145	9.63E-01	15.880	1.18E+00	9.63E-01	16.714	1.18E+00
Nd146	1.07E+00	17.601	1.31E+00	1.07E+00	18.526	1.31E+00
Nd148	5.45E-01	8.801	6.66E-01	5.45E-01	9.263	6.66E-01
Nd150	2.61E-01	4.157	3.19E-01	2.61E-01	4.375	3.19E-01
Nd total	6.06E+00	100.000	7.41E+00	5.76E+00	100.000	7.04E+00
Pm147	6.83E-02		8.35E-02	2.00E-01		2.44E-01
Sm147	2.73E-01	25.214	3.34E-01	1.54E-01	15.926	1.88E-01
Sm148	2.33E-01	21.318	2.85E-01	2.33E-01	23.957	2.85E-01
Sm149	2.65E-03	0.241	3.24E-03	2.65E-03	0.271	3.24E-03
Sm150	3.90E-01	35.213	4.77E-01	3.90E-01	39.572	4.77E-01
Sm151	9.50E-03	0.853	1.16E-02	9.79E-03	0.987	1.20E-02
Sm152	1.42E-01	12.689	1.74E-01	1.42E-01	14.260	1.74E-01
Sm154	5.08E-02	4.473	6.21E-02	5.08E-02	5.027	6.21E-02
Sm total	1.10E+00	100.000	1.35E+00	9.82E-01	100.000	1.20E+00
Eu151	6.04E-04	0.334	7.39E-04	3.47E-04	0.180	4.24E-04
Eu153	1.55E-01	84.871	1.90E-01	1.55E-01	79.406	1.90E-01
Eu154	1.96E-02	10.661	2.40E-02	2.69E-02	13.669	3.29E-02
Eu155	7.67E-03	4.134	9.38E-03	1.34E-02	6.745	1.63E-02
Eu total	1.83E-01	100.000	2.24E-01	1.96E-01	100.000	2.40E-01
Gd154						
Gd155	4.98E-03		6.09E-03	!(-2.33E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	9.05E-01		1.11E+00	1.01E+00		1.23E+00
Mo95	1.20E+00		1.47E+00	1.20E+00		1.47E+00
Tc99	1.14E+00		1.39E+00	1.14E+00		1.39E+00
Ru101	1.00E+00		1.23E+00	1.00E+00		1.23E+00
Ru106	1.51E-02		1.85E-02	1.31E-01		1.60E-01
Rh103	5.05E-01		6.17E-01	5.05E-01		6.17E-01
Ag109	4.68E-02		5.72E-02	4.68E-02		5.72E-02
Sb125	2.94E-03		3.59E-03	6.53E-03		7.98E-03
I129 (*)	2.12E-01		2.59E-01	2.12E-01		2.59E-01
Cs133	1.50E+00	41.914	1.83E+00	1.50E+00	39.085	1.83E+00
Cs134	4.94E-02	1.369	6.04E-02	1.73E-01	4.468	2.11E-01
Cs135	5.08E-01	13.992	6.21E-01	5.08E-01	13.047	6.21E-01
Cs137	1.57E+00	42.725	1.93E+00	1.71E+00	43.399	2.10E+00
Cs total	3.63E+00	100.000	4.44E+00	3.90E+00	100.000	4.76E+00

(*) Iodine solution Build - up correction

Table 3.5 / 19 - Results normalized to solid fuel

Sample reference: BM1
Laboratory: PSI

Main solution - Actinides

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	7.50E-02	0.0095	9.34E-02			
U235	8.65E-01	0.1092	1.08E+00	8.65E-01	0.1092	1.08E+00
U236	2.58E-01	0.0324	3.21E-01	2.58E-01	0.0324	3.21E-01
U238	8.01E+02	99.8489	9.99E+02	8.01E+02	99.8584	9.99E+02
U total	8.03E+02	100.0000	1.00E+03	8.02E+02	100.0000	1.00E+03
Np237	1.50E-01		1.87E-01	1.50E-01		1.87E-01
Pu238	9.95E-01	3.2701	1.24E+00			
Pu239	1.10E+01	36.0211	1.37E+01	1.10E+01	35.7596	1.37E+01
Pu240	1.09E+01	35.4161	1.35E+01	1.08E+01	34.8096	1.34E+01
Pu241	4.32E+00	14.0024	5.38E+00	5.66E+00	18.2240	7.05E+00
Pu242	3.49E+00	11.2903	4.35E+00	3.49E+00	11.2067	4.35E+00
Pu244						
Pu total	3.07E+01	100.0000	3.82E+01		100.0000	
Am241	2.40E+00	68.020	2.99E+00	8.61E-01	43.281	1.07E+00
Am242m	1.61E-02	0.455	2.01E-02	1.66E-02	0.833	2.07E-02
Am243	1.12E+00	31.524	1.40E+00	1.12E+00	55.886	1.40E+00
Am total	3.53E+00	100.000	4.40E+00	2.00E+00	100.000	2.49E+00
Cm242						
Cm243						
Cm244	4.58E-01	87.556	5.70E-01	5.91E-01	90.077	7.36E-01
Cm245	5.88E-02	11.209	7.33E-02	5.89E-02	8.938	7.34E-02
Cm246	6.51E-03	1.235	8.11E-03	6.52E-03	0.985	8.12E-03
Cm Total	5.23E-01	100.000	6.52E-01	6.56E-01	100.000	8.18E-01

Build - up (+ decay if any) correction

Table 3.5 / 20 - Results normalized to solid fuel

Sample reference : BM1
Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	7.51E-04		9.36E-04	2.38E-01		2.97E-01
Ce total						
Nd142	1.65E-02	0.400	2.06E-02	1.65E-02	0.424	2.06E-02
Nd143	8.80E-01	21.113	1.10E+00	8.80E-01	22.375	1.10E+00
Nd144	1.16E+00	27.739	1.45E+00	9.27E-01	23.420	1.16E+00
Nd145	7.00E-01	16.565	8.72E-01	7.00E-01	17.555	8.72E-01
Nd146	7.46E-01	17.524	9.29E-01	7.46E-01	18.571	9.29E-01
Nd148	4.51E-01	10.463	5.62E-01	4.51E-01	11.088	5.62E-01
Nd150	2.71E-01	6.196	3.38E-01	2.71E-01	6.566	3.38E-01
Nd total	4.23E+00	100.000	5.27E+00	3.99E+00	100.000	4.97E+00
Pm147						
Sm147	2.59E-01	24.158	3.23E-01			
Sm148	1.93E-01	17.868	2.40E-01	1.93E-01	23.526	2.40E-01
Sm149	5.02E-03	0.462	6.25E-03	5.02E-03	0.608	6.25E-03
Sm150	3.69E-01	33.721	4.60E-01	3.69E-01	44.399	4.60E-01
Sm151	2.37E-02	2.153	2.96E-02	2.49E-02	2.976	3.10E-02
Sm152	1.60E-01	14.460	2.00E-01	1.60E-01	19.039	2.00E-01
Sm154	8.06E-02	7.178	1.00E-01	8.06E-02	9.451	1.01E-01
Sm total	1.09E+00	100.000	1.36E+00		100.000	
Eu151	1.59E-03	0.672	1.98E-03	4.04E-04	0.149	5.04E-04
Eu153	1.94E-01	80.873	2.42E-01	1.94E-01	70.661	2.42E-01
Eu154	3.68E-02	15.238	4.58E-02	6.14E-02	22.241	7.65E-02
Eu155	7.81E-03	3.216	9.73E-03	1.93E-02	6.949	2.41E-02
Eu total	2.40E-01	100.000	2.99E-01	2.75E-01	100.000	3.43E-01
Gd154	2.71E-02	11.711	3.38E-02			
Gd155	9.37E-03	4.021	1.17E-02	!(-2.14E-03)!		
Gd156	1.53E-01	65.410	1.91E-01			
Gd157						
Gd158	4.15E-02	17.460	5.17E-02			
Gd160	3.36E-03	1.398	4.19E-03			
Gd total	2.35E-01	100.000	2.92E-01			
Sr90	2.81E-01		3.50E-01	3.28E-01		4.09E-01
Mo95	5.81E-01		7.23E-01	5.81E-01		7.23E-01
Tc99	5.28E-01		6.58E-01	5.28E-01		6.58E-01
Ru101	3.22E-01		4.02E-01	3.22E-01		4.02E-01
Ru106	1.01E-03		1.26E-03	8.25E-02		1.03E-01
Rh103	3.27E-01		4.08E-01	3.27E-01		4.08E-01
Ag109	6.89E-02		8.58E-02	6.89E-02		8.58E-02
Sb125	1.30E-03		1.62E-03	6.63E-03		8.26E-03
I129 (*)						
Cs133	1.42E+00	38.074	1.77E+00	1.42E+00	34.707	1.77E+00
Cs134	1.89E-02	0.505	2.36E-02	1.64E-01	3.974	2.04E-01
Cs135	9.28E-01	24.537	1.16E+00	9.28E-01	22.367	1.16E+00
Cs137	1.42E+00	36.884	1.76E+00	1.64E+00	38.952	2.04E+00
Cs total	3.78E+00	100.000	4.71E+00	4.15E+00	100.000	5.17E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 21 - Results normalized to solid fuel

Sample reference: BM3
Laboratory: PSI Main solution - Actinides

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	8.72E-02	0.0110	1.08E-01			
U235	8.99E-01	0.1129	1.11E+00			
U236	2.66E-01	0.0333	3.30E-01			
U238	8.05E+02	99.8428	9.98E+02			
U total	8.07E+02	100.0000	1.00E+03			
Np237						
Pu238	1.18E+00	3.3646	1.46E+00			
Pu239	1.25E+01	35.6487	1.55E+01			
Pu240	1.26E+01	35.7679	1.56E+01			
Pu241	4.85E+00	13.7125	6.02E+00			
Pu242	4.09E+00	11.5064	5.07E+00			
Pu244						
Pu total	3.52E+01	100.0000	4.37E+01			
Am241						
Am242m						
Am243						
Am total						
Cm242						
Cm243						
Cm244						
Cm245						
Cm246						
Cm Total						

Table 3.5 / 22 - Results normalized to solid fuel

Sample reference : BM3

Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144						
Ce total						
Nd142	1.80E-02	0.401	2.23E-02			
Nd143	9.76E-01	21.557	1.21E+00			
Nd144	1.28E+00	28.132	1.59E+00			
Nd145	7.53E-01	16.416	9.34E-01			
Nd146	8.07E-01	17.464	1.00E+00			
Nd148	4.63E-01	9.894	5.75E-01			
Nd150	2.91E-01	6.136	3.61E-01			
Nd total	4.59E+00	100.000	5.69E+00			
Pm147						
Sm147						
Sm148						
Sm149						
Sm150						
Sm151						
Sm152						
Sm154						
Sm total						
Eu151						
Eu153						
Eu154						
Eu155						
Eu total						
Gd154						
Gd155						
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90						
Mo95						
Tc99						
Ru101						
Ru106						
Rh103						
Ag109						
Sb125						
I129 (*)						
Cs133						
Cs134						
Cs135						
Cs137						
Cs total						

(*) Iodine solution

Table 3.5 / 23 - Results normalized to solid fuel

Sample reference: BM4-D
Laboratory: PSI Main solution - Actinides

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	8.22E-02	0.0106	1.04E-01			
U235	1.08E+00	0.1382	1.36E+00			
U236	2.25E-01	0.0288	2.86E-01			
U238	7.88E+02	99.8224	9.98E+02			
U total	7.89E+02	100.0000	1.00E+03			
Np237						
Pu238	1.08E+00	2.9461	1.36E+00			
Pu239	1.44E+01	39.2089	1.82E+01			
Pu240	1.31E+01	35.4103	1.65E+01			
Pu241	4.79E+00	12.9305	6.07E+00			
Pu242	3.53E+00	9.5041	4.48E+00			
Pu244						
Pu total	3.68E+01	100.0000	4.67E+01			
Am241						
Am242m						
Am243						
Am total						
Cm242						
Cm243						
Cm244						
Cm245						
Cm246						
Cm Total						

Table 3.5 / 24 - Results normalized to solid fuel

Sample reference : BM4-D

Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 01 / 04 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144						
Ce total						
Nd142	1.91E-02	0.471	2.43E-02			
Nd143	9.30E-01	22.749	1.18E+00			
Nd144	1.12E+00	27.141	1.42E+00			
Nd145	7.03E-01	16.950	8.91E-01			
Nd146	7.09E-01	16.971	8.98E-01			
Nd148	4.08E-01	9.635	5.17E-01			
Nd150	2.61E-01	6.083	3.31E-01			
Nd total	4.15E+00	100.000	5.26E+00			
Pm147						
Sm147						
Sm148						
Sm149						
Sm150						
Sm151						
Sm152						
Sm154						
Sm total						
Eu151						
Eu153						
Eu154						
Eu155						
Eu total						
Gd154						
Gd155						
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90						
Mo95						
Tc99						
Ru101						
Ru106						
Rh103						
Ag109						
Sb125						
I129 (*)						
Cs133						
Cs134						
Cs135						
Cs137						
Cs total						

(*) Iodine solution

Table 3.5 / 25 - Results normalized to solid fuel

Sample reference: BM5
Laboratory: PSI

Main solution - Actinides

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	4.48E-02	0.0057	5.61E-02			
U235	7.39E-01	0.0937	9.25E-01	7.39E-01	0.0937	9.25E-01
U236	2.68E-01	0.0339	3.36E-01	2.68E-01	0.0339	3.36E-01
U238	7.98E+02	99.8668	9.99E+02	7.98E+02	99.8725	9.99E+02
U total	7.99E+02	100.0000	1.00E+03	7.99E+02	100.0000	
Np237	1.75E-01		2.19E-01	1.75E-01		2.19E-01
Pu238	8.65E-01	3.1488	1.08E+00			
Pu239	9.25E+00	33.5558	1.16E+01	9.26E+00	33.9280	1.16E+01
Pu240	9.59E+00	34.6380	1.20E+01	9.51E+00	34.7134	1.19E+01
Pu241	4.47E+00	16.0640	5.59E+00	5.12E+00	18.6265	6.41E+00
Pu242	3.52E+00	12.5934	4.40E+00	3.52E+00	12.7321	4.40E+00
Pu244						
Pu total	2.77E+01	100.0000	3.47E+01		100.0000	
Am241	1.08E+00	55.406	1.35E+00	3.06E-01	26.049	3.83E-01
Am242m	1.04E-02	0.534	1.31E-02	1.06E-02	0.900	1.33E-02
Am243	8.64E-01	44.060	1.08E+00	8.65E-01	73.051	1.08E+00
Am total	1.95E+00	100.000	2.44E+00	1.18E+00	100.000	1.48E+00
Cm242						
Cm243						
Cm244	7.49E-01	87.623	9.37E-01	8.53E-01	88.969	1.07E+00
Cm245	9.13E-02	10.645	1.14E-01	9.13E-02	9.488	1.14E-01
Cm246	1.49E-02	1.731	1.87E-02	1.49E-02	1.544	1.87E-02
Cm Total	8.55E-01	100.000	1.07E+00	9.59E-01	100.000	1.20E+00

Build - up (+ decay if any) correction

Table 3.5 / 26 - Results normalized to solid fuel

Sample reference : BM5
Laboratory: PSI — Main solution - Fission products

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	1.24E-02		1.56E-02	2.23E-01		2.79E-01
Ce total						
Nd142	2.85E-02	0.576	3.56E-02	2.85E-02	0.600	3.57E-02
Nd143	9.60E-01	19.257	1.20E+00	9.60E-01	20.083	1.20E+00
Nd144	1.46E+00	29.034	1.82E+00	1.25E+00	25.989	1.57E+00
Nd145	8.08E-01	15.989	1.01E+00	8.08E-01	16.675	1.01E+00
Nd146	9.41E-01	18.495	1.18E+00	9.41E-01	19.289	1.18E+00
Nd148	5.43E-01	10.535	6.80E-01	5.43E-01	10.987	6.80E-01
Nd150	3.20E-01	6.115	4.00E-01	3.20E-01	6.377	4.00E-01
Nd total	5.06E+00	100.000	6.33E+00	4.85E+00	100.000	6.07E+00
Pm147	6.67E-02		8.34E-02	1.67E-01		2.10E-01
Sm147	2.45E-01	18.907	3.07E-01	1.51E-01	12.564	1.89E-01
Sm148	2.90E-01	22.274	3.64E-01	2.90E-01	24.003	3.64E-01
Sm149	5.15E-03	0.393	6.45E-03	5.15E-03	0.423	6.45E-03
Sm150	4.71E-01	35.620	5.89E-01	4.71E-01	38.385	5.89E-01
Sm151	2.44E-02	1.837	3.06E-02	2.50E-02	2.027	3.13E-02
Sm152	1.76E-01	13.166	2.21E-01	1.76E-01	14.188	2.21E-01
Sm154	1.06E-01	7.804	1.33E-01	1.06E-01	8.410	1.33E-01
Sm total	1.32E+00	100.000	1.65E+00	1.22E+00	100.000	1.53E+00
Eu151	7.55E-04	0.258	9.45E-04	1.62E-04	0.052	2.03E-04
Eu153	2.32E-01	78.017	2.90E-01	2.32E-01	72.821	2.90E-01
Eu154	5.29E-02	17.682	6.62E-02	6.81E-02	21.237	8.52E-02
Eu155	1.22E-02	4.044	1.52E-02	1.90E-02	5.890	2.38E-02
Eu total	2.98E-01	100.000	3.73E-01	3.19E-01	100.000	3.99E-01
Gd154	2.76E-02	7.819	3.45E-02			
Gd155	8.17E-03	2.302	1.02E-02	1.35E-03		1.68E-03
Gd156	2.60E-01	72.798	3.25E-01			
Gd157						
Gd158	5.75E-02	15.904	7.20E-02			
Gd160	4.31E-03	1.177	5.40E-03			
Gd total	3.58E-01	100.000	4.48E-01			
Sr90	4.02E-01		5.03E-01	4.35E-01		5.44E-01
Mo95	6.87E-01		8.60E-01	6.87E-01		8.60E-01
Tc99	5.58E-01		6.98E-01	5.58E-01		6.98E-01
Ru101	3.68E-01		4.61E-01	3.68E-01		4.61E-01
Ru106	9.68E-03		1.21E-02	8.81E-02		1.10E-01
Rh103	3.64E-01		4.55E-01	3.64E-01		4.55E-01
Ag109	2.66E-02		3.33E-02	2.66E-02		3.33E-02
Sb125	2.56E-03		3.21E-03	5.80E-03		7.26E-03
I129 (*)	8.82E-02		1.10E-01	8.82E-02		1.10E-01
Cs133	1.58E+00	36.032	1.98E+00	1.58E+00	33.986	1.98E+00
Cs134	7.26E-02	1.640	9.08E-02	2.11E-01	4.496	2.64E-01
Cs135	1.07E+00	24.060	1.34E+00	1.07E+00	22.694	1.34E+00
Cs137	1.73E+00	38.268	2.17E+00	1.86E+00	38.823	2.33E+00
Cs total	4.46E+00	100.000	5.58E+00	4.73E+00	100.000	5.92E+00

(*) Iodine solution — Build - up correction

Table 3.5 / 27 - Results normalized to solid fuel

Sample reference: BM6

Laboratory: PSI

Main solution - Actinides

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	4.95E-02	0.0063	6.19E-02			
U235	9.56E-01	0.1211	1.20E+00	9.56E-01	0.1211	1.20E+00
U236	2.09E-01	0.0264	2.61E-01	2.09E-01	0.0264	2.61E-01
U238	7.98E+02	99.8463	9.98E+02	7.98E+02	99.8525	9.99E+02
U total	8.00E+02	100.0000	1.00E+03	8.00E+02	100.0000	1.00E+03
Np237	1.25E-01		1.56E-01	1.25E-01		1.56E-01
Pu238	7.82E-01	2.4730	9.78E-01			
Pu239	1.33E+01	41.7996	1.66E+01	1.33E+01	41.9993	1.66E+01
Pu240	1.09E+01	34.0746	1.36E+01	1.08E+01	34.1432	1.35E+01
Pu241	4.56E+00	14.2351	5.70E+00	5.23E+00	16.4050	6.54E+00
Pu242	2.38E+00	7.4177	2.98E+00	2.38E+00	7.4525	2.98E+00
Pu244						
Pu total	3.19E+01	100.0000	3.98E+01		100.0000	
Am241	1.68E+00	69.389	2.11E+00	8.99E-01	54.715	1.12E+00
Am242m	2.20E-02	0.902	2.75E-02	2.24E-02	1.355	2.80E-02
Am243	7.27E-01	29.709	9.10E-01	7.28E-01	43.930	9.10E-01
Am total	2.43E+00	100.000	3.04E+00	1.65E+00	100.000	2.06E+00
Cm242						
Cm243						
Cm244	2.78E-01	89.685	3.48E-01	3.17E-01	90.832	3.97E-01
Cm245	2.97E-02	9.545	3.72E-02	2.97E-02	8.483	3.72E-02
Cm246	2.41E-03	0.770	3.01E-03	2.41E-03	0.684	3.01E-03
Cm Total	3.10E-01	100.000	3.88E-01	3.35E-01	100.000	4.19E-01

Build - up (+ decay if any) correction

Table 3.5 / 28 - Results normalized to solid fuel

Sample reference : BM6
Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 28 / 06 / 96		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	8.63E-03		1.08E-02	1.54E-01		1.93E-01
Ce total						
Nd142	9.34E-03	0.303	1.17E-02	9.34E-03	0.318	1.17E-02
Nd143	6.83E-01	22.022	8.54E-01	6.83E-01	23.074	8.54E-01
Nd144	8.29E-01	26.538	1.04E+00	6.87E-01	23.028	8.59E-01
Nd145	5.35E-01	17.022	6.70E-01	5.35E-01	17.835	6.70E-01
Nd146	5.52E-01	17.425	6.90E-01	5.52E-01	18.257	6.90E-01
Nd148	3.41E-01	10.616	4.26E-01	3.41E-01	11.123	4.26E-01
Nd150	1.98E-01	6.074	2.47E-01	1.98E-01	6.365	2.47E-01
Nd total	3.15E+00	100.000	3.94E+00	3.01E+00	100.000	3.76E+00
Pm147	5.32E-02		6.66E-02	1.34E-01		1.67E-01
Sm147	2.02E-01	23.907	2.53E-01	1.27E-01	16.479	1.59E-01
Sm148	1.46E-01	17.126	1.82E-01	1.46E-01	18.781	1.82E-01
Sm149	4.66E-03	0.544	5.83E-03	4.66E-03	0.597	5.83E-03
Sm150	2.82E-01	32.668	3.52E-01	2.82E-01	35.825	3.52E-01
Sm151	2.43E-02	2.802	3.04E-02	2.49E-02	3.147	3.12E-02
Sm152	1.39E-01	15.878	1.73E-01	1.39E-01	17.413	1.73E-01
Sm154	6.26E-02	7.075	7.83E-02	6.26E-02	7.758	7.83E-02
Sm total	8.60E-01	100.000	1.08E+00	7.85E-01	100.000	9.82E-01
Eu151	8.30E-04	0.438	1.04E-03	2.39E-04	0.118	2.99E-04
Eu153	1.52E-01	79.082	1.90E-01	1.52E-01	74.161	1.90E-01
Eu154	3.21E-02	16.603	4.01E-02	4.13E-02	20.044	5.17E-02
Eu155	7.54E-03	3.877	9.43E-03	1.18E-02	5.677	1.47E-02
Eu total	1.92E-01	100.000	2.41E-01	2.05E-01	100.000	2.57E-01
Gd154	1.43E-02	9.687	1.79E-02			
Gd155	4.39E-03	2.953	5.49E-03	1.53E-04		1.91E-04
Gd156	9.82E-02	65.662	1.23E-01			
Gd157						
Gd158	3.03E-02	20.030	3.79E-02			
Gd160	2.56E-03	1.667	3.20E-03			
Gd total	1.50E-01	100.000	1.87E-01			
Sr90	2.33E-01		2.92E-01	2.53E-01		3.16E-01
Mo95	5.50E-01		6.88E-01	5.50E-01		6.88E-01
Tc99	4.74E-01		5.93E-01	4.74E-01		5.93E-01
Ru101	3.20E-01		4.01E-01	3.20E-01		4.01E-01
Ru106	7.82E-03		9.78E-03	7.09E-02		8.87E-02
Rh103	3.44E-01		4.30E-01	3.44E-01		4.30E-01
Ag109	1.40E-02		1.75E-02	1.40E-02		1.75E-02
Sb125	2.15E-03		2.69E-03	4.85E-03		6.07E-03
I129 (*)	8.34E-02		1.04E-01	8.34E-02		1.04E-01
Cs133	1.08E+00	35.706	1.35E+00	1.08E+00	34.106	1.35E+00
Cs134	3.23E-02	1.058	4.04E-02	9.39E-02	2.940	1.17E-01
Cs135	8.58E-01	27.908	1.07E+00	8.58E-01	26.658	1.07E+00
Cs137	1.10E+00	35.328	1.38E+00	1.19E+00	36.297	1.48E+00
Cs total	3.07E+00	100.000	3.84E+00	3.22E+00	100.000	4.03E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 29 - Results normalized to solid fuel

Sample reference: DM1
Laboratory: PSI

Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	8.91E-02	0.0115	1.13E-01			
U235	4.88E-01	0.0628	6.20E-01	4.88E-01	0.0628	6.20E-01
U236	2.82E-01	0.0361	3.58E-01	2.82E-01	0.0361	3.58E-01
U238	7.86E+02	99.8896	9.99E+02	7.86E+02	99.9011	9.99E+02
U total	7.87E+02	100.0000	1.00E+03	7.87E+02	100.0000	1.00E+03
Np237	1.31E-01		1.66E-01	1.31E-01		1.66E-01
Pu238	1.03E+00	3.8233	1.31E+00			
Pu239	5.77E+00	21.2707	7.33E+00	5.77E+00	21.3421	7.33E+00
Pu240	1.10E+01	40.2280	1.39E+01	1.08E+01	39.7690	1.37E+01
Pu241	3.28E+00	11.9827	4.16E+00	4.40E+00	16.1212	5.59E+00
Pu242	6.24E+00	22.6953	7.92E+00	6.24E+00	22.7677	7.92E+00
Pu244						
Pu total	2.73E+01	100.0000	3.47E+01		100.0000	
Am241	1.32E+00	48.583	1.68E+00	1.23E-01	8.069	1.56E-01
Am242m	4.98E-03	0.182	6.33E-03	5.15E-03	0.336	6.54E-03
Am243	1.41E+00	51.235	1.79E+00	1.41E+00	91.594	1.79E+00
Am total	2.74E+00	100.000	3.48E+00	1.54E+00	100.000	1.95E+00
Cm242						
Cm243						
Cm244	6.29E-01	89.099	7.99E-01	8.12E-01	91.342	1.03E+00
Cm245	6.16E-02	8.685	7.82E-02	6.16E-02	6.897	7.83E-02
Cm246	1.58E-02	2.216	2.00E-02	1.58E-02	1.761	2.01E-02
Cm Total	7.06E-01	100.000	8.97E-01	3.76E-01	100.000	4.78E-01

Build - up (+ decay if any) correction

Table 3.5 / 30 - Results normalized to solid fuel

Sample reference : DM1

Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	6.87E-04		8.73E-04	2.17E-01		2.75E-01
Ce total						
Nd142	3.44E-02	0.656	4.37E-02	3.44E-02	0.684	4.37E-02
Nd143	8.76E-01	16.618	1.11E+00	8.76E-01	17.322	1.11E+00
Nd144	1.67E+00	31.543	2.13E+00	1.46E+00	28.641	1.85E+00
Nd145	8.60E-01	16.085	1.09E+00	8.60E-01	16.767	1.09E+00
Nd146	9.88E-01	18.347	1.25E+00	9.88E-01	19.125	1.25E+00
Nd148	5.78E-01	10.590	7.34E-01	5.78E-01	11.039	7.34E-01
Nd150	3.41E-01	6.161	4.33E-01	3.41E-01	6.422	4.33E-01
Nd total	5.35E+00	100.000	6.80E+00	5.14E+00	100.000	6.53E+00
Pm147						
Sm147	3.30E-01	23.852	4.19E-01			
Sm148	2.60E-01	18.640	3.30E-01	2.60E-01	24.462	3.30E-01
Sm149	3.09E-03	0.220	3.92E-03	3.09E-03	0.289	3.92E-03
Sm150	4.88E-01	34.565	6.20E-01	4.88E-01	45.360	6.20E-01
Sm151	1.52E-02	1.071	1.93E-02	1.60E-02	1.476	2.03E-02
Sm152	2.06E-01	14.415	2.62E-01	2.06E-01	18.917	2.62E-01
Sm154	1.05E-01	7.236	1.33E-01	1.05E-01	9.496	1.33E-01
Sm total	1.41E+00	100.000	1.79E+00		100.000	
Eu151	1.00E-03	0.330	1.27E-03	2.36E-04	0.069	3.00E-04
Eu153	2.61E-01	84.837	3.32E-01	2.61E-01	75.543	3.32E-01
Eu154	3.63E-02	11.722	4.62E-02	6.09E-02	17.495	7.74E-02
Eu155	9.71E-03	3.112	1.23E-02	2.42E-02	6.893	3.07E-02
Eu total	3.08E-01	100.000	3.92E-01	3.47E-01	100.000	4.40E-01
Gd154	2.96E-02	7.607	3.76E-02			
Gd155	1.22E-02	3.125	1.55E-02	!(-2.21E-03)!		
Gd156	2.89E-01	73.432	3.68E-01			
Gd157						
Gd158	5.87E-02	14.715	7.46E-02			
Gd160	4.53E-03	1.121	5.76E-03			
Gd total	3.95E-01	100.000	5.01E-01			
Sr90						
Mo95						
Tc99	4.58E-01		5.82E-01	4.58E-01		5.82E-01
Ru101						
Ru106	1.05E-03		1.34E-03	8.58E-02		1.09E-01
Rh103						
Ag109						
Sb125	1.39E-03		1.76E-03	7.06E-03		8.97E-03
I129 (*)						
Cs133	1.73E+00	40.579	2.19E+00	1.73E+00	36.832	2.19E+00
Cs134	2.17E-02	0.507	2.76E-02	1.88E-01	3.987	2.39E-01
Cs135	8.35E-01	19.337	1.06E+00	8.35E-01	17.552	1.06E+00
Cs137	1.73E+00	39.577	2.20E+00	2.01E+00	41.629	2.55E+00
Cs total	4.32E+00	100.000	5.49E+00	4.76E+00	100.000	6.05E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 31 - Results normalized to solid fuel

Sample reference: DU1
Laboratory: PSI Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.31E-01	0.0162	1.59E-01			
U235	5.40E+00	0.6642	6.56E+00	5.40E+00	0.6643	6.56E+00
U236	6.33E+00	0.7745	7.68E+00	6.33E+00	0.7747	7.68E+00
U238	8.12E+02	98.5451	9.86E+02	8.12E+02	98.5610	9.86E+02
U total	8.24E+02	100.0000	1.00E+03	8.24E+02	100.0000	1.00E+03
Np237	5.95E-01		7.23E-01	5.95E-01		7.23E-01
Pu238	2.37E-01	3.3070	2.87E-01			
Pu239	3.30E+00	45.9581	4.01E+00	3.31E+00	45.9575	4.01E+00
Pu240	2.26E+00	31.3503	2.75E+00	2.25E+00	31.1870	2.73E+00
Pu241	7.04E-01	9.7124	8.55E-01	9.56E-01	13.1851	1.16E+00
Pu242	7.04E-01	9.6722	8.55E-01	7.04E-01	9.6704	8.55E-01
Pu244						
Pu total	7.21E+00	100.0000	8.76E+00		100.0000	
Am241	3.24E-01	67.187	3.93E-01	5.56E-02	26.005	6.75E-02
Am242m	6.21E-04	0.128	7.54E-04	6.42E-04	0.299	7.80E-04
Am243	1.59E-01	32.685	1.93E-01	1.59E-01	73.696	1.93E-01
Am total	4.83E-01	100.000	5.86E-01	2.15E-01	100.000	2.61E-01
Cm242						
Cm243						
Cm244	4.65E-02	93.348	5.64E-02	6.06E-02	94.809	7.35E-02
Cm245	2.75E-03	5.507	3.34E-03	2.76E-03	4.297	3.35E-03
Cm246	5.75E-04	1.145	6.98E-04	5.76E-04	0.894	6.99E-04
Cm Total	4.98E-02	100.000	6.05E-02	6.39E-02	100.000	7.76E-02

Build - up (+ decay if any) correction

Table 3.5 / 32 - Results normalized to solid fuel

Sample reference : DU1

Laboratory: PSI

Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 01 / 93		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	7.95E-04		9.66E-04	3.05E-01		3.70E-01
Ce total						
Nd142	4.42E-02	0.764	5.37E-02	4.42E-02	0.806	5.37E-02
Nd143	8.65E-01	14.836	1.05E+00	8.65E-01	15.646	1.05E+00
Nd144	2.17E+00	36.947	2.63E+00	1.87E+00	33.505	2.26E+00
Nd145	9.52E-01	16.097	1.16E+00	9.52E-01	16.976	1.16E+00
Nd146	1.08E+00	18.220	1.32E+00	1.08E+00	19.214	1.32E+00
Nd148	5.48E-01	9.079	6.65E-01	5.48E-01	9.575	6.65E-01
Nd150	2.48E-01	4.057	3.01E-01	2.48E-01	4.278	3.01E-01
Nd total	5.91E+00	100.000	7.17E+00	5.61E+00	100.000	6.81E+00
Pm147	2.71E-02		3.29E-02	1.70E-01		2.07E-01
Sm147	3.15E-01	27.470	3.82E-01	1.74E-01	17.316	2.11E-01
Sm148	2.37E-01	20.534	2.87E-01	2.37E-01	23.395	2.87E-01
Sm149	2.15E-03	0.185	2.61E-03	2.15E-03	0.211	2.61E-03
Sm150	4.01E-01	34.292	4.86E-01	4.01E-01	39.071	4.86E-01
Sm151	9.48E-03	0.806	1.15E-02	9.97E-03	0.966	1.21E-02
Sm152	1.47E-01	12.378	1.78E-01	1.47E-01	14.102	1.78E-01
Sm154	5.20E-02	4.335	6.31E-02	5.20E-02	4.939	6.31E-02
Sm total	1.16E+00	100.000	1.41E+00	1.02E+00	100.000	1.24E+00
Eu151	5.46E-04	0.320	6.63E-04	5.23E-05	0.027	6.35E-05
Eu153	1.50E-01	86.877	1.82E-01	1.50E-01	78.030	1.82E-01
Eu154	1.71E-02	9.796	2.07E-02	2.91E-02	15.010	3.53E-02
Eu155	5.27E-03	3.007	6.40E-03	1.35E-02	6.933	1.64E-02
Eu total	1.73E-01	100.000	2.10E-01	1.93E-01	100.000	2.34E-01
Gd154	1.46E-02	6.977	1.77E-02			
Gd155	7.15E-03	3.394	8.68E-03	!(-1.11E-03)!		
Gd156	1.67E-01	78.652	2.02E-01			
Gd157						
Gd158	2.21E-02	10.290	2.68E-02			
Gd160	1.50E-03	0.687	1.81E-03			
Gd total	2.12E-01	100.000	2.58E-01			
Sr90	7.48E-01		9.07E-01	8.79E-01		1.07E+00
Mo95	9.60E-01		1.16E+00	9.60E-01		1.16E+00
Tc99	8.66E-01		1.05E+00	8.66E-01		1.05E+00
Ru101	7.62E-01		9.25E-01	7.62E-01		9.25E-01
Ru106	1.22E-03		1.48E-03	1.16E-01		1.40E-01
Rh103	4.58E-01		5.56E-01	4.58E-01		5.56E-01
Ag109	3.97E-02		4.81E-02	3.97E-02		4.82E-02
Sb125	1.08E-03		1.32E-03	5.83E-03		7.08E-03
I129 (*)						
Cs133	1.52E+00	43.471	1.85E+00	1.52E+00	39.071	1.85E+00
Cs134	1.86E-02	0.528	2.26E-02	1.74E-01	4.436	2.11E-01
Cs135	5.13E-01	14.431	6.22E-01	5.13E-01	12.970	6.23E-01
Cs137	1.50E+00	41.570	1.82E+00	1.75E+00	43.523	2.12E+00
Cs total	3.55E+00	100.000	4.31E+00	3.96E+00	100.000	4.80E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 33 - Results normalized to solid fuel

Sample reference: GU3
Laboratory: ITU

Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 06 / 97		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.24E-01	0.0152	1.50E-01			
U235	5.31E+00	0.6502	6.42E+00	5.31E+00	0.6503	6.42E+00
U236	4.99E+00	0.6084	6.03E+00	4.99E+00	0.6085	6.03E+00
U238	8.17E+02	98.7262	9.87E+02	8.17E+02	98.7412	9.88E+02
U total	8.28E+02	100.0000	1.00E+03	8.28E+02	100.0000	1.00E+03
Np237	7.27E-01		8.78E-01	7.27E-01		8.78E-01
Pu238	3.28E-01	3.2041	3.96E-01			
Pu239	5.11E+00	49.7286	6.18E+00	5.11E+00	50.8020	6.18E+00
Pu240	2.50E+00	24.1974	3.02E+00	2.49E+00	24.6358	3.01E+00
Pu241	1.48E+00	14.2731	1.79E+00	1.60E+00	15.7802	1.94E+00
Pu242	8.95E-01	8.5968	1.08E+00	8.95E-01	8.7819	1.08E+00
Pu244						
Pu total	1.03E+01	100.0000	1.25E+01		100.0000	
Am241	1.67E-01	41.615	2.02E-01	1.87E-02	7.389	2.26E-02
Am242m						
Am243	2.36E-01	58.385	2.86E-01	2.36E-01	92.611	2.86E-01
Am total	4.03E-01	100.000	4.87E-01	2.55E-01	100.000	3.08E-01
Cm242						
Cm243						
Cm244	1.36E-01	93.050	1.64E-01	1.47E-01	93.534	1.77E-01
Cm245	1.02E-02	6.950	1.23E-02	1.02E-02	6.466	1.23E-02
Cm246						
Cm Total	1.46E-01	100.000	1.76E-01	1.57E-01	100.000	1.90E-01

Build - up (+ decay if any) correction

Table 3.5 / 34 - Results normalized to solid fuel

Sample reference : GU3

Laboratory: ITU

Main solution - Fission products

Isotope	At analysis date mg/g fuel	at %	mg / g U		at %	mg / g U
Ce140						
Ce142						
Ce144	7.13E-02		8.61E-02	3.87E-01		
Ce total						
Nd142	3.19E-02	0.629	3.86E-02	3.19E-02	0.669	3.86E-02
Nd143	8.76E-01	17.148	1.06E+00	8.76E-01	18.242	1.06E+00
Nd144	1.75E+00	33.926	2.11E+00	1.44E+00	29.713	1.74E+00
Nd145	8.22E-01	15.863	9.93E-01	8.22E-01	16.874	9.93E-01
Nd146	9.58E-01	18.358	1.16E+00	9.58E-01	19.528	1.16E+00
Nd148	4.94E-01	9.337	5.96E-01	4.94E-01	9.932	5.97E-01
Nd150	2.54E-01	4.739	3.07E-01	2.54E-01	5.041	3.07E-01
Nd total	5.18E+00	100.000	6.26E+00	4.87E+00	100.000	5.89E+00
Pm147	1.41E-01		1.70E-01	2.33E-01		
Sm147	1.63E-01	17.134	1.97E-01	7.10E-02	8.259	8.58E-02
Sm148	2.31E-01	24.108	2.79E-01	2.31E-01	26.684	2.79E-01
Sm149	4.07E-03	0.423	4.92E-03	4.07E-03	0.468	4.92E-03
Sm150	3.94E-01	40.577	4.76E-01	3.94E-01	44.912	4.76E-01
Sm151	1.29E-02	1.320	1.56E-02	1.31E-02	1.483	1.58E-02
Sm152	1.15E-01	11.736	1.39E-01	1.15E-01	12.990	1.39E-01
Sm154	4.69E-02	4.702	5.66E-02	4.69E-02	5.204	5.66E-02
Sm total	9.67E-01	100.000	1.17E+00	8.75E-01	100.000	1.06E+00
Eu151						
Eu153	1.65E-01	79.261	1.99E-01	1.65E-01	76.057	1.99E-01
Eu154	3.27E-02	15.587	3.95E-02	3.81E-02	17.453	4.61E-02
Eu155	1.09E-02	5.151	1.31E-02	1.43E-02	6.490	1.72E-02
Eu total	2.09E-01	100.000	2.52E-01	2.32E-01	100.000	2.80E-01
Gd154						
Gd155	3.67E-03		4.43E-03	!(-3.74E-04)!		
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	6.45E-01		7.80E-01	6.83E-01		8.25E-01
Mo95	6.93E-01		8.37E-01	6.93E-01		8.37E-01
Tc99	5.62E-01		6.79E-01	5.62E-01		6.79E-01
Ru101	6.66E-01		8.04E-01	6.66E-01		8.04E-01
Ru106	2.92E-02		3.53E-02	1.42E-01		1.72E-01
Rh103	2.40E-01		2.90E-01	2.40E-01		2.90E-01
Ag109						
Sb125						
I129 (*)	2.31E-01		2.79E-01	2.31E-01		2.79E-01
Cs133	1.47E+00	41.466	1.78E+00	1.47E+00	39.445	1.78E+00
Cs134	1.28E-01	3.566	1.54E-01	2.42E-01	6.430	2.92E-01
Cs135	4.24E-01	11.747	5.12E-01	4.24E-01	11.175	5.12E-01
Cs137	1.58E+00	43.222	1.91E+00	1.65E+00	42.951	2.00E+00
Cs total	3.61E+00	100.000	4.36E+00	3.79E+00	100.000	4.58E+00

(*) Iodine solution

Build - up correction

Table 3.5 / 35 - Results normalized to solid fuel

Sample reference: GU4
Laboratory: ITU

Main solution - Actinides

Isotope	At analysis date			At end of life : 07 / 06 / 97		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
U232						
U234	1.72E-01	0.0206	2.02E-01			
U235	1.28E+01	1.5306	1.51E+01	1.28E+01	1.5309	1.51E+01
U236	4.05E+00	0.4810	4.77E+00	4.05E+00	0.4811	4.77E+00
U238	8.32E+02	97.9678	9.80E+02	8.32E+02	97.9879	9.80E+02
U total	8.49E+02	100.0000	1.00E+03	8.48E+02	100.0000	1.00E+03
Np237	4.63E-01		5.45E-01	4.63E-01		5.45E-01
Pu238	9.80E-02	1.3316	1.15E-01			
Pu239	4.55E+00	61.5436	5.36E+00	4.55E+00	61.5692	5.36E+00
Pu240	1.62E+00	21.7947	1.91E+00	1.62E+00	21.7948	1.91E+00
Pu241	8.70E-01	11.6771	1.03E+00	9.67E-01	12.9817	1.14E+00
Pu242	2.73E-01	3.6529	3.22E-01	2.73E-01	3.6542	3.22E-01
Pu244						
Pu total	7.41E+00	100.0000	8.73E+00	7.41E+00	100.0000	8.73E+00
Am241	1.30E-01	77.212	1.53E-01	4.03E-02	51.274	4.75E-02
Am242m						
Am243	3.86E-02	22.788	4.55E-02	3.86E-02	48.726	4.55E-02
Am total	1.68E-01	100.000	1.98E-01	7.89E-02	100.000	9.30E-02
Cm242						
Cm243						
Cm244	1.09E-02	95.591	1.29E-02	1.18E-02	95.906	1.39E-02
Cm245	5.06E-04	4.409	5.96E-04	5.06E-04	4.094	5.97E-04
Cm246						
Cm Total	1.14E-02	100.000	1.35E-02	1.23E-02	100.000	1.45E-02

Build - up (+ decay if any) correction

Table 3.5 / 36 - Results normalized to solid fuel

Sample reference : GU4

Laboratory: ITU

Main solution - Fission products

Isotope	At analysis date			At end of life : 07 / 06 / 97		
	mg/g fuel	at %	mg / g U	mg/g fuel	at %	mg / g U
Ce140						
Ce142						
Ce144	3.20E-02		3.77E-02	2.50E-01		2.95E-01
Ce total						
Nd142	1.06E-02	0.313	1.25E-02	1.06E-02	0.334	1.25E-02
Nd143	7.60E-01	22.253	8.96E-01	7.60E-01	23.758	8.96E-01
Nd144	1.08E+00	31.290	1.27E+00	8.58E-01	26.640	1.01E+00
Nd145	5.96E-01	17.203	7.02E-01	5.96E-01	18.367	7.02E-01
Nd146	5.73E-01	16.429	6.75E-01	5.73E-01	17.541	6.75E-01
Nd148	3.06E-01	8.645	3.60E-01	3.06E-01	9.230	3.60E-01
Nd150	1.39E-01	3.868	1.63E-01	1.39E-01	4.129	1.63E-01
Nd total	3.46E+00	100.000	4.08E+00	3.24E+00	100.000	3.82E+00
Pm147	9.63E-02		1.13E-01	1.78E-01		2.09E-01
Sm147	1.42E-01	25.209	1.67E-01	6.08E-02	12.604	7.17E-02
Sm148	9.74E-02	17.166	1.15E-01	9.74E-02	20.051	1.15E-01
Sm149	2.66E-03	0.466	3.14E-03	2.66E-03	0.545	3.14E-03
Sm150	2.14E-01	37.190	2.52E-01	2.14E-01	43.439	2.52E-01
Sm151	9.94E-03	1.717	1.17E-02	1.01E-02	2.042	1.19E-02
Sm152	8.34E-02	14.303	9.82E-02	8.34E-02	16.707	9.82E-02
Sm154	2.33E-02	3.949	2.75E-02	2.33E-02	4.612	2.75E-02
Sm total	5.73E-01	100.000	6.75E-01	4.92E-01	100.000	5.79E-01
Eu151						
Eu153	8.28E-02	83.864	9.76E-02	8.28E-02	80.587	9.76E-02
Eu154	1.22E-02	12.258	1.44E-02	1.47E-02	14.220	1.73E-02
Eu155	3.88E-03	3.877	4.57E-03	5.41E-03	5.194	6.37E-03
Eu total	9.88E-02	100.000	1.16E-01	1.03E-01	100.000	1.21E-01
Gd154						
Gd155	2.33E-03		2.74E-03	7.99E-04		9.42E-04
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	4.45E-01		5.25E-01	4.72E-01		5.56E-01
Mo95	3.89E-01		4.58E-01	3.89E-01		4.58E-01
Tc99	3.84E-01		4.53E-01	3.84E-01		4.53E-01
Ru101	2.73E-01		3.22E-01	2.73E-01		3.22E-01
Ru106	1.05E-02		1.23E-02	5.48E-02		6.46E-02
Rh103	1.42E-01		1.67E-01	1.42E-01		1.67E-01
Ag109						
Sb125						
I129 (*)	1.46E-01		1.73E-01	1.46E-01		1.73E-01
Cs133	9.54E-01	44.051	1.12E+00	9.54E-01	42.300	1.12E+00
Cs134	3.65E-02	1.671	4.30E-02	7.97E-02	3.508	9.39E-02
Cs135	3.29E-01	14.970	3.88E-01	3.29E-01	14.375	3.88E-01
Cs137	8.77E-01	39.308	1.03E+00	9.25E-01	39.816	1.09E+00
Cs total	2.20E+00	100.000	2.59E+00	2.29E+00	100.000	2.70E+00

(*) Iodine solution

Build - up correction

Table 3.6a - Build - up and decay considered for the EOL corrections of the selected isotopes.

Build - up from		Element	Decay to	by	Element half - life	
	NC	U232	Th228	α	68.9	y
Pu238	α	U234		NC	2.455E+05	y
	NC	U235		NC	7.038E+08	y
	NC	U236		NC	2.342E+07	y
	NC	U238		NC	4.468E+09	y
	NC	Np237		NC	2.144E+06	y
Cm242	α	Pu238	U234	α	87.7	y
	NC	Pu239	U235	α	2.411E+04	y
Cm244	α	Pu240	U236	α	6563	y
	NC	Pu241	Am241	β	14.4	y
	NC	Pu242		NC	3.735E+05	y
	NC	Pu244		NC	8.080E+07	y
Pu241	β	Am241	Np237	α	432.7	y
	NC	Am242m	Np238	α	141	y
	NC	Am243	Np239	α	7370	y
Am242m	α	Cm242	Pu238	α	162.79	d
	NC	Cm243	Pu239	α	29.1	y
	NC	Cm244	Pu240	α	18.1	y
	NC	Cm245	Pu241	α	8500	y
	NC	Cm246	Pu242	α	4730	y
	NC	Ce140			stable	
	NC	Ce142			stable	
	NC	Ce144	Nd144	β	285	d
	NC	Nd142			stable	
	NC	Nd143			stable	
Ce144	β	Nd144		NC	2.290E+15	y
	NC	Nd145			stable	
	NC	Nd146			stable	
	NC	Nd148			stable	
	NC	Nd150		NC	1.7E+19	y

NC = not considered

Table 3.6b - Build - up and decay considered for the EOL corrections of the selected isotopes.

Build - up from		Element	Decay to	by	Element half - life	
NC		Pm147	Sm147	β	2.6234	y
Pm147	β	Sm147	NC		1.06E+11	y
NC		Sm148	NC		7.0E+15	y
NC		Sm149			stable	
NC		Sm150			stable	
NC		Sm151	Eu151	β	90	y
NC		Sm152			stable	
NC		Sm154			stable	
Sm151	β	Eu151			stable	
NC		Eu153			stable	
NC		Eu154	Gd154	β	8.558	y
NC		Eu155	Gd155	β	4.85	y
Eu154	β	Gd154			stable	
Eu155	β	Gd155			stable	
NC		Gd156			stable	
NC		Gd157			stable	
NC		Gd158			stable	
NC		Gd160			stable	
NC		Sr90	Y90	β	28.78	y
NC		Mo95			stable	
NC		Tc99	NC		2.111E+05	y
NC		Ru101			stable	
NC		Ru106	Rh / Pd106	β	372.6	d
NC		Rh103			stable	
NC		Ag109			stable	
NC		Sb125	Te125	β	2.76	y
NC		I129	NC		1.6E+07	y
NC		Cs133			stable	
NC		Cs134	Ba134	β	754.28	d
NC		Cs135	NC		2.3E+06	y
NC		Cs137	Ba137	β	30.25	y

NC = not considered

Table 3.7 - Presence of the elements analysed in the three solutions.

Element	Main solution (*)	Iodine solution (*)	Residue solution (*)
U	T	--	--
Np	T	--	--
Pu	T	--	--
Am	T	--	--
Cm	T	--	--
Sr	T	--	--
I	--	T	--
Cs	T	--	--
Mo	X	--	X
Tc	X	--	X
Ru	X	--	X
Rh	X	--	X
Ag	X	--	X
Sb	X	--	X
Ce	T	--	--
Nd	T	--	--
Pm	T	--	--
Sm	T	--	--
Eu	T	--	--
Gd	T	--	--

(*) T = more than 99.9 % of the total content
X = partially present
-- = not present

Table 3.8 / 1 - Measurement results - Residue Solution
Tc 99 (Base programme)

Sample	Date of analysis	Method of analysis	µg $Tc99_{res}$ / g sol	mg $Tc99_{res}$ / g residue	mg $Tc99_{residue}$ / g fuel at analysis	mg $Tc99_{residue}$ / g fuel at EOL
SCK-CEN						
BM1	19-04-00	ICP-MS		2.603E+00	5.918E-02	5.918E-02
BM5'	19-04-00	ICP-MS		3.680E+00	2.834E-02	2.834E-02
GU1	19-04-00	ICP-MS		5.558E+01	4.911E-01	4.911E-01
GU3'	19-04-00	ICP-MS		8.494E+01	1.469E-01	1.469E-01
DM1	19-04-00	ICP-MS		5.531E+01	4.585E-01	4.585E-01
DM2	19-04-00	ICP-MS		6.092E+01	2.627E-01	2.627E-01
DM3	19-04-00	ICP-MS		6.541E+00	7.542E-02	7.542E-02
DM4	19-04-00	ICP-MS		5.899E+00	2.143E-02	2.143E-02
DU1	19-04-00	ICP-MS		4.480E+01	1.230E-01	1.230E-01
PSI						
BM1	20-01-00	ICP-MS	1.952E-01	2.005E+00	4.557E-02	4.557E-02
BM5	20-01-00	ICP-MS	4.310E+00	5.456E+01	5.140E-01	5.140E-01
BM6	20-01-00	ICP-MS	1.779E+00	1.797E+01	2.021E-01	2.021E-01
DU1	20-01-00	ICP-MS	5.484E+00	4.815E+01	1.322E-01	1.322E-01
DM1	20-01-00	ICP-MS	4.172E+00	4.698E+01	3.895E-01	3.895E-01
ITU						
GU3	19-11-99	ICP-MS	1.500E+02	1.684E+02	4.151E-01	4.151E-01
GU4	19-11-99	ICP-MS	2.095E+01	2.218E+01	1.437E-01	1.437E-01

Table 3.8 / 2 - Measurement results - Residue Solution
Mo 95 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Mo95_{res}$ / g sol	mg $Mo95_{res}$ / g residue	mg $Mo95_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	19-04-00	ICP-MS		1.422E+00	3.232E-02	3.232E-02
BM5'	19-04-00	ICP-MS		4.896E+00	3.771E-02	3.771E-02
GU1	19-04-00	ICP-MS		4.167E+01	3.682E-01	3.682E-01
GU3'	19-04-00	ICP-MS		1.037E+02	1.793E-01	1.793E-01
DM1	19-04-00	ICP-MS		2.732E+01	2.264E-01	2.264E-01
DM2	19-04-00	ICP-MS		3.080E+01	1.328E-01	1.328E-01
DU1	19-04-00	ICP-MS		4.094E+01	1.124E-01	1.124E-01
PSI						
BM1	17-01-00	ICP-MS	1.150E-01	1.181E+00	2.684E-02	2.684E-02
BM5	11-01-00	ICP-MS	2.097E+00	2.656E+01	2.502E-01	2.502E-01
BM6	11-01-00	ICP-MS	6.758E-01	6.833E+00	7.684E-02	7.684E-02
DU1	11-01-00	ICP-MS	4.726E+00	4.149E+01	1.139E-01	1.139E-01
ITU						
GU3	19-11-99	ICP-MS	1.220E+02	1.370E+02	3.376E-01	3.376E-01
GU4	19-11-99	ICP-MS	4.070E+01	4.309E+01	2.791E-01	2.791E-01

Table 3.8 / 3 - Measurement results - Residue Solution
Ru101 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Ru101_{res}$ / g sol	mg $Ru101_{res}$ / g residue	mg $Ru101_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	19-04-00	ICP-MS		9.418E+00	2.141E-01	2.141E-01
BM5'	19-04-00	ICP-MS		1.587E+01	1.222E-01	1.222E-01
GU1	19-04-00	ICP-MS		8.899E+01	7.862E-01	7.862E-01
GU3'	19-04-00	ICP-MS		2.111E+02	3.650E-01	3.650E-01
DM1	19-04-00	ICP-MS		8.498E+01	7.045E-01	7.045E-01
DM2	19-04-00	ICP-MS		1.142E+02	4.925E-01	4.925E-01
DU1	19-04-00	ICP-MS		9.438E+01	2.592E-01	2.592E-01
PSI						
BM1	17-01-00	ICP-MS	6.950E-01	7.137E+00	1.622E-01	1.622E-01
BM5	11-01-00	ICP-MS	7.625E+00	9.658E+01	9.098E-01	9.098E-01
BM6	11-01-00	ICP-MS	4.083E+00	4.128E+01	4.642E-01	4.642E-01
DU1	11-01-00	ICP-MS	7.935E+00	6.967E+01	1.913E-01	1.913E-01
ITU						
GU3	19-11-99	ICP-MS	1.470E+02	1.650E+02	4.068E-01	4.068E-01
GU4	19-11-99	ICP-MS	5.640E+01	5.971E+01	3.868E-01	3.868E-01

Table 3.8 / 4 - Measurement results - Residue Solution
Ru106 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Ru106_{res}$ / g sol	mg $Ru106_{res}$ / g residue	mg $Ru106_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	12-05-97	gamma	1.275E-02	1.316E-01	2.991E-03	4.890E-02
BM5'	26-01-00	gamma		3.189E-01	2.456E-03	2.793E-02
GU1	25-05-97	gamma		2.161E+00	1.909E-02	1.440E-01
GU3'	26-01-00	gamma		6.968E+00	1.205E-02	7.227E-02
DM1	05-12-96	gamma		1.127E+00	9.342E-03	1.331E-01
DM2	05-12-96	gamma		7.895E-01	3.405E-03	9.529E-02
DU1	05-12-96	gamma		6.531E-01	1.793E-03	2.555E-02
PSI						
BM5	21-12-99	gamma	1.290E-01	1.635E+00	1.540E-02	1.638E-01
BM6	21-12-99	gamma	7.370E-02	7.460E-01	8.388E-03	8.924E-02
DU1	20-12-99	gamma	6.460E-03	5.677E-02	1.559E-04	1.751E-02
DM1	20-12-99	gamma	8.630E-03	9.723E-02	8.060E-04	9.054E-02
ITU						
GU3	19-11-99	ICP-MS	2.030E+01	2.279E+01	5.617E-02	2.969E-01
GU4	19-11-99	ICP-MS	1.640E+00	1.736E+00	1.125E-02	5.945E-02

Table 3.8 / 5 - Measurement results - Residue Solution
Rh103 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Rh103_{res}$ / g sol	mg $Rh103_{res}$ / g residue	mg $Rh103_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	19-04-00	ICP-MS		6.376E+00	1.449E-01	1.449E-01
BM5'	19-04-00	ICP-MS		1.393E+00	1.073E-02	1.073E-02
GU1	19-04-00	ICP-MS		3.802E+01	3.359E-01	3.359E-01
GU3'	19-04-00	ICP-MS		1.831E+01	3.166E-02	3.166E-02
DM1	19-04-00	ICP-MS		1.875E+01	1.554E-01	1.554E-01
DM2	19-04-00	ICP-MS		4.182E+01	1.804E-01	1.804E-01
DU1	19-04-00	ICP-MS		2.464E+01	6.766E-02	6.766E-02
PSI						
BM5	13-12-99	ICP-MS	5.932E+00	7.519E+01	7.083E-01	7.083E-01
BM6	13-12-99	ICP-MS	3.372E+00	3.413E+01	3.838E-01	3.838E-01
DU1	13-12-99	ICP-MS	3.364E+00	2.956E+01	8.117E-02	8.117E-02
ITU						
GU3	19-11-99	ICP-MS	8.320E+01	9.340E+01	2.302E-01	2.302E-01
GU4	19-11-99	ICP-MS	3.762E+01	3.983E+01	2.580E-01	2.580E-01

Table 3.8 / 6 - Measurement results - Residue Solution
Ag109 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Ag109_{res}$ / g sol	mg $Ag109_{res}$ / g residue	mg $Ag109_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	19-04-00	ICP-MS		7.664E-01	1.742E-02	1.742E-02
BM5'	19-04-00	ICP-MS		1.923E+00	1.481E-02	1.481E-02
GU1	19-04-00	ICP-MS		6.380E+00	5.637E-02	5.637E-02
GU3'	19-04-00	ICP-MS		1.684E+01	2.911E-02	2.911E-02
DM1	19-04-00	ICP-MS		2.469E+00	2.047E-02	2.047E-02
DM2	19-04-00	ICP-MS		1.075E+00	4.637E-03	4.637E-03
DU1	19-04-00	ICP-MS		7.347E-01	2.017E-03	2.017E-03
PSI						
BM1	17-01-00	ICP-MS	7.774E-02	7.983E-01	1.815E-02	1.815E-02
BM5	11-01-00	ICP-MS	6.922E-01	8.768E+00	8.259E-02	8.259E-02
BM6	11-01-00	ICP-MS	1.120E+00	1.132E+01	1.273E-01	1.273E-01
DU1	11-01-00	ICP-MS	9.259E-02	8.129E-01	2.232E-03	2.232E-03
ITU						
GU3	19-11-99	ICP-MS	not measurable	--	--	--
GU4	19-11-99	ICP-MS	not measurable	--	--	--

Table 3.8 / 7 - Measurement results - Residue Solution
Sb 125 (TOP 25)

Sample	Date of analysis	Method of analysis	µg $Sb125_{res}$ / g sol	mg $Sb125_{res}$ / g residue	mg $Sb125_{residue}$ / g fuel	
					at analysis	at EOL
SCK-CEN						
BM1	12-05-97	gamma	3.195E-04	3.297E-03	7.495E-05	2.106E-04
BM5'	26-01-00	gamma		6.604E-02	5.085E-04	1.250E-03
GU1	25-05-97	gamma		8.790E-02	7.767E-04	1.639E-03
GU3'	26-01-00	gamma		1.127E-01	1.948E-04	3.778E-04
DM1	05-12-96	gamma		4.400E-02	3.648E-04	9.741E-04
DM2	05-12-96	gamma		2.308E-02	9.955E-05	3.412E-04
DU1	05-12-96	gamma		3.306E-02	9.079E-05	2.424E-04
PSI						
BM5	21-12-99	gamma	1.055E-02	1.337E-01	1.260E-03	3.019E-03
BM6	21-12-99	gamma	5.780E-03	5.850E-02	6.579E-04	1.577E-03
DU1	20-12-99	gamma	1.343E-03	1.180E-02	3.241E-05	1.857E-04
DM1	20-12-99	gamma	1.040E-03	1.172E-02	9.713E-05	5.566E-04
ITU						
GU3	19-11-99	ICP-MS	BDL (*)	--	--	--
GU4	19-11-99	ICP-MS	BDL (*)	--	--	--

(*) Below detection limit

Table 3.9 / 1 - Mother + Residue total content at EOL Tc99 (Base Programme)

Sample	Tc99 (mg / g fuel)			
	Mother	Residue	Total	fraction in residue
SCK-CEN				
BM1	5.613E-01	5.918E-02	6.205E-01	0.10
BM5'	9.405E-01	2.834E-02	9.688E-01	0.03
GU1	6.104E-01	4.911E-01	1.102E+00	0.45
GU3'	9.961E-01	1.469E-01	1.143E+00	0.13
DM1	5.004E-01	4.585E-01	9.589E-01	0.48
DM2	4.843E-01	2.627E-01	7.471E-01	0.35
DM3	4.700E-01	7.542E-02	5.454E-01	0.14
DM4	6.085E-01	2.143E-02	6.299E-01	0.03
DU1	1.136E+00	1.230E-01	1.259E+00	0.10
PSI				
BM1	5.280E-01	4.557E-02	5.736E-01	0.08
BM5	5.580E-01	5.140E-01	1.072E+00	0.48
BM6	4.741E-01	2.021E-01	6.761E-01	0.30
DU1	8.655E-01	1.322E-01	9.977E-01	0.13
DM1	4.585E-01	3.895E-01	8.479E-01	0.46
ITU				
GU3	5.623E-01	4.151E-01	9.774E-01	0.42
GU4	3.843E-01	1.437E-01	5.280E-01	0.27

Table 3.9 / 2 - Mother + Residue total content at EOL
Mo95 , Sb125

Sample	Mo95 (mg / g fuel)				Sb125 (mg / g fuel)			
	Mother	Residue	Total	fraction in residue	Mother	Residue	Total	fraction in residue
SCK-CEN								
BM1	5.640E-01	3.232E-02	5.963E-01	0.05	6.523E-03	2.106E-04	6.734E-03	0.03
BM5'	8.621E-01	3.771E-02	8.998E-01	0.04	5.927E-03	1.250E-03	7.177E-03	0.17
GU1	7.142E-01	3.682E-01	1.082E+00	0.34	6.551E-03	1.639E-03	8.191E-03	0.20
GU3'	9.682E-01	1.793E-01	1.147E+00	0.16	6.234E-03	3.778E-04	6.612E-03	0.06
DM1	6.717E-01	2.264E-01	8.981E-01	0.25	8.470E-03	9.741E-04	9.444E-03	0.10
DM2	5.328E-01	1.328E-01	6.656E-01	0.20	7.536E-03	3.412E-04	7.877E-03	0.04
DU1	1.205E+00	1.124E-01	1.317E+00	0.09	6.526E-03	2.424E-04	6.768E-03	0.04
PSI								
BM1	5.805E-01	2.684E-02	6.074E-01	0.04	6.632E-03	--	--	--
BM5	6.871E-01	2.502E-01	9.373E-01	0.27	5.797E-03	3.019E-03	8.817E-03	0.34
BM6	5.501E-01	7.684E-02	6.269E-01	0.12	4.852E-03	1.577E-03	6.428E-03	0.25
DU1	9.596E-01	1.139E-01	1.074E+00	0.11	5.829E-03	1.857E-04	6.015E-03	0.03
DM1	--	--	--	--	7.061E-03	5.566E-04	7.618E-03	0.07
ITU								
GU3	6.927E-01	3.376E-01	1.030E+00	0.33	BDL (*)	BDL (*)	--	--
GU4	3.888E-01	2.791E-01	6.679E-01	0.42	BDL (*)	BDL (*)	--	--

(*) BDL = below detection limit

Table 3.9 / 3 - Mother + Residue total content at EOL
Ru101 , Ru106

Sample	Ru101 (mg / g fuel)				Ru106 (mg / g fuel)			
	Mother	Residue	Total	fraction in residue	Mother	Residue	Total	fraction in residue
SCK-CEN								
BM1	3.139E-01	2.141E-01	5.280E-01	0.41	8.959E-02	4.890E-02	1.385E-01	0.35
BM5'	7.719E-01	1.222E-01	8.941E-01	0.14	1.613E-01	2.793E-02	1.892E-01	0.15
GU1	3.494E-01	7.862E-01	1.136E+00	0.69	8.244E-02	1.440E-01	2.264E-01	0.64
GU3'	8.491E-01	3.650E-01	1.214E+00	0.30	1.835E-01	7.227E-02	2.558E-01	0.28
DM1	3.829E-01	7.045E-01	1.087E+00	0.65	1.199E-01	1.331E-01	2.530E-01	0.53
DM2	3.948E-01	4.925E-01	8.873E-01	0.56	9.806E-02	9.529E-02	1.934E-01	0.49
DU1	1.002E+00	2.592E-01	1.261E+00	0.21	1.309E-01	2.555E-02	1.564E-01	0.16
PSI								
BM1	3.224E-01	1.622E-01	4.846E-01	0.33	8.253E-02	--	--	--
BM5	3.683E-01	9.098E-01	1.278E+00	0.71	8.812E-02	1.638E-01	2.520E-01	0.65
BM6	3.203E-01	4.642E-01	7.845E-01	0.59	7.088E-02	8.924E-02	1.601E-01	0.56
DU1	7.621E-01	1.913E-01	9.534E-01	0.20	1.156E-01	1.751E-02	1.331E-01	0.13
DM1					8.581E-02	9.054E-02	1.763E-01	0.51
ITU								
GU3	6.655E-01	4.068E-01	1.072E+00	0.38	1.425E-01	2.969E-01	4.394E-01	0.68
GU4	2.735E-01	3.868E-01	6.603E-01	0.59	5.485E-02	5.945E-02	1.143E-01	0.52

Table 3.9 / 4 - Mother + Residue total content at EOL
Rh103 , Ag109

Sample	Rh103 (mg / g fuel)				Ag109 (mg / g fuel)			
	Mother	Residue	Total	fraction in residue	Mother	Residue	Total	fraction in residue
SCK-CEN								
BM1	2.961E-01	1.449E-01	4.410E-01	0.33	7.212E-02	1.742E-02	8.954E-02	0.19
BM5'	6.055E-01	1.073E-02	6.162E-01	0.02	1.498E-01	1.481E-02	1.646E-01	0.09
GU1	2.043E-01	3.359E-01	5.402E-01	0.62	9.866E-03	5.637E-02	6.624E-02	0.85
GU3'	4.623E-01	3.166E-02	4.939E-01	0.06	7.615E-02	2.911E-02	1.053E-01	0.28
DM1	3.101E-01	1.554E-01	4.655E-01	0.33	9.268E-02	2.047E-02	1.131E-01	0.18
DM2	3.429E-01	1.804E-01	5.233E-01	0.34	1.088E-01	4.637E-03	1.134E-01	0.04
DU1	5.045E-01	6.766E-02	5.722E-01	0.12	4.680E-02	2.017E-03	4.882E-02	0.04
PSI								
BM1	3.273E-01	--	--	--	6.886E-02	1.815E-02	8.701E-02	0.21
BM5	3.635E-01	7.083E-01	1.072E+00	0.66	2.664E-02	8.259E-02	1.092E-01	0.76
BM6	3.440E-01	3.838E-01	7.278E-01	0.53	1.396E-02	1.273E-01	1.413E-01	0.90
DU1	4.579E-01	8.117E-02	5.391E-01	0.15	3.966E-02	2.232E-03	4.190E-02	0.05
ITU								
GU3	2.404E-01	2.302E-01	4.706E-01	0.49	NM (*)	NM (*)		
GU4	1.420E-01	2.580E-01	4.001E-01	0.64	NM (*)	NM (*)		

(*) NM = Not measurable

Table 4.1 - SIMS analysis - Radiochemical data for samples BM1 , BM3 , BM4-D (*)

Sample Corresponding SIMS sample		BM1 BM1S	BM3 BM3S	BM4-D BM4S
Uranium data (at %)	U234	0.010	0.011	0.011
	U235	0.109	0.113	0.138
	U236	0.032	0.033	0.029
	U238	99.849	99.843	99.822
Plutonium data (at %)	Pu238	3.27	3.36	2.95
	Pu239	36.02	36.65	39.21
	Pu240	35.42	35.77	35.41
	Pu241	14.00	13.71	12.93
	Pu242	11.29	11.51	9.50
Plutonium content (at %)	Pu / U + Pu	4.01	4.15	4.43
Neodymium data (at %)	Nd142	0.40	0.40	0.47
	Nd143	21.11	21.56	22.75
	Nd144	27.74	28.13	27.14
	Nd145	16.57	16.42	16.95
	Nd146	17.52	17.46	16.97
	Nd148	10.46	9.89	9.64
	Nd150	6.20	6.14	6.08
Burnup	at % FIMA	4.68	4.76	4.29

(*) as used for the SIMS renormalization

Table 4.2 - Mass list and acquisition time for SIMS measurements.

	Mass (amu)	Isotope / molecule	Acquisition time (s)
1	16	^{16}O	10
2	85	^{85}Rb	5
3	87	^{87}Rb	3
4	88	^{88}Sr	5
5	90	^{90}Sr / Zr	3
6	97	^{97}Mo	10
7	99	^{99}Tc	10
8	106	$^{90}Zr^{16}O$	3
9	133	^{133}Cs	3
10	134	^{134}Cs	3
11	135	^{135}Cs	3
12	137	^{137}Cs	3
13	138	^{138}Ba	3
14	155	$^{139}La^{16}O$	3
15	156	$^{140}Ce^{16}O$	3
16	159	$^{143}Nd^{16}O$	5
17	160	^{144}Nd / $Ce^{16}O$	5
18	161	$^{145}Nd^{16}O$	7
19	162	$^{146}Nd^{16}O$	7
20	164	^{148}Nd / $Sm^{16}O$	10
21	166	^{150}Nd / $Sm^{16}O$	7
22	251	$^{235}U^{16}O$	20
23	254	$^{238}U^{16}O$	5
24	255	$^{239}Pu^{16}O$	20
25	256	$^{240}Pu^{16}O$	20
26	257	$^{241}Pu^{16}O$	20
27	258	$^{242}Pu^{16}O$	20
28	267	$^{235}U^{16}O_2$	20
29	270	$^{238}U^{16}O_2$	5

Table 4.3 - Normalization constants used for the SIMS data analysis

To be determined	Normalization factor
Burn - up distribution Relative Pu isotope distribution Relative fission product distribution	$N_F + \Sigma Pu_i + \Sigma U_i$
Plutonium isotopic composition	ΣPu_i
^{235}U isotopic composition	ΣU_i
Pu / (U + Pu) ratio distribution	$\Sigma Pu_i + \Sigma U_i$
Neodymium isotopic composition	ΣNd_i

Table 5.1 / 1 - Results uncertainties

Samples reference: BM1 - BM5' **(at analysis date)**

Laboratory: SCK-CEN Main solution - Actinides

Isotope	BM1			BM5'		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232						
U234	6.42E-02	6.4E-03	10.01	4.97E-02	5.0E-03	10.01
U235	8.26E-01	1.7E-02	2.05	5.86E-01	1.2E-02	2.05
U236	2.55E-01	1.3E-02	5.02	2.69E-01	1.4E-02	5.02
U238	8.08E+02	3.7E+00	0.45	7.98E+02	3.6E+00	0.45
U total	8.09E+02	3.7E+00	0.45	7.98E+02	3.6E+00	0.45
Np237	≤ 0.94	3.9E-01	41.00	1.84E-01	2.0E-02	10.97
Pu238	1.11E+00	3.4E-02	3.05	9.95E-01	3.0E-02	3.05
Pu239	1.19E+01	6.7E-02	0.56	9.80E+00	5.6E-02	0.57
Pu240	1.18E+01	6.7E-02	0.56	1.01E+01	5.7E-02	0.57
Pu241	4.99E+00	2.8E-02	0.56	4.60E+00	2.6E-02	0.57
Pu242	3.88E+00	2.2E-02	0.56	3.67E+00	2.1E-02	0.57
Pu244	6.85E-04	3.4E-04	50.00	1.00E-03	5.0E-04	50.00
Pu total	3.37E+01	1.0E-01	0.30	2.91E+01	9.2E-02	0.32
Am241	1.56E+00	5.6E-02	3.56	1.13E+00	4.0E-02	3.51
Am242m	1.41E-02	1.5E-03	10.60	1.06E-02	1.1E-03	10.59
Am243	9.84E-01	3.5E-02	3.56	9.37E-01	3.3E-02	3.51
Am total	2.56E+00	6.6E-02	2.57	2.08E+00	5.2E-02	2.48
Cm242	3.01E-04	1.1E-05	3.50	1.49E-03	5.2E-05	3.46
Cm243	7.91E-03	5.1E-04	6.46	6.90E-03	7.3E-04	10.60
Cm244	5.35E-01	9.6E-03	1.80	7.07E-01	2.2E-02	3.13
Cm245	6.44E-02	3.5E-03	5.39	8.76E-02	4.5E-03	5.13
Cm246	7.02E-03	1.4E-03	20.10	1.40E-02	1.5E-03	10.50
Cm total	6.15E-01	1.0E-02	1.68	8.16E-01	2.3E-02	2.77

(*) 95 % confidence level

Table 5.1 / 2 - Results uncertainties

Samples reference: BM1 - BM5' **(at analysis date)**

Laboratory: SCK-CEN Main solution - Fission products

Isotope	BM1			BM5'		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140						
Ce142						
Ce144	8.02E-03	7.2E-04	9.02	1.68E-02	1.0E-03	5.94
Ce total						
Nd142	1.80E-02	1.8E-03	10.01	2.97E-02	3.0E-03	10.01
Nd143	9.00E-01	5.0E-03	0.56	1.04E+00	5.8E-03	0.56
Nd144	1.18E+00	6.6E-03	0.56	1.55E+00	8.7E-03	0.56
Nd145	7.01E-01	3.9E-03	0.56	8.41E-01	4.7E-03	0.56
Nd146	7.40E-01	4.1E-03	0.56	9.58E-01	5.4E-03	0.56
Nd148	4.43E-01	2.5E-03	0.56	5.49E-01	3.1E-03	0.56
Nd150	2.65E-01	1.5E-03	0.58	3.28E-01	1.9E-03	0.58
Nd total	4.25E+00	1.0E-02	0.25	5.29E+00	1.3E-02	0.25
Pm147	6.41E-02	5.4E-03	8.41	7.32E-02	1.2E-02	16.01
Sm147	2.37E-01	1.5E-03	0.64	2.34E-01	1.5E-03	0.64
Sm148	1.89E-01	1.2E-03	0.64	2.71E-01	1.7E-03	0.64
Sm149	5.03E-03	1.1E-04	2.09	4.08E-03	8.5E-05	2.09
Sm150	3.62E-01	2.3E-03	0.64	4.33E-01	2.8E-03	0.64
Sm151	2.39E-02	1.9E-04	0.79	2.19E-02	1.7E-04	0.79
Sm152	1.64E-01	1.1E-03	0.64	1.58E-01	1.0E-03	0.64
Sm154	7.95E-02	5.3E-04	0.66	8.87E-02	5.9E-04	0.66
Sm total	1.06E+00	3.3E-03	0.31	1.21E+00	3.8E-03	0.31
Eu151	8.50E-04	1.8E-05	2.10	7.76E-04	1.6E-05	2.10
Eu153	1.96E-01	1.3E-03	0.67	2.33E-01	1.5E-03	0.67
Eu154	3.69E-02	1.1E-03	3.01	5.06E-02	1.5E-03	3.01
Eu155	9.44E-03	4.3E-04	4.55	1.35E-02	1.2E-03	8.81
Eu total	2.43E-01	1.8E-03	0.73	2.97E-01	2.5E-03	0.83
Gd154						
Gd155	6.65E-03	3.3E-04	5.00	7.34E-03	1.5E-04	2.09
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	3.56E-01	5.3E-02	15.00	3.14E-01	5.0E-02	16.01
Mo95	5.64E-01	see table 5.1/17		8.62E-01	see table 5.1/17	
Tc99	5.61E-01	see table 5.1/17		9.40E-01	see table 5.1/17	
Ru101	3.14E-01	see table 5.1/17		7.72E-01	see table 5.1/17	
Ru106	6.28E-03	see table 5.1/17		2.09E-02	see table 5.1/17	
Rh103	2.96E-01	see table 5.1/17		6.05E-01	see table 5.1/17	
Ag109	7.21E-02	see table 5.1/17		1.50E-01	see table 5.1/17	
Sb125	2.44E-03	see table 5.1/17		2.79E-03	see table 5.1/17	
I129				2.24E-01	2.5E-02	11.24
Cs133	1.32E+00	2.6E-02	1.99	1.52E+00	4.6E-02	3.06
Cs134	3.74E-02	7.6E-04	2.04	7.40E-02	2.3E-03	3.09
Cs135	8.45E-01	1.7E-02	1.99	1.04E+00	3.2E-02	3.06
Cs137	1.36E+00	2.7E-02	1.96	1.67E+00	5.1E-02	3.04
Cs total	3.57E+00	4.1E-02	1.15	4.30E+00	7.6E-02	1.76

(*) 95 % confidence level

Table 5.1 / 3 - Results uncertainties

Samples reference : GU1 - GU3' **(at analysis date)**

Laboratory: SCK-CEN Main solution - Actinides

Isotope	GU1			GU3'		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232						
U234	1.06E-01	5.32E-03	5.02	1.24E-01	6.2E-03	5.02
U235	1.86E+00	3.80E-02	2.05	5.33E+00	3.5E-02	0.67
U236	4.26E+00	2.84E-02	0.67	4.97E+00	3.3E-02	0.67
U238	8.11E+02	3.67E+00	0.45	8.16E+02	3.7E+00	0.45
U total	8.17E+02	3.67E+00	0.45	8.26E+02	3.7E+00	0.44
Np237	≤ 21.6	4.45E+00	20.60	7.09E-01	5.4E-02	7.68
Pu238	4.00E-01	1.22E-02	3.05	3.32E-01	1.0E-02	3.05
Pu239	4.31E+00	2.48E-02	0.57	5.13E+00	2.9E-02	0.57
Pu240	2.80E+00	1.61E-02	0.57	2.50E+00	1.4E-02	0.57
Pu241	1.27E+00	7.33E-03	0.57	1.43E+00	8.2E-03	0.57
Pu242	1.37E+00	7.85E-03	0.57	8.93E-01	5.3E-03	0.59
Pu244	2.58E-04	1.29E-04	50.00	1.63E-04	8.1E-05	50.00
Pu total	1.01E+01	3.37E-02	0.33	1.03E+01	3.5E-02	0.34
Am241	2.19E-01	7.81E-03	3.56	1.97E-01	6.9E-03	3.48
Am242m	6.04E-04	6.41E-05	10.60	8.10E-04	8.6E-05	10.58
Am243	3.55E-01	1.27E-02	3.56	2.10E-01	7.3E-03	3.48
Am total	5.75E-01	1.49E-02	2.59	4.07E-01	1.0E-02	2.46
Cm242	2.72E-04	1.96E-05	7.22	9.82E-04	4.0E-05	4.03
Cm243	2.98E-04	2.19E-04	73.49	5.23E-04	1.0E-04	19.21
Cm244	2.15E-01	6.48E-03	3.02	1.14E-01	3.7E-03	3.24
Cm245	1.54E-02	9.05E-04	5.89	8.54E-03	4.4E-04	5.17
Cm246	4.66E-03	9.44E-04	20.24	1.27E-03	1.3E-04	10.52
Cm total	2.35E-01	6.61E-03	2.81	1.25E-01	3.7E-03	2.97

(*) 95 % confidence level

Table 5.1 / 4 - Results uncertainties

Samples reference: GU1 - GU3' **(at analysis date)**

Laboratory: SCK-CEN Main solution - Fission products

Isotope	GU1			GU3'		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140						
Ce142						
Ce144	2.97E-02	2.33E-03	7.84	6.32E-02	2.2E-03	3.51
Ce total						
Nd142	5.97E-02	5.97E-03	10.01	3.73E-02	3.7E-03	10.01
Nd143	8.22E-01	4.68E-03	0.57	9.45E-01	5.3E-03	0.56
Nd144	2.32E+00	1.32E-02	0.57	1.89E+00	1.1E-02	0.56
Nd145	9.18E-01	5.23E-03	0.57	8.72E-01	4.9E-03	0.56
Nd146	1.17E+00	6.64E-03	0.57	1.01E+00	5.7E-03	0.56
Nd148	5.87E-01	3.46E-03	0.59	5.17E-01	3.0E-03	0.58
Nd150	2.99E-01	1.76E-03	0.59	2.52E-01	1.5E-03	0.58
Nd total	6.18E+00	1.79E-02	0.29	5.53E+00	1.5E-02	0.27
Pm147	5.61E-02	5.75E-03	10.25	8.25E-02	1.5E-02	18.01
Sm147	1.96E-01	1.26E-03	0.64	1.73E-01	1.1E-03	0.64
Sm148	2.86E-01	1.84E-03	0.64	2.24E-01	1.4E-03	0.64
Sm149	2.89E-03	6.05E-05	2.09	2.96E-03	6.2E-05	2.09
Sm150	4.48E-01	2.89E-03	0.64	3.93E-01	2.5E-03	0.64
Sm151	1.15E-02	9.09E-05	0.79	1.27E-02	1.0E-04	0.79
Sm152	1.46E-01	9.43E-04	0.64	1.18E-01	7.6E-04	0.64
Sm154	7.09E-02	4.69E-04	0.66	5.06E-02	3.3E-04	0.66
Sm total	1.16E+00	3.80E-03	0.33	9.74E-01	3.2E-03	0.33
Eu151	6.33E-04	1.33E-05	2.10	3.70E-04	7.8E-06	2.10
Eu153	1.85E-01	1.23E-03	0.67	1.62E-01	1.1E-03	0.67
Eu154	2.84E-02	1.11E-03	3.89	3.06E-02	1.6E-03	5.29
Eu155	9.95E-03	5.26E-04	5.28	9.97E-03	9.8E-04	9.83
Eu total	2.24E-01	1.74E-03	0.78	2.03E-01	2.2E-03	1.07
Gd154						
Gd155	4.96E-03	2.48E-04	5.00	3.41E-03	7.1E-05	2.10
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	8.57E-01	1.29E-01	15.00	6.30E-01	1.0E-01	16.01
Mo95	7.14E-01	see table 5.1/17		9.68E-01	see table 5.1/17	
Tc99	6.10E-01	see table 5.1/17		9.96E-01	see table 5.1/17	
Ru101	3.49E-01	see table 5.1/17		8.49E-01	see table 5.1/17	
Ru106	1.28E-02	see table 5.1/17		4.51E-02	see table 5.1/17	
Rh103	2.04E-01	see table 5.1/17		4.62E-01	see table 5.1/17	
Ag109	9.87E-03	see table 5.1/17		7.62E-02	see table 5.1/17	
Sb125	3.29E-03	see table 5.1/17		3.71E-03	see table 5.1/17	
I129				2.39E-01	2.7E-02	11.24
Cs133	1.52E+00	7.45E-02	4.91	1.39E+00	4.2E-02	3.06
Cs134	9.56E-02	4.72E-03	4.94	1.09E-01	3.3E-03	3.06
Cs135	4.55E-01	2.24E-02	4.91	4.05E-01	1.2E-02	3.06
Cs137	1.79E+00	8.76E-02	4.90	1.59E+00	4.8E-02	3.04
Cs total	3.85E+00	1.17E-01	3.04	3.49E+00	6.5E-02	1.88

(*) 95 % confidence level

Table 5.1 / 5 - Results uncertainties

Samples reference: DM1 - DM2 - DM3 **(at analysis date)**

Laboratory: SCK-CEN Main solution - Actinides

Isotope	DM1			DM2			DM3		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232									
U234	6.38E-02	6.4E-03	10.01	7.42E-02	7.4E-03	10.01	8.76E-02	4.4E-03	5.02
U235	4.47E-01	9.2E-03	2.05	8.96E-01	1.8E-02	2.05	6.79E-01	1.4E-02	2.05
U236	2.94E-01	1.5E-02	5.02	2.11E-01	1.1E-02	5.02	2.69E-01	1.3E-02	5.02
U238	7.97E+02	3.6E+00	0.45	8.11E+02	3.6E+00	0.45	8.05E+02	3.6E+00	0.45
U total	7.98E+02	3.6E+00	0.45	8.12E+02	3.7E+00	0.45	8.06E+02	3.6E+00	0.45
Np237	1.27E-01	1.0E-02	8.00	8.63E-02	5.2E-03	5.98	1.17E-01	9.0E-03	7.63
Pu238	1.06E+00	3.2E-02	3.05	1.01E+00	3.1E-02	3.05	1.08E+00	3.3E-02	3.05
Pu239	5.43E+00	3.1E-02	0.57	8.27E+00	4.7E-02	0.57	7.27E+00	4.2E-02	0.57
Pu240	1.01E+01	5.8E-02	0.57	1.45E+01	8.2E-02	0.57	1.22E+01	7.0E-02	0.57
Pu241	3.55E+00	2.0E-02	0.57	3.78E+00	2.2E-02	0.57	3.79E+00	2.2E-02	0.57
Pu242	5.80E+00	3.3E-02	0.57	4.52E+00	2.6E-02	0.57	5.09E+00	2.9E-02	0.57
Pu244	1.00E-03	5.0E-04	50.00	3.91E-04	2.0E-04	50.00	9.88E-04	4.9E-04	50.00
Pu total	2.60E+01	8.3E-02	0.32	3.20E+01	1.1E-01	0.33	2.95E+01	9.5E-02	0.32
Am241	8.65E-01	3.0E-02	3.50	1.41E+00	5.0E-02	3.55	1.57E+00	5.6E-02	3.56
Am242m	5.80E-03	6.1E-04	10.58	9.41E-03	1.0E-03	10.60	7.13E-03	7.6E-04	10.60
Am243	1.34E+00	4.7E-02	3.50	6.74E-01	2.4E-02	3.55	1.12E+00	4.0E-02	3.56
Am total	2.21E+00	5.6E-02	2.53	2.09E+00	5.6E-02	2.65	2.70E+00	6.9E-02	2.55
Cm242	7.51E-04	2.2E-05	2.99	1.57E-04	6.9E-06	4.41	7.54E-05	2.3E-06	3.05
Cm243	5.59E-03	1.9E-03	34.11	3.49E-03	1.5E-03	43.82	6.51E-03	1.1E-03	17.18
Cm244	8.49E-01	2.4E-02	2.77	1.77E-01	7.4E-03	4.15	5.29E-01	1.4E-02	2.64
Cm245	6.49E-02	3.2E-03	4.90	8.39E-03	4.9E-04	5.78	4.51E-02	2.2E-03	4.83
Cm246	1.62E-02	1.7E-03	10.39	1.07E-03	1.2E-04	10.84	7.23E-03	7.5E-04	10.36
Cm total	9.36E-01	2.4E-02	2.55	1.90E-01	7.5E-03	3.96	5.88E-01	1.4E-02	2.41

(*) 95 % confidence level

Table 5.1 / 6 - Results uncertainties

Samples reference: DM1 - DM2 - DM3 **(at analysis date)**

Laboratory: SCK-CEN Main solution - Fission products

Isotope	DM1			DM2			DM3		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140									
Ce142									
Ce144	1.69E-02	1.2E-03	7.09	4.35E-03	4.3E-04	9.78	1.79E-03	1.9E-04	10.58
Ce total									
Nd142	5.11E-02	5.1E-03	10.01	1.11E-02	1.1E-03	10.01	2.15E-02	2.2E-03	10.01
Nd143	9.99E-01	5.6E-03	0.56	7.47E-01	4.2E-03	0.56	9.28E-01	5.2E-03	0.56
Nd144	1.84E+00	1.0E-02	0.56	9.97E-01	5.6E-03	0.56	1.41E+00	7.9E-03	0.56
Nd145	9.21E-01	5.2E-03	0.56	6.11E-01	3.4E-03	0.56	7.81E-01	4.4E-03	0.56
Nd146	1.04E+00	5.9E-03	0.56	5.81E-01	3.2E-03	0.56	8.19E-01	4.6E-03	0.56
Nd148	6.00E-01	3.4E-03	0.56	3.66E-01	2.0E-03	0.56	4.96E-01	2.8E-03	0.56
Nd150	3.58E-01	2.1E-03	0.58	2.17E-01	1.3E-03	0.58	2.93E-01	1.7E-03	0.58
Nd total	5.81E+00	1.6E-02	0.27	3.53E+00	8.8E-03	0.25	4.74E+00	1.2E-02	0.25
Pm147				4.85E-02	3.5E-03	7.24			
Sm147	2.89E-01	1.9E-03	0.64	2.68E-01	1.8E-03	0.69	3.00E-01	1.9E-03	0.64
Sm148	2.57E-01	1.6E-03	0.64	9.28E-02	6.4E-04	0.69	1.82E-01	1.2E-03	0.64
Sm149	4.64E-03	9.7E-05	2.09	2.77E-03	5.8E-05	2.10	3.46E-03	7.2E-05	2.09
Sm150	4.76E-01	3.1E-03	0.64	2.82E-01	1.9E-03	0.69	4.03E-01	2.6E-03	0.64
Sm151	1.50E-02	1.2E-04	0.79	1.37E-02	1.1E-04	0.82	1.63E-02	1.3E-04	0.79
Sm152	2.06E-01	1.3E-03	0.64	1.88E-01	1.3E-03	0.69	1.92E-01	1.2E-03	0.64
Sm154	1.01E-01	6.7E-04	0.66	6.03E-02	4.2E-04	0.70	8.34E-02	5.5E-04	0.66
Sm total	1.35E+00	4.2E-03	0.31	9.08E-01	3.1E-03	0.34	1.18E+00	3.7E-03	0.31
Eu151	8.57E-04	1.8E-05	2.07	7.75E-04	1.6E-05	2.08	8.07E-04	1.7E-05	2.10
Eu153	2.48E-01	1.5E-03	0.59	1.52E-01	9.1E-04	0.60	2.15E-01	1.4E-03	0.67
Eu154	3.80E-02	1.4E-03	3.56	1.50E-02	3.8E-04	2.56	2.68E-02	3.3E-04	1.23
Eu155	1.35E-02	7.3E-04	5.40	5.96E-03	2.7E-04	4.61	7.42E-03	1.5E-04	2.05
Eu total	3.01E-01	2.1E-03	0.70	1.74E-01	1.0E-03	0.59	2.50E-01	1.5E-03	0.59
Gd154									
Gd155	1.04E-02	5.2E-04	5.00	5.07E-03	2.5E-04	5.00			
Gd156									
Gd157									
Gd158									
Gd160									
Gd total									
Sr90				2.80E-01	4.2E-02	15.00			
Mo95	6.72E-01	see table 5.1/17		5.33E-01	see table 5.1/17		6.27E-01	see table 5.1/17	
Tc99	5.00E-01	see table 5.1/17		4.84E-01	see table 5.1/17		4.70E-01	see table 5.1/17	
Ru101	3.83E-01	see table 5.1/17		3.95E-01	see table 5.1/17		3.57E-01	see table 5.1/17	
Ru106	1.38E-02	see table 5.1/17		5.76E-03	see table 5.1/17				
Rh103	3.10E-01	see table 5.1/17		3.43E-01	see table 5.1/17		2.96E-01	see table 5.1/17	
Ag109	9.27E-02	see table 5.1/17		1.09E-01	see table 5.1/17		1.37E-01	see table 5.1/17	
Sb125	3.81E-03	see table 5.1/17		2.64E-03	see table 5.1/17				
I129	2.78E-01	5.1E-02	18.40	1.97E-01	3.4E-02	17.40	3.04E-01	3.4E-02	11.24
Cs133	1.69E+00	5.4E-02	3.22	1.18E+00	3.2E-02	2.73	1.48E+00	2.3E-02	1.53
Cs134	5.71E-02	1.9E-03	3.25	1.28E-02	4.3E-04	3.38	2.16E-02	3.5E-04	1.60
Cs135	8.15E-01	2.6E-02	3.22	5.60E-01	1.5E-02	2.73	7.13E-01	1.1E-02	1.53
Cs137	1.81E+00	5.8E-02	3.20	1.10E+00	3.0E-02	2.71	1.46E+00	2.2E-02	1.50
Cs total	4.37E+00	8.4E-02	1.91	2.86E+00	4.7E-02	1.63	3.67E+00	3.3E-02	0.91

(*) 95 % confidence level

Table 5.1 / 7 - Results uncertainties

Samples reference: DM4 - DU1 **(at analysis date)**

Laboratory: SCK-CEN Main solution - Actinides

Isotope	DM4			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232						
U234	8.92E-02	4.5E-03	5.02	1.24E-01	6.2E-03	5.02
U235	8.72E-01	1.8E-02	2.05	5.08E+00	3.4E-02	0.67
U236	2.31E-01	1.2E-02	5.02	6.27E+00	4.2E-02	0.67
U238	7.98E+02	3.6E+00	0.45	8.06E+02	3.6E+00	0.45
U total	7.99E+02	3.6E+00	0.45	8.18E+02	3.6E+00	0.45
Np237	9.47E-02	8.9E-03	9.37	6.24E-01	2.3E-02	3.65
Pu238	1.15E+00	3.5E-02	3.05	2.69E-01	8.2E-03	3.03
Pu239	9.13E+00	5.2E-02	0.57	3.42E+00	1.7E-02	0.50
Pu240	1.34E+01	7.7E-02	0.57	2.39E+00	1.2E-02	0.50
Pu241	4.03E+00	2.3E-02	0.57	8.67E-01	4.3E-03	0.50
Pu242	4.37E+00	2.5E-02	0.57	7.53E-01	3.8E-03	0.50
Pu244	1.08E-03	5.4E-04	50.00	7.05E-05	3.5E-05	50.00
Pu total	3.21E+01	1.0E-01	0.33	7.70E+00	2.3E-02	0.30
Am241	1.64E+00	5.8E-02	3.56	1.81E-01	6.3E-03	3.48
Am242m	1.19E-02	1.3E-03	10.60	6.01E-04	6.4E-05	10.58
Am243	8.56E-01	3.0E-02	3.56	1.52E-01	5.3E-03	3.48
Am total	2.50E+00	6.6E-02	2.63	3.34E-01	8.2E-03	2.47
Cm242	1.27E-04	7.4E-06	5.84	9.29E-05	5.6E-06	6.02
Cm243	4.46E-03	7.6E-04	17.14	4.41E-04	1.4E-04	32.21
Cm244	3.16E-01	9.3E-03	2.93	5.88E-02	3.3E-03	5.63
Cm245	2.30E-02	1.1E-03	4.99	2.95E-03	2.0E-04	6.92
Cm246	2.42E-03	2.5E-04	10.43	6.52E-04	7.5E-05	11.49
Cm total	3.46E-01	9.4E-03	2.71	6.29E-02	3.3E-03	5.28

(*) 95 % confidence level

Table 5.1 / 8 - Results uncertainties

Samples reference: DM4 - DU1 **(at analysis date)**
Laboratory: SCK-CEN Main solution - Fission products

Isotope	DM4			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140						
Ce142						
Ce144	2.72E-03	3.0E-04	11.06	1.87E-02	1.3E-03	6.99
Ce total						
Nd142	1.46E-02	1.5E-03	10.01	4.95E-02	5.0E-03	10.01
Nd143	7.89E-01	4.4E-03	0.56	9.26E-01	5.2E-03	0.57
Nd144	1.05E+00	5.9E-03	0.56	2.24E+00	1.3E-02	0.57
Nd145	6.35E-01	3.5E-03	0.56	9.63E-01	5.5E-03	0.57
Nd146	6.27E-01	3.5E-03	0.56	1.07E+00	6.1E-03	0.57
Nd148	3.82E-01	2.1E-03	0.56	5.45E-01	3.2E-03	0.59
Nd150	2.22E-01	1.3E-03	0.58	2.61E-01	1.5E-03	0.59
Nd total	3.72E+00	9.3E-03	0.25	6.06E+00	1.7E-02	0.28
Pm147				6.83E-02	3.8E-03	5.51
Sm147	2.65E-01	1.7E-03	0.64	2.73E-01	1.9E-03	0.69
Sm148	1.25E-01	8.0E-04	0.64	2.33E-01	1.6E-03	0.69
Sm149	3.35E-03	7.0E-05	2.09	2.65E-03	5.6E-05	2.11
Sm150	3.10E-01	2.0E-03	0.64	3.90E-01	2.7E-03	0.69
Sm151	1.68E-02	1.3E-04	0.79	9.50E-03	7.8E-05	0.83
Sm152	1.79E-01	1.1E-03	0.64	1.42E-01	9.8E-04	0.69
Sm154	6.95E-02	4.6E-04	0.66	5.08E-02	3.6E-04	0.70
Sm total	9.68E-01	3.0E-03	0.31	1.10E+00	3.8E-03	0.34
Eu151	8.43E-04	1.8E-05	2.10	6.04E-04	1.3E-05	2.10
Eu153	1.69E-01	1.1E-03	0.66	1.55E-01	1.0E-03	0.67
Eu154	2.06E-02	2.8E-04	1.36	1.96E-02	5.6E-04	2.87
Eu155	6.27E-03	1.5E-04	2.38	7.67E-03	3.7E-04	4.80
Eu total	1.97E-01	1.2E-03	0.59	1.83E-01	1.2E-03	0.67
Gd154						
Gd155				4.98E-03	2.5E-04	5.00
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90				9.05E-01	1.4E-01	15.00
Mo95	5.68E-01	see table 5.1/17		1.20E+00	see table 5.1/17	
Tc99	6.08E-01	see table 5.1/17		1.14E+00	see table 5.1/17	
Ru101	4.67E-01	see table 5.1/17		1.00E+00	see table 5.1/17	
Ru106				1.51E-02	see table 5.1/17	
Rh103	4.09E-01	see table 5.1/17		5.05E-01	see table 5.1/17	
Ag109	1.27E-01	see table 5.1/17		4.68E-02	see table 5.1/17	
Sb125				2.94E-03	see table 5.1/17	
I129	2.33E-01	2.6E-02	11.24	2.12E-01	3.7E-02	17.40
Cs133	1.22E+00	1.9E-02	1.53	1.50E+00	4.2E-02	2.82
Cs134	1.70E-02	2.7E-04	1.60	4.94E-02	1.4E-03	2.86
Cs135	7.24E-01	1.1E-02	1.53	5.08E-01	1.4E-02	2.82
Cs137	1.16E+00	1.7E-02	1.49	1.57E+00	4.4E-02	2.80
Cs total	3.12E+00	2.8E-02	0.89	3.63E+00	6.3E-02	1.73

(*) 95 % confidence level

Table 5.1 / 9 - Results uncertainties

Samples reference: BM1 - BM5 - BM6 **(at analysis date)**

Laboratory: PSI Main solution - Actinides

Isotope	BM1			BM5			BM6		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232									
U234	7.50E-02	2.00E-02	26.70	4.48E-02	1.11E-02	24.83	4.95E-02	6.60E-03	13.33
U235	8.65E-01	7.23E-02	8.35	7.39E-01	1.31E-01	17.68	9.56E-01	4.21E-02	4.41
U236	2.58E-01	1.86E-02	7.22	2.68E-01	2.86E-02	10.67	2.09E-01	3.32E-02	15.89
U238	8.01E+02	4.17E+01	5.20	7.98E+02	3.34E+01	4.18	7.98E+02	1.22E+01	1.53
U total	8.03E+02			7.99E+02			8.00E+02		
Np237	1.50E-01	1.81E-02	12.02	1.75E-01	7.51E-04	0.43	1.25E-01	2.31E-03	1.85
Pu238	9.95E-01	3.89E-02	3.91	8.65E-01	1.03E-01	11.89	7.82E-01	5.84E-02	7.47
Pu239	1.10E+01	2.78E-01	2.52	9.25E+00	8.34E-02	0.90	1.33E+01	1.28E-01	0.96
Pu240	1.09E+01	2.59E-01	2.38	9.59E+00	9.45E-02	0.99	1.09E+01	1.06E-01	0.97
Pu241	4.32E+00	1.03E-01	2.38	4.47E+00	4.73E-02	1.06	4.56E+00	4.17E-02	0.92
Pu242	3.49E+00	8.62E-02	2.47	3.52E+00	4.45E-02	1.26	2.38E+00	2.25E-02	0.94
Pu244									
Pu total	3.07E+01			2.77E+01			3.19E+01		
Am241	2.40E+00	4.73E-01	19.72	1.08E+00	5.00E-02	4.64	1.68E+00	5.84E-01	34.65
Am242m	1.61E-02	3.34E-03	20.71	1.04E-02	5.56E-04	5.33	2.20E-02	7.78E-03	35.40
Am243	1.12E+00	2.25E-01	20.10	8.64E-01	4.17E-02	4.82	7.27E-01	2.59E-01	35.54
Am total	3.53E+00			1.95E+00			2.43E+00		
Cm242									
Cm243									
Cm244	4.58E-01	1.20E-02	2.61	7.49E-01	3.06E-02	4.09	2.78E-01	7.78E-03	2.80
Cm245	5.88E-02	1.72E-03	2.93	9.13E-02	4.17E-03	4.57	2.97E-02	1.25E-03	4.21
Cm246	6.51E-03	2.36E-04	3.63	1.49E-02	7.78E-04	5.22	2.41E-03	2.14E-04	8.89
Cm total	5.23E-01			8.55E-01			3.10E-01		

(*) 95 % confidence level

Table 5.1 / 10 - Results uncertainties

Samples reference: BM1 - BM5 - BM6 **(at analysis date)**

Laboratory: PSI Main solution - Fission products

Isotope	BM1			BM5			BM6		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140									
Ce142									
Ce144	7.51E-04	8.06E-05	10.73	1.24E-02	1.28E-03	10.28	8.63E-03	8.62E-04	9.99
Ce total									
Nd142	1.65E-02	1.61E-03	9.74	2.85E-02	2.81E-03	9.86	9.34E-03	4.73E-04	5.06
Nd143	8.80E-01	8.62E-02	9.79	9.60E-01	6.39E-02	6.66	6.83E-01	3.61E-02	5.29
Nd144	1.16E+00	1.14E-01	9.79	1.46E+00	9.73E-02	6.68	8.29E-01	3.89E-02	4.69
Nd145	7.00E-01	6.95E-02	9.93	8.08E-01	5.56E-02	6.88	5.35E-01	2.50E-02	4.67
Nd146	7.46E-01	7.23E-02	9.69	9.41E-01	6.39E-02	6.79	5.52E-01	2.78E-02	5.04
Nd148	4.51E-01	4.45E-02	9.86	5.43E-01	3.61E-02	6.65	3.41E-01	1.67E-02	4.89
Nd150	2.71E-01	2.78E-02	10.26	3.20E-01	2.22E-02	6.96	1.98E-01	1.11E-02	5.62
Nd total	4.23E+00			5.06E+00			3.15E+00		
Pm147				6.67E-02	9.17E-03	13.76	5.32E-02	7.51E-03	14.10
Sm147	2.59E-01	1.17E-02	4.51	2.45E-01	5.00E-03	2.04	2.02E-01	3.34E-03	1.65
Sm148	1.93E-01	7.78E-03	4.03	2.90E-01	4.45E-03	1.53	1.46E-01	2.22E-03	1.53
Sm149	5.02E-03	5.56E-04	11.08	5.15E-03	5.28E-04	10.25	4.66E-03	2.50E-04	5.37
Sm150	3.69E-01	1.56E-02	4.22	4.71E-01	7.78E-03	1.65	2.82E-01	3.89E-03	1.38
Sm151	2.37E-02	1.11E-03	4.69	2.44E-02	5.56E-04	2.28	2.43E-02	4.45E-04	1.83
Sm152	1.60E-01	6.39E-03	3.99	1.76E-01	3.34E-03	1.89	1.39E-01	2.50E-03	1.80
Sm154	8.06E-02	3.34E-03	4.14	1.06E-01	2.39E-03	2.26	6.26E-02	1.20E-03	1.91
Sm total	1.09E+00			1.32E+00			8.60E-01		
Eu151	1.59E-03	9.45E-04	59.43	7.55E-04	3.61E-04	47.84	8.30E-04	4.73E-05	5.69
Eu153	1.94E-01	7.51E-03	3.87	2.32E-01	4.73E-03	2.04	1.52E-01	2.25E-03	1.48
Eu154	3.68E-02	1.58E-03	4.31	5.29E-02	1.33E-03	2.52	3.21E-02	6.39E-04	1.99
Eu155	7.81E-03	4.45E-04	5.70	1.22E-02	5.84E-04	4.79	7.54E-03	3.89E-04	5.16
Eu total	2.40E-01			2.98E-01			1.92E-01		
Gd154	2.71E-02	8.06E-04	2.97	2.76E-02	1.00E-03	3.63	1.43E-02	1.67E-04	1.17
Gd155	9.37E-03	3.34E-04	3.56	8.17E-03	5.56E-04	6.81	4.39E-03	1.64E-04	3.74
Gd156	1.53E-01	2.09E-03	1.36	2.60E-01	8.06E-03	3.10	9.82E-02	6.39E-04	0.65
Gd157		0.00E+00			0.00E+00				
Gd158	4.15E-02	9.17E-04	2.21	5.75E-02	2.06E-03	3.58	3.03E-02	3.89E-04	1.28
Gd160	3.36E-03	2.31E-04	6.86	4.31E-03	2.14E-04	4.96	2.56E-03	9.17E-05	3.59
Gd total	2.35E-01			3.58E-01			1.50E-01		
Sr90	2.81E-01	2.78E-02	9.91	4.02E-01	4.45E-02	11.07	2.33E-01	7.23E-03	3.10
Mo95	5.81E-01	2.36E-02	4.07	6.87E-01	3.34E-02	4.86	5.50E-01	2.34E-02	4.25
Tc99	5.28E-01	1.61E-02	3.05	5.58E-01	1.17E-02	2.09	4.74E-01	2.59E-02	5.45
Ru101	3.22E-01	1.47E-02	4.57	3.68E-01	1.36E-02	3.70	3.20E-01	8.62E-03	2.69
Ru106	1.01E-03	1.08E-04	10.76	9.68E-03	8.62E-04	8.90	7.82E-03	6.95E-04	8.89
Rh103	3.27E-01	9.73E-03	2.97	3.64E-01	3.61E-03	0.99	3.44E-01	3.06E-03	0.89
Ag109	6.89E-02	1.47E-03	2.14	2.66E-02	8.06E-04	3.03	1.40E-02	5.00E-04	3.58
Sb125	1.30E-03	5.56E-05	4.27	2.56E-03	1.08E-04	4.23	2.15E-03	7.78E-05	3.63
I129				8.82E-02	1.61E-02	18.28	8.34E-02	1.86E-02	22.33
Cs133	1.42E+00	5.84E-02	4.12	1.58E+00	4.73E-02	2.99	1.08E+00	4.73E-02	4.37
Cs134	1.89E-02	8.62E-04	4.55	7.26E-02	2.47E-03	3.41	3.23E-02	1.31E-03	4.05
Cs135	9.28E-01	3.89E-02	4.20	1.07E+00	3.06E-02	2.85	8.58E-01	3.61E-02	4.21
Cs137	1.42E+00	5.84E-02	4.13	1.73E+00	5.28E-02	3.05	1.10E+00	5.00E-02	4.54
Cs total	3.78E+00			4.46E+00			3.07E+00		

(*) 95 % confidence level

Table 5.1 / 11 - Results uncertainties

Samples reference: DM1 - DU1 **(at analysis date)**

Laboratory: PSI — Main solution - Actinides

Isotope	DM1			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232						
U234	8.91E-02	1.53E-02	17.16	1.31E-01	9.17E-03	6.99
U235	4.88E-01	2.78E-02	5.70	5.40E+00	1.89E-01	3.50
U236	2.82E-01	2.20E-02	7.79	6.33E+00	2.10E-01	3.32
U238	7.86E+02	2.78E+01	3.54	8.12E+02	1.11E+01	1.37
U total	7.87E+02			8.24E+02		
Np237	1.31E-01	1.39E-03	1.06	5.95E-01	1.67E-02	2.80
Pu238	1.03E+00	8.62E-02	8.34	2.37E-01	2.78E-03	1.17
Pu239	5.77E+00	5.56E-02	0.96	3.30E+00	2.78E-02	0.84
Pu240	1.10E+01	1.00E-01	0.91	2.26E+00	2.78E-02	1.23
Pu241	3.28E+00	3.89E-02	1.19	7.04E-01	1.39E-02	1.97
Pu242	6.24E+00	6.67E-02	1.07	7.04E-01	1.67E-02	2.37
Pu244						
Pu total	2.73E+01			7.21E+00		
Am241	1.32E+00	1.83E-01	13.86	3.24E-01	1.28E-02	3.95
Am242m	4.98E-03	9.45E-04	18.97	6.21E-04	8.90E-05	14.32
Am243	1.41E+00	1.95E-01	13.82	1.59E-01	6.39E-03	4.03
Am total	2.74E+00			4.83E-01		
Cm242						
Cm243						
Cm244	6.29E-01	1.53E-02	2.43	4.65E-02	8.34E-04	1.79
Cm245	6.16E-02	1.61E-03	2.62	2.75E-03	1.22E-04	4.44
Cm246	1.58E-02	5.00E-04	3.17	5.75E-04	6.67E-05	11.60
Cm total	7.06E-01			4.98E-02		

(*) 95 % confidence level

Table 5.1 / 12 - Results uncertainties

Samples reference: DM1 - DU1 **(at analysis date)**

Laboratory: PSI Main solution - Fission products

Isotope	DM1			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140						
Ce142						
Ce144	6.87E-04	7.51E-05	10.92	7.95E-04	8.62E-05	10.83
Ce total						
Nd142	3.44E-02	3.75E-03	10.92	4.42E-02	3.36E-03	7.61
Nd143	8.76E-01	6.95E-02	7.93	8.65E-01	6.67E-02	7.71
Nd144	1.67E+00	1.36E-01	8.13	2.17E+00	1.67E-01	7.69
Nd145	8.60E-01	6.95E-02	8.08	9.52E-01	7.23E-02	7.60
Nd146	9.88E-01	8.06E-02	8.16	1.08E+00	8.34E-02	7.69
Nd148	5.78E-01	4.73E-02	8.18	5.48E-01	4.45E-02	8.12
Nd150	3.41E-01	2.78E-02	8.16	2.48E-01	1.95E-02	7.84
Nd total	5.35E+00			5.91E+00		
Pm147				2.71E-02	3.89E-03	14.36
Sm147	3.30E-01	1.64E-02	4.97	3.15E-01	3.61E-03	1.15
Sm148	2.60E-01	1.22E-02	4.71	2.37E-01	3.61E-03	1.53
Sm149	3.09E-03	3.61E-04	11.71	2.15E-03	8.34E-05	3.88
Sm150	4.88E-01	1.89E-02	3.88	4.01E-01	5.00E-03	1.25
Sm151	1.52E-02	7.51E-04	4.94	9.48E-03	1.33E-04	1.41
Sm152	2.06E-01	1.08E-02	5.26	1.47E-01	1.64E-03	1.12
Sm154	1.05E-01	7.23E-03	6.89	5.20E-02	6.39E-04	1.23
Sm total	1.41E+00			1.16E+00		
Eu151	1.00E-03	2.78E-04	27.76	5.46E-04	6.39E-05	11.70
Eu153	2.61E-01	9.45E-03	3.62	1.50E-01	2.25E-03	1.50
Eu154	3.63E-02	1.36E-03	3.75	1.71E-02	3.06E-04	1.79
Eu155	9.71E-03	4.73E-04	4.87	5.27E-03	5.84E-04	11.08
Eu total	3.08E-01			1.73E-01		
Gd154	2.96E-02	6.95E-04	2.35	1.46E-02	1.95E-04	1.33
Gd155	1.22E-02	2.47E-04	2.02	7.15E-03	2.31E-04	3.23
Gd156	2.89E-01	1.64E-03	0.57	1.67E-01	8.62E-04	0.52
Gd157						
Gd158	5.87E-02	1.11E-03	1.89	2.21E-02	3.89E-04	1.76
Gd160	4.53E-03	4.17E-04	9.20	1.50E-03	1.31E-04	8.74
Gd total	3.95E-01			2.12E-01		
Sr90				7.48E-01	3.34E-02	4.46
Mo95				9.60E-01	6.95E-02	7.24
Tc99	4.58E-01	1.20E-02	2.61	8.66E-01	2.78E-02	3.21
Ru101				7.62E-01	3.06E-02	4.01
Ru106	1.05E-03	1.00E-04	9.51	1.22E-03	1.11E-04	9.11
Rh103				4.58E-01	6.39E-03	1.40
Ag109				3.97E-02	1.22E-03	3.08
Sb125	1.39E-03	5.28E-05	3.81	1.08E-03	3.89E-05	3.59
I129						
Cs133	1.73E+00	6.95E-02	4.03	1.52E+00	4.73E-02	3.11
Cs134	2.17E-02	1.00E-03	4.61	1.86E-02	5.84E-04	3.14
Cs135	8.35E-01	3.34E-02	3.99	5.13E-01	1.58E-02	3.09
Cs137	1.73E+00	6.95E-02	4.01	1.50E+00	4.45E-02	2.97
Cs total	4.32E+00			3.55E+00		

(*) 95 % confidence level

Table 5.1 / 13 - Results uncertainties

Samples reference: GU3 - GU4 **(at analysis date)**

Laboratory: ITU — Main solution - Actinides

Isotope	GU3			GU4		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
U232						
U234	1.24E-01	2.27E-05	0.02	1.72E-01	3.13E-05	0.02
U235	5.31E+00	1.27E-01	2.40	1.28E+01	1.14E-01	0.89
U236	4.99E+00	7.85E-02	1.57	4.05E+00	3.60E-02	0.89
U238	8.17E+02	1.57E-01	0.02	8.32E+02	1.51E-01	0.02
U total	8.28E+02			8.49E+02		
Np237	7.27E-01	6.98E-02	9.61	4.63E-01	2.22E-02	4.81
Pu238	3.28E-01	1.83E-03	0.56	9.80E-02	2.10E-03	2.15
Pu239	5.11E+00	2.62E-02	0.51	4.55E+00	2.12E-02	0.47
Pu240	2.50E+00	8.73E-03	0.35	1.62E+00	8.25E-03	0.51
Pu241	1.48E+00	3.67E-02	2.48	8.70E-01	2.96E-02	3.40
Pu242	8.95E-01	3.49E-04	0.04	2.73E-01	1.51E-03	0.55
Pu244						
Pu total	1.03E+01			7.41E+00		
Am241	1.67E-01	3.49E-03	2.09	1.30E-01	1.54E-02	11.87
Am242m						
Am243	2.36E-01	8.73E-03	3.69	3.86E-02	5.13E-03	13.29
Am total	4.03E-01			1.68E-01		
Cm242						
Cm243						
Cm244	1.36E-01	1.75E-02	12.85	1.09E-02	3.42E-04	3.13
Cm245	1.02E-02	3.49E-04	3.43	5.06E-04	1.03E-04	20.29
Cm246						
Cm total	1.46E-01			1.14E-02		

(*) 95 % confidence level

Table 5.1 / 14 - Results uncertainties

Samples reference: GU3 - GU4 **(at analysis date)**

Laboratory: ITU Main solution - Fission products

Isotope	GU3			GU4		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Ce140						
Ce142						
Ce144	7.13E-02	1.75E-03	2.45	3.20E-02	2.40E-03	7.49
Ce total						
Nd142	3.19E-02	5.24E-04	1.64	1.06E-02	1.08E-03	10.18
Nd143	8.76E-01	3.49E-02	3.98	7.60E-01	9.36E-02	12.32
Nd144	1.75E+00	6.98E-02	4.00	1.08E+00	1.28E-01	11.89
Nd145	8.22E-01	3.49E-02	4.25	5.96E-01	7.02E-02	11.78
Nd146	9.58E-01	3.49E-02	3.65	5.73E-01	8.44E-02	14.73
Nd148	4.94E-01	1.22E-02	2.47	3.06E-01	4.10E-02	13.40
Nd150	2.54E-01	6.98E-03	2.75	1.39E-01	1.88E-02	13.55
Nd total	5.18E+00			3.46E+00		
Pm147	1.41E-01	3.49E-03	2.48	9.63E-02	1.30E-02	13.51
Sm147	1.63E-01	1.75E-02	10.71	1.42E-01	3.00E-02	21.14
Sm148	2.31E-01	1.75E-02	7.56	9.74E-02	7.80E-03	8.01
Sm149	4.07E-03	1.75E-03	42.83	2.66E-03	3.13E-04	11.76
Sm150	3.94E-01	1.75E-02	4.43	2.14E-01	1.47E-02	6.87
Sm151	1.29E-02	8.73E-03	67.63	9.94E-03	4.38E-04	4.41
Sm152	1.15E-01	5.24E-03	4.54	8.34E-02	5.34E-03	6.41
Sm154	4.69E-02	3.49E-03	7.45	2.33E-02	2.64E-03	11.30
Sm total	9.67E-01			5.73E-01		
Eu151						
Eu153	1.65E-01	6.98E-03	4.23	8.28E-02	9.08E-03	10.97
Eu154	3.27E-02	5.24E-04	1.60	1.22E-02	2.89E-03	23.73
Eu155	1.09E-02	3.49E-03	32.13	3.88E-03	2.82E-04	7.28
Eu total	2.09E-01			9.88E-02		
Gd154						
Gd155	3.67E-03	2.27E-04	6.19	2.33E-03	3.19E-04	13.72
Gd156						
Gd157						
Gd158						
Gd160						
Gd total						
Sr90	6.45E-01	4.08E-03	0.63	4.45E-01	3.42E-03	0.77
Mo95	6.93E-01	6.98E-03	1.01	3.89E-01	8.56E-03	2.20
Tc99	5.62E-01	5.24E-03	0.93	3.84E-01	6.85E-03	1.78
Ru101	6.66E-01	4.01E-03	0.60	2.73E-01	5.13E-03	1.88
Ru106	2.92E-02	8.73E-04	2.99	1.05E-02	8.56E-04	8.18
Rh103	2.40E-01	1.57E-02	6.53	1.42E-01	6.85E-03	4.82
Ag109						
Sb125						
I129	2.31E-01	3.49E-02	15.12	1.46E-01	3.42E-02	23.36
Cs133	1.47E+00	3.49E-02	2.37	9.54E-01	3.11E-02	3.27
Cs134	1.28E-01	1.05E-02	8.20	3.65E-02	9.26E-04	2.54
Cs135	4.24E-01	1.40E-02	3.29	3.29E-01	7.92E-03	2.41
Cs137	1.58E+00	1.75E-02	1.10	8.77E-01	2.63E-02	3.00
Cs total	3.61E+00			2.20E+00		

(*) 95 % confidence level

Table 5.1 / 15 - Results uncertainties
Residue solution at EOL

Laboratory: PSI

Isotope	BM1			BM5		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	2.68E-02	1.78E-03	6.63	2.50E-01	1.47E-02	5.89
Tc99	4.56E-02	1.45E-03	3.17	5.14E-01	4.73E-02	9.19
Ru101	1.62E-01	9.73E-03	6.00	9.10E-01	5.28E-02	5.81
Ru106				1.64E-01	2.04E-02	12.45
Rh103				7.08E-01	2.78E-02	3.92
Ag109	1.81E-02	8.06E-04	4.44	8.26E-02	4.73E-03	5.72
Sb125				3.02E-03	2.93E-04	9.71

Isotope	BM6			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	7.68E-02	6.67E-03	8.68	1.14E-01	7.51E-03	6.59
Tc99	2.02E-01	1.61E-02	7.98	1.32E-01	7.78E-03	5.89
Ru101	4.64E-01	3.61E-02	7.78	1.91E-01	1.17E-02	6.10
Ru106	8.92E-02	1.21E-02	13.59	1.75E-02	3.65E-03	20.87
Rh103	3.84E-01	2.78E-02	7.24	8.12E-02	4.45E-03	5.48
Ag109	1.27E-01	1.06E-02	8.30	2.23E-03	1.36E-04	6.10
Sb125	1.58E-03	1.80E-04	11.41	1.86E-04	2.72E-05	14.67

Isotope	DM1		
		uncertainty (*)	
	mg/g fuel	mg/g fuel	%
Tc99	3.89E-01	1.92E-02	4.93
Ru106	9.05E-02	1.81E-02	20.04
Sb125	5.57E-04	7.55E-05	13.57

(*) 95 % confidence level

Table 5.1 / 16 - Results uncertainties
Residue solution at EOL

Laboratory: ITU

Isotope	GU3			GU4		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	3.38E-01	3.12E-02	9.25	2.79E-01	1.89E-02	6.77
Tc99	4.15E-01	3.84E-02	9.26	1.44E-01	1.03E-02	7.20
Ru101	4.07E-01	3.76E-02	9.25	3.87E-01	2.59E-02	6.69
Ru106	2.97E-01	3.11E-02	10.47	5.95E-02	4.19E-03	7.04
Rh103	2.30E-01	2.14E-02	9.29	2.58E-01	1.75E-02	6.80
Ag109						
Sb125						

(*) 95 % confidence level

Table 5.1 / 17 - Results uncertainties
(Main + residue) solutions at EOL

Laboratory: SCK-CEN

Isotope	BM1			BM5'			GU1		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	5.96E-01	7.96E-02	13.34	9.00E-01	8.73E-02	9.70	1.08E+00	8.38E-02	7.74
Tc99	6.20E-01	1.69E-01	27.23	9.69E-01	1.89E-01	19.47	1.10E+00	1.39E-01	12.60
Ru101	5.28E-01	9.74E-02	18.45	8.94E-01	1.44E-01	16.13	1.14E+00	1.04E-01	9.15
Ru106	1.38E-01	4.59E-03	3.31	1.89E-01	2.88E-02	15.24	2.26E-01	1.28E-02	5.64
Rh103	4.41E-01	3.43E-02	7.77	6.16E-01	6.12E-02	9.93	5.40E-01	4.85E-02	8.98
Ag109	8.95E-02	1.49E-02	16.64	1.65E-01	3.06E-02	18.58	6.62E-02	6.85E-03	10.35
Sb125	6.73E-03	4.03E-04	5.99	7.18E-03	4.98E-04	6.93	8.19E-03	8.31E-04	10.14

Isotope	GU3'			DM1			DM2		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	1.15E+00	1.05E-01	9.14	8.98E-01	1.08E-01	12.0 (**)	6.66E-01	7.03E-02	10.56
Tc99	1.14E+00	2.02E-01	17.70	9.59E-01	1.43E-01	14.96	7.47E-01	1.13E-01	15.19
Ru101	1.21E+00	2.96E-01	24.42	1.09E+00	2.17E-01	20.0 (**)	8.87E-01	1.01E-01	11.42
Ru106	2.56E-01	7.27E-02	28.41	2.53E-01	3.80E-02	15.0 (**)	1.93E-01	1.51E-02	7.83
Rh103	4.94E-01	4.82E-02	9.77	4.66E-01	5.59E-02	12.0 (**)	5.23E-01	7.88E-02	15.07
Ag109	1.05E-01	1.91E-02	18.12	1.13E-01	2.26E-02	20.0 (**)	1.13E-01	2.19E-02	19.30
Sb125	6.61E-03	1.25E-03	18.85	9.44E-03	1.42E-03	15.0 (**)	7.88E-03	4.88E-04	6.19

Isotope	DM3			DM4			DU1		
		uncertainty (*)			uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95							1.32E+00	1.47E-01	11.19
Tc99	5.45E-01	1.02E-01	18.65	6.30E-01	1.22E-01	19.37	1.26E+00	1.40E-01	11.11
Ru101							1.26E+00	1.10E-01	8.76
Ru106							1.56E-01	6.18E-03	3.95
Rh103							5.72E-01	5.74E-02	10.03
Ag109							4.88E-02	9.42E-03	19.29
Sb125							6.77E-03	5.72E-04	8.46

(*) 95 % confidence level (**) Estimated uncertainty

Table 5.1 / 18 - Results uncertainties (Main + residue) solutions at EOL

Laboratory: PSI

Isotope	BM1			BM5		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	6.07E-01	2.37E-02	3.90	9.37E-01	3.65E-02	3.89
Tc99	5.74E-01	1.62E-02	2.82	1.07E+00	4.87E-02	4.54
Ru101	4.85E-01	1.77E-02	3.64	1.28E+00	5.45E-02	4.27
Ru106				2.52E-01	2.19E-02	8.68
Rh103				1.07E+00	2.80E-02	2.62
Ag109	8.70E-02	1.68E-03	1.93	1.09E-01	4.79E-03	4.39
Sb125				8.82E-03	3.82E-04	4.34

Isotope	BM6			DU1		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	6.27E-01	2.43E-02	3.87	1.07E+00	6.99E-02	6.51
Tc99	6.76E-01	3.05E-02	4.51	9.98E-01	2.89E-02	2.89
Ru101	7.84E-01	3.72E-02	4.74	9.53E-01	3.27E-02	3.43
Ru106	1.60E-01	1.37E-02	8.53	1.33E-01	1.11E-02	8.37
Rh103	7.28E-01	2.80E-02	3.84	5.39E-01	7.79E-03	1.44
Ag109	1.41E-01	1.06E-02	7.48	4.19E-02	1.23E-03	2.94
Sb125	6.43E-03	2.52E-04	3.91	6.02E-03	2.11E-04	3.51

Isotope	DM1		
		uncertainty (*)	
	mg/g fuel	mg/g fuel	%
Tc99	8.48E-01	2.26E-02	2.67
Ru106	1.76E-01	1.99E-02	11.28
Sb125	7.62E-03	2.79E-04	3.67

(*) 95 % confidence level

Table 5.1 / 19 - Results uncertainties
(Main + residue) solutions at EOL

Laboratory: ITU

Isotope	GU3			GU4		
		uncertainty (*)			uncertainty (*)	
	mg/g fuel	mg/g fuel	%	mg/g fuel	mg/g fuel	%
Mo95	1.03E+00	3.20E-02	3.11	6.68E-01	2.07E-02	3.11
Tc99	9.77E-01	3.88E-02	3.97	5.28E-01	1.24E-02	2.35
Ru101	1.07E+00	3.78E-02	3.53	6.60E-01	2.64E-02	4.00
Ru106	4.39E-01	3.14E-02	7.14	1.14E-01	6.14E-03	5.37
Rh103	4.71E-01	2.65E-02	5.64	4.00E-01	1.88E-02	4.71
Ag109						
Sb125						

(*) 95 % confidence level

Table 5.2 / 1 - Laboratory crosscheck analysis

Sample	BM1 - S	BM1 - P	BM5 - S	BM5 -P	DM1 - S	DM1 - P	DU1 - S	DU1 - P	GU3 - S	GU3 - I
Burnup (%FIMA)	4.62		5.66		6.13		5.78		5.35	
Content	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel
Isotope										
U232										
U234	6.42E-02	7.50E-02	4.97E-02	4.48E-02	6.38E-02	8.91E-02	1.24E-01	1.31E-01	1.24E-01	1.24E-01
U234 last date	7.84E-02	7.50E-02	4.97E-02	4.81E-02	8.85E-02	8.91E-02	1.31E-01	1.31E-01	1.24E-01	1.26E-01
U234 EOL	2.95E-02		2.41E-02		3.63E-02		1.18E-01		1.18E-01	
U235	8.26E-01	8.65E-01	5.86E-01	7.39E-01	4.47E-01	4.88E-01	5.08E+00	5.40E+00	5.33E+00	5.31E+00
U236	2.55E-01	2.58E-01	2.69E-01	2.68E-01	2.94E-01	2.82E-01	6.27E+00	6.33E+00	4.97E+00	4.99E+00
U238	8.08E+02	8.01E+02	7.98E+02	7.98E+02	7.97E+02	7.86E+02	8.06E+02	8.12E+02	8.16E+02	8.17E+02
Np237		1.50E-01	1.84E-01	1.75E-01	1.27E-01	1.31E-01	6.24E-01	5.95E-01	7.09E-01	7.27E-01
Pu238	1.11E+00	9.95E-01	9.95E-01	8.65E-01	1.06E+00	1.03E+00	2.69E-01	2.37E-01	3.32E-01	3.28E-01
Pu238 EOL	9.65E-01		8.66E-01		9.37E-01		2.57E-01		3.15E-01	
Pu239	1.19E+01	1.10E+01	9.80E+00	9.25E+00	5.43E+00	5.77E+00	3.42E+00	3.30E+00	5.13E+00	5.11E+00
Pu240	1.18E+01	1.09E+01	1.01E+01	9.59E+00	1.01E+01	1.10E+01	2.39E+00	2.26E+00	2.50E+00	2.50E+00
Pu240 EOL	1.17E+01	1.08E+01	9.97E+00	9.51E+00	1.00E+01	1.08E+01	2.39E+00	2.25E+00	2.49E+00	2.49E+00
Pu241	4.99E+00	4.32E+00	4.60E+00	4.47E+00	3.55E+00	3.28E+00	8.67E-01	7.04E-01	1.43E+00	1.48E+00
Pu241 EOL	6.06E+00	5.66E+00	5.39E+00	5.12E+00	4.17E+00	4.40E+00	1.01E+00	9.56E-01	1.60E+00	1.60E+00
Pu242	3.88E+00	3.49E+00	3.67E+00	3.52E+00	5.80E+00	6.24E+00	7.53E-01	7.04E-01	8.93E-01	8.95E-01
Pu244	6.85E-04		1.00E-03		1.00E-03		7.05E-05		1.63E-04	

Value is maintained and either combined (results within uncertainty) or recommended (results out of uncertainty)

Value is dropped

No cross-check

Table 5.2 / 2 - Laboratory crosscheck analysis

Sample	BM1 - S	BM1 - P	BM5 - S	BM5 -P	DM1 - S	DM1 - P	DU1 - S	DU1 - P	GU3 - S	GU3 - I
Burnup (%FIMA)	4.62		5.66		6.13		5.78		5.35	
Content	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel
Isotope										
Am241	1.56E+00	2.40E+00	1.13E+00	1.08E+00	8.65E-01	1.32E+00	1.81E-01	3.24E-01	1.97E-01	1.67E-01
Am241 last date	2.17E+00	2.40E+00	1.13E+00	1.09E+00	1.41E+00	1.32E+00	3.13E-01	3.24E-01	1.97E-01	2.03E-01
Am241 EOL	5.14E-01	8.61E-01	3.50E-01	3.06E-01	2.57E-01	1.23E-01	3.56E-02	5.56E-02	2.74E-02	1.87E-02
Am242m	1.41E-02	1.61E-02	1.06E-02	1.04E-02	5.80E-03	4.98E-03	6.01E-04	6.21E-04	8.10E-04	
Am242m EOL	1.44E-02	1.66E-02	1.08E-02	1.06E-02	5.90E-03	5.15E-03	6.11E-04	6.42E-04	8.20E-04	
Am243	9.84E-01	1.12E+00	9.37E-01	8.64E-01	1.34E+00	1.41E+00	1.52E-01	1.59E-01	2.10E-01	2.36E-01
Cm242	3.01E-04		1.49E-03		7.51E-04		9.29E-05		9.82E-04	
Cm242 EOL	1.70E-01		1.56E-01		1.55E-01		1.92E-02		2.43E-02	
Cm243	7.91E-03		6.90E-03		5.59E-03		4.41E-04		5.23E-04	
Cm243 EOL	8.74E-03		7.42E-03		6.07E-03		4.79E-04		5.50E-04	
Cm244	5.35E-01	4.58E-01	7.07E-01	7.49E-01	8.49E-01	6.29E-01	5.88E-02	4.65E-02	1.14E-01	1.36E-01
Cm244 EOL	6.28E-01	5.91E-01	7.93E-01	8.53E-01	9.69E-01	8.12E-01	6.71E-02	6.06E-02	1.23E-01	1.47E-01
Cm245	6.44E-02	5.88E-02	8.76E-02	9.13E-02	6.49E-02	6.16E-02	2.95E-03	2.75E-03	8.54E-03	1.02E-02
Cm246	7.02E-03	6.51E-03	1.40E-02	1.49E-02	1.62E-02	1.58E-02	6.52E-04	5.75E-04	1.27E-03	

Value is maintained and either combined (results within uncertainty) or recommended (results out of uncertainty)

Value maintained, results are **out of** uncertainty

Value is dropped

No cross-check

Table 5.2 / 3 - Laboratory crosscheck analysis

Sample	BM1 - S	BM1 - P	BM5 - S	BM5 -P	DM1 - S	DM1 - P	DU1 - S	DU1 - P	GU3 - S	GU3 - I
Burnup (%FIMA)	4.62		5.66		6.13		5.78		5.35	
Content	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel
Isotope										
Ce144	8.02E-03	7.51E-04	1.68E-02	1.24E-02	1.69E-02	6.87E-04	1.87E-02	7.95E-04	6.32E-02	7.13E-02
Ce144 EOL	2.59E-01	2.38E-01	2.43E-01	2.23E-01	2.84E-01	2.17E-01	3.15E-01	3.05E-01	3.95E-01	3.87E-01
Nd142	1.80E-02	1.65E-02	2.97E-02	2.85E-02	5.11E-02	3.44E-02	4.95E-02	4.42E-02	3.73E-02	3.19E-02
Nd143	9.00E-01	8.80E-01	1.04E+00	9.60E-01	9.99E-01	8.76E-01	9.26E-01	8.65E-01	9.45E-01	8.76E-01
Nd144	1.18E+00	1.16E+00	1.55E+00	1.46E+00	1.84E+00	1.67E+00	2.24E+00	2.17E+00	1.89E+00	1.75E+00
Nd144 last date	1.19E+00	1.16E+00	1.55E+00	1.46E+00	1.85E+00	1.67E+00	2.25E+00	2.17E+00	1.89E+00	1.78E+00
Nd144 EOL	9.31E-01	9.27E-01	1.31E+00	1.25E+00	1.57E+00	1.46E+00	1.94E+00	1.87E+00	1.55E+00	1.44E+00
Nd145	7.01E-01	7.00E-01	8.41E-01	8.08E-01	9.21E-01	8.60E-01	9.63E-01	9.52E-01	8.72E-01	8.22E-01
Nd146	7.40E-01	7.46E-01	9.58E-01	9.41E-01	1.04E+00	9.88E-01	1.07E+00	1.08E+00	1.01E+00	9.58E-01
Nd148	4.43E-01	4.51E-01	5.49E-01	5.43E-01	6.00E-01	5.78E-01	5.45E-01	5.48E-01	5.17E-01	4.94E-01
Nd150	2.65E-01	2.71E-01	3.28E-01	3.20E-01	3.58E-01	3.41E-01	2.61E-01	2.48E-01	2.52E-01	2.54E-01
Pm147	6.41E-02		7.32E-02	6.67E-02			6.83E-02	2.71E-02	8.25E-02	1.41E-01
Pm147 EOL	1.85E-01		1.94E-01	1.67E-01			2.00E-01	1.70E-01	1.70E-01	2.33E-01

Value is maintained and either combined (results within uncertainty) or recommended (results out of uncertainty)

Value maintained, results are **out of** uncertainty

Value is dropped

No cross-check

Table 5.2 / 4 - Laboratory crosscheck analysis

Sample	BM1 - S	BM1 - P	BM5 - S	BM5 -P	DM1 - S	DM1 - P	DU1 - S	DU1 - P	GU3 - S	GU3 - I
Burnup (%FIMA)	4.62		5.66		6.13		5.78		5.35	
Content	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel
Isotope										
Sm147	2.37E-01	2.59E-01	2.34E-01	2.45E-01	2.89E-01	3.30E-01	2.73E-01	3.15E-01	1.73E-01	1.63E-01
Sm147 last date	2.66E-01	2.59E-01	2.34E-01	2.51E-01			3.10E-01	3.15E-01	1.73E-01	1.84E-01
Sm147 EOL	1.16E-01		1.21E-01	1.51E-01			1.54E-01	1.74E-01	9.42E-02	7.10E-02
Sm148	1.89E-01	1.93E-01	2.71E-01	2.90E-01	2.57E-01	2.60E-01	2.33E-01	2.37E-01	2.24E-01	2.31E-01
Sm149	5.03E-03	5.02E-03	4.08E-03	5.15E-03	4.64E-03	3.09E-03	2.65E-03	2.15E-03	2.96E-03	4.07E-03
Sm150	3.62E-01	3.69E-01	4.33E-01	4.71E-01	4.76E-01	4.88E-01	3.90E-01	4.01E-01	3.93E-01	3.94E-01
Sm151	2.39E-02	2.37E-02	2.19E-02	2.44E-02	1.50E-02	1.52E-02	9.50E-03	9.48E-03	1.27E-02	1.29E-02
Sm151 EOL	2.47E-02	2.49E-02	2.25E-02	2.50E-02	1.55E-02	1.60E-02	9.79E-03	9.97E-03	1.30E-02	1.31E-02
Sm152	1.64E-01	1.60E-01	1.58E-01	1.76E-01	2.06E-01	2.06E-01	1.42E-01	1.47E-01	1.18E-01	1.15E-01
Sm154	7.95E-02	8.06E-02	8.87E-02	1.06E-01	1.01E-01	1.05E-01	5.08E-02	5.20E-02	5.06E-02	4.69E-02
Eu151	8.50E-04	1.59E-03	7.76E-04	7.55E-04	8.57E-04	1.00E-03	6.04E-04	5.46E-04	3.70E-04	
Eu151 last date	1.27E-03	1.59E-03	7.94E-04	7.55E-04	1.17E-03	1.00E-03	8.00E-04	5.46E-04	3.70E-04	
Eu151 EOL	1.00E-04	4.04E-04	2.13E-04	1.62E-04	4.51E-04	2.36E-04	3.47E-04	5.23E-05	1.37E-04	
Eu153	1.96E-01	1.94E-01	2.33E-01	2.32E-01	2.48E-01	2.61E-01	1.55E-01	1.50E-01	1.62E-01	1.65E-01
Eu154	3.69E-02	3.68E-02	5.06E-02	5.29E-02	3.80E-02	3.63E-02	1.96E-02	1.71E-02	3.06E-02	3.27E-02
Eu154 EOL	5.13E-02	6.14E-02	6.45E-02	6.81E-02	5.22E-02	6.09E-02	2.69E-02	2.91E-02	3.61E-02	3.81E-02
Eu155	9.44E-03	7.81E-03	1.35E-02	1.22E-02	1.35E-02	9.71E-03	7.67E-03	5.27E-03	9.97E-03	1.09E-02
Eu155 EOL	1.69E-02	1.93E-02	2.08E-02	1.90E-02	2.36E-02	2.42E-02	1.34E-02	1.35E-02	1.34E-02	1.43E-02

Value is maintained and either combined (results within uncertainty) or recommended (results out of uncertainty)

Value maintained, results are **out of** uncertainty

No cross-check

No possible comparison

Table 5.2 / 5 - Laboratory crosscheck analysis

Sample	BM1 - S	BM1 - P	BM5 - S	BM5 -P	DM1 - S	DM1 - P	DU1 - S	DU1 - P	GU3 - S	GU3 - I
Burnup (%FIMA)	4.62		5.66		6.13		5.78		5.35	
Content	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel	mg/g fuel
Isotope										
Gd155	6.65E-03	9.37E-03	7.34E-03	8.17E-03	1.04E-02	1.22E-02	4.98E-03	7.15E-03	3.41E-03	3.67E-03
Gd155 last date	9.34E-03	9.37E-03	7.34E-03	8.70E-03	1.56E-02	1.22E-02	7.92E-03	7.15E-03	3.41E-03	3.89E-03
Sr90	3.56E-01	2.81E-01	3.14E-01	4.02E-01			9.05E-01	7.48E-01	6.30E-01	6.45E-01
Sr90 EOL	3.94E-01	3.28E-01	3.45E-01	4.35E-01			1.01E+00	8.79E-01	6.76E-01	6.83E-01
Mo95	5.96E-01	6.07E-01	9.00E-01	9.37E-01	8.98E-01		1.32E+00	1.07E+00	1.15E+00	1.03E+00
Tc99	6.20E-01	5.74E-01	9.69E-01	1.07E+00	9.59E-01	8.48E-01	1.26E+00	9.98E-01	1.14E+00	9.77E-01
Ru101	5.28E-01	4.85E-01	8.94E-01	1.28E+00	1.09E+00		1.26E+00	9.53E-01	1.21E+00	1.07E+00
Ru106 EOL	1.38E-01		1.89E-01	2.52E-01	2.53E-01	1.76E-01	1.56E-01	1.33E-01	2.56E-01	4.39E-01
Rh103	4.41E-01		6.16E-01	1.07E+00	4.66E-01		5.72E-01	5.39E-01	4.94E-01	4.71E-01
Ag109	8.95E-02	8.70E-02	1.65E-01	1.09E-01	1.13E-01		4.88E-02	4.19E-02	1.05E-01	
Sb125 EOL	6.73E-03		7.18E-03	8.82E-03	9.44E-03	7.62E-03	6.77E-03	6.02E-03	6.61E-03	
I129 (*)			2.24E-01	8.82E-02	2.78E-01		2.12E-01		2.39E-01	2.31E-01
Cs133	1.32E+00	1.42E+00	1.52E+00	1.58E+00	1.69E+00	1.73E+00	1.50E+00	1.52E+00	1.39E+00	1.47E+00
Cs134	3.74E-02	1.89E-02	7.40E-02	7.26E-02	5.71E-02	2.17E-02	4.94E-02	1.86E-02	1.09E-01	1.28E-01
Cs134 EOL	1.51E-01	1.64E-01	2.03E-01	2.11E-01	2.00E-01	1.88E-01	1.73E-01	1.74E-01	2.18E-01	2.42E-01
Cs135	8.45E-01	9.28E-01	1.04E+00	1.07E+00	8.15E-01	8.35E-01	5.08E-01	5.13E-01	4.05E-01	4.24E-01
Cs137	1.36E+00	1.42E+00	1.67E+00	1.73E+00	1.81E+00	1.73E+00	1.57E+00	1.50E+00	1.59E+00	1.58E+00
Cs137 EOL	1.50E+00	1.64E+00	1.79E+00	1.86E+00	1.97E+00	2.01E+00	1.71E+00	1.75E+00	1.66E+00	1.65E+00

Value is maintained and either combined (results within uncertainty) or recommended (results out of uncertainty)

Value maintained, results are **out of** uncertainty

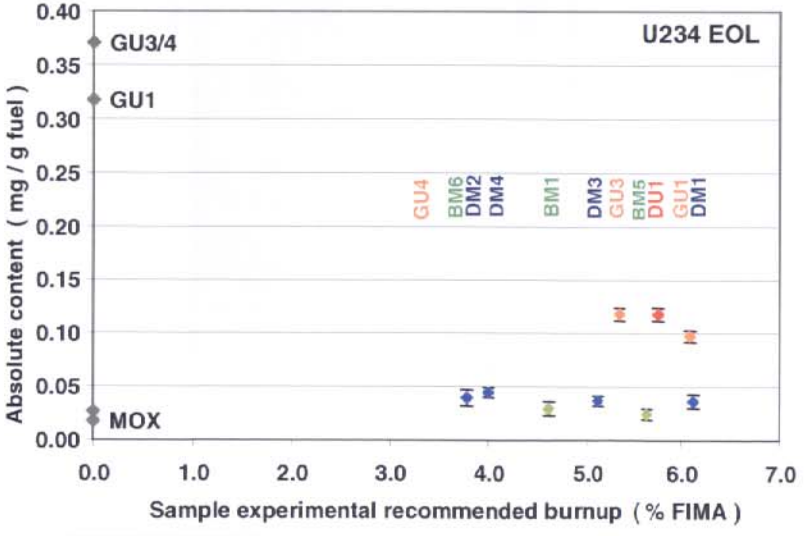
Value is dropped

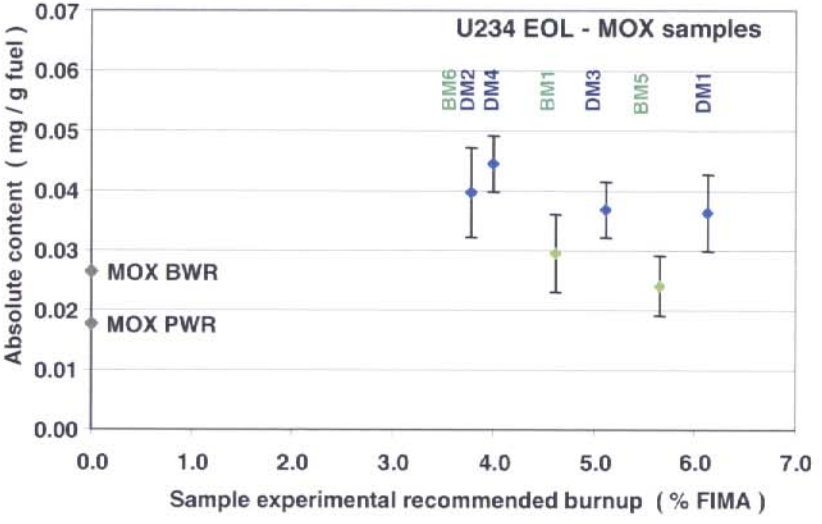
No cross-check

Table 5.3 / 1 - Results analysis and recommended values - U234

U234

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ / x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	At last date(*) content x	At last date(*) 95% uncertainty Δx	At last date(*) Δx / x	At last date(*) x_S-$x_{P/I}$ / x_S	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.42E-02	6.43E-03	10.01	-16.69	2.95E-02	6.52E-03	22.06	7.84E-02	6.45E-03	8.22	4.4	last date	7.81E-02	6.13E-03	7.86
BM1 - P	4.62	7.50E-02	2.00E-02	26.70					7.50E-02	2.00E-02	26.70					
BM5 - S	5.66	4.97E-02	4.97E-03	10.01	9.80	2.41E-02	5.03E-03	20.91	4.97E-02	4.97E-03	10.01	3.22	last date	4.94E-02	4.54E-03	9.19
BM5 -P	5.66	4.48E-02	1.11E-02	24.83					4.81E-02	1.11E-02	23.15					
DM1 - S	6.13	6.38E-02	6.39E-03	10.01	-39.53	3.63E-02	6.45E-03	17.76	8.85E-02	6.43E-03	7.27	-0.65	last date	8.86E-02	5.93E-03	6.69
DM1 - P	6.13	8.91E-02	1.53E-02	17.16					8.91E-02	1.53E-02	17.16					
DU1 - S	5.78	1.24E-01	6.25E-03	5.02	-5.40	1.18E-01	6.25E-03	5.32	1.31E-01	6.25E-03	4.78	-0.39	last date	1.31E-01	5.17E-03	3.95
DU1 - P	5.78	1.31E-01	9.17E-03	6.99					1.31E-01	9.17E-03	6.99					
GU3 - S	5.35	1.24E-01	6.21E-03	5.02	-0.02	1.18E-01	6.22E-03	5.28	1.24E-01	6.21E-03	5.02	-1.49	last date	1.26E-01	2.49E-05	0.02
GU3 - I	5.35	1.24E-01	2.27E-05	0.02					1.26E-01	2.49E-05	0.02					
DM2	3.78	7.42E-02	7.43E-03	10.01		3.97E-02	7.50E-03	18.90	7.42E-02	7.43E-03	10.01					
DM3	5.12	8.76E-02	4.40E-03	5.02		3.68E-02	4.66E-03	12.66	8.76E-02	4.40E-03	5.02					
DM4	4.00	8.92E-02	4.48E-03	5.02		4.45E-02	4.68E-03	10.51	8.92E-02	4.48E-03	5.02					
GU1	6.09	1.06E-01	5.32E-03	5.02		9.71E-02	5.33E-03	5.49	1.06E-01	5.32E-03	5.02					
BM6	3.69	4.95E-02	6.60E-03	13.33					4.95E-02	6.60E-03	13.33					
GU4	3.16	1.72E-01	3.13E-05	0.02					1.72E-01	3.13E-05	0.02					





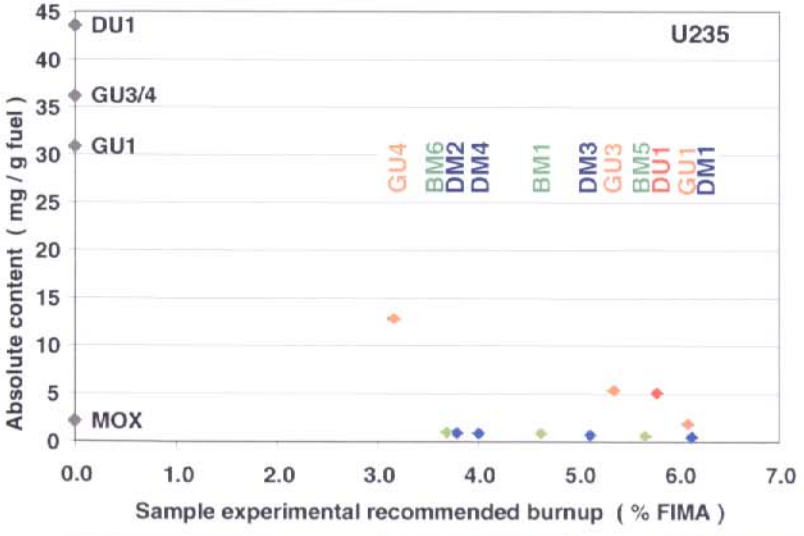
value is maintained

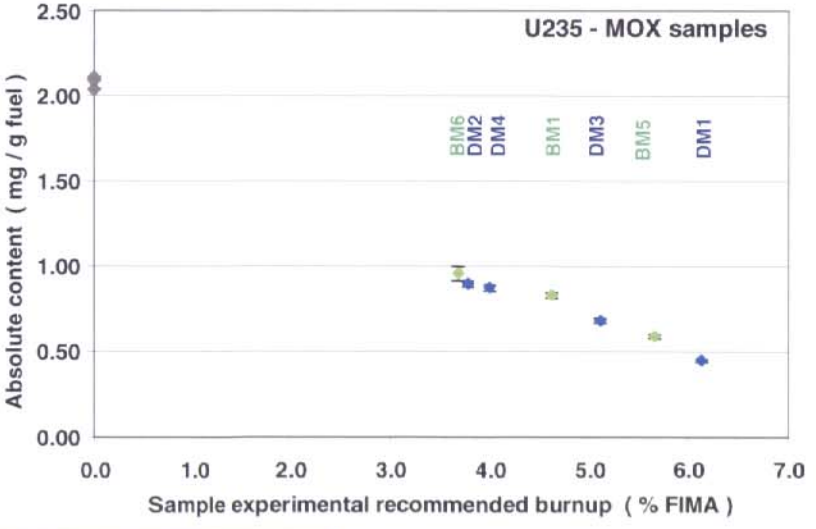
results are within uncertainties and combined

Table 5.3 / 2 - Results analysis and recommended values - U235

U235

Sample	Burnup	At analysis (*) content x	At analysis (*) 95% uncertainty Δx	At analysis (*) Δx / x	At analysis (*) $x_S-x_{P/I}/x_S$	at EOL (=at analysis) content x	at EOL (=at analysis) 95% uncertainty Δx	at EOL (=at analysis) Δx / x	At last date (=at analysis) content x	At last date (=at analysis) 95% uncertainty Δx	At last date (=at analysis) Δx / x	At last date (=at analysis) $x_S-x_{P/I}/x_S$	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	8.26E-01	1.69E-02	2.05	-4.71								≥ EOL	8.28E-01	1.65E-02	1.99
BM1 - P	4.62	8.65E-01	7.23E-02	8.35												
BM5 - S	5.66	5.86E-01	1.20E-02	2.05	-26.00								≥ EOL	5.86E-01	1.20E-02	2.05
BM5 -P	5.66	7.39E-01	1.31E-01	17.68												
DM1 - S	6.13	4.47E-01	9.16E-03	2.05	-9.15								≥ EOL	4.47E-01	9.16E-03	2.05
DM1 - P	6.13	4.88E-01	2.78E-02	5.70												
DU1 - S	5.78	5.08E+00	3.39E-02	0.67	-6.29								≥ EOL	5.08E+00	3.39E-02	0.67
DU1 - P	5.78	5.40E+00	1.89E-01	3.50												
GU3 - S	5.35	5.33E+00	3.54E-02	0.67	0.27								≥ EOL	5.33E+00	3.41E-02	0.64
GU3 - I	5.35	5.31E+00	1.27E-01	2.40												
DM2	3.78	8.96E-01	1.83E-02	2.05												
DM3	5.12	6.79E-01	1.39E-02	2.05												
DM4	4.00	8.72E-01	1.79E-02	2.05												
GU1	6.09	1.86E+00	3.80E-02	2.05												
BM6	3.69	9.56E-01	4.21E-02	4.41												
GU4	3.16	1.28E+01	1.14E-01	0.89												



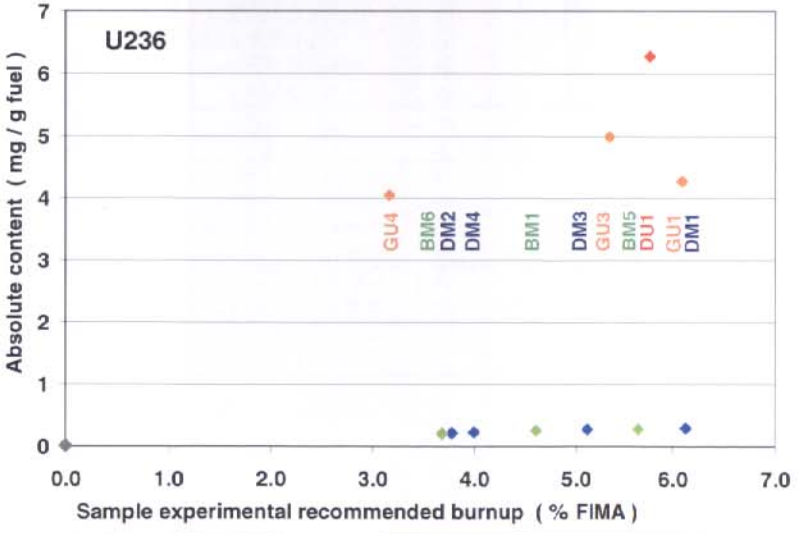


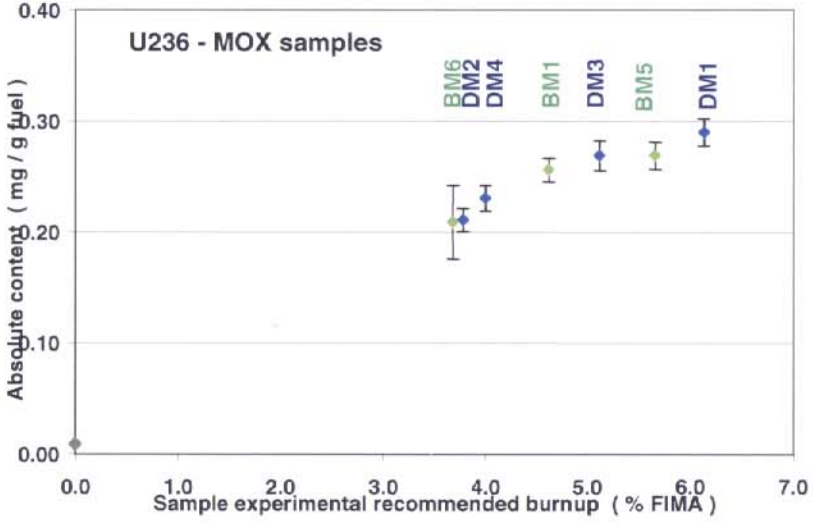
value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 3 - Results analysis and recommended values - U236

U236

Sample	Burnup	At analysis (*) content x	At analysis (*) 95% uncertainty Δx	At analysis (*) Δx / x	At analysis (*) $x_S-x_{P/I}/x_S$	at EOL (=at analysis) content x	at EOL (=at analysis) 95% uncertainty Δx	at EOL (=at analysis) Δx / x	At last date (=at analysis) content x	At last date (=at analysis) 95% uncertainty Δx	At last date (=at analysis) Δx / x	At last date (=at analysis) $x_S-x_{P/I}/x_S$	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	2.55E-01	1.28E-02	5.02	-1.02								≥ EOL	2.56E-01	1.06E-02	4.12
BM1 - P	4.62	2.58E-01	1.86E-02	7.22												
BM5 - S	5.66	2.69E-01	1.35E-02	5.02	0.29								≥ EOL	2.69E-01	1.22E-02	4.54
BM5 -P	5.66	2.68E-01	2.86E-02	10.67												
DM1 - S	6.13	2.94E-01	1.47E-02	5.02	4.00								≥ EOL	2.90E-01	1.22E-02	4.22
DM1 - P	6.13	2.82E-01	2.20E-02	7.79												
DU1 - S	5.78	6.27E+00	4.18E-02	0.67	-0.90								≥ EOL	6.27E+00	4.10E-02	0.65
DU1 - P	5.78	6.33E+00	2.10E-01	3.32												
GU3 - S	5.35	4.97E+00	3.31E-02	0.67	-0.39								≥ EOL	4.98E+00	3.05E-02	0.61
GU3 - I	5.35	4.99E+00	7.85E-02	1.57												
DM2	3.78	2.11E-01	1.06E-02	5.02												
DM3	5.12	2.69E-01	1.35E-02	5.02												
DM4	4.00	2.31E-01	1.16E-02	5.02												
GU1	6.09	4.26E+00	2.84E-02	0.67												
BM6	3.69	2.09E-01	3.32E-02	15.89												
GU4	3.16	4.05E+00	3.60E-02	0.89												





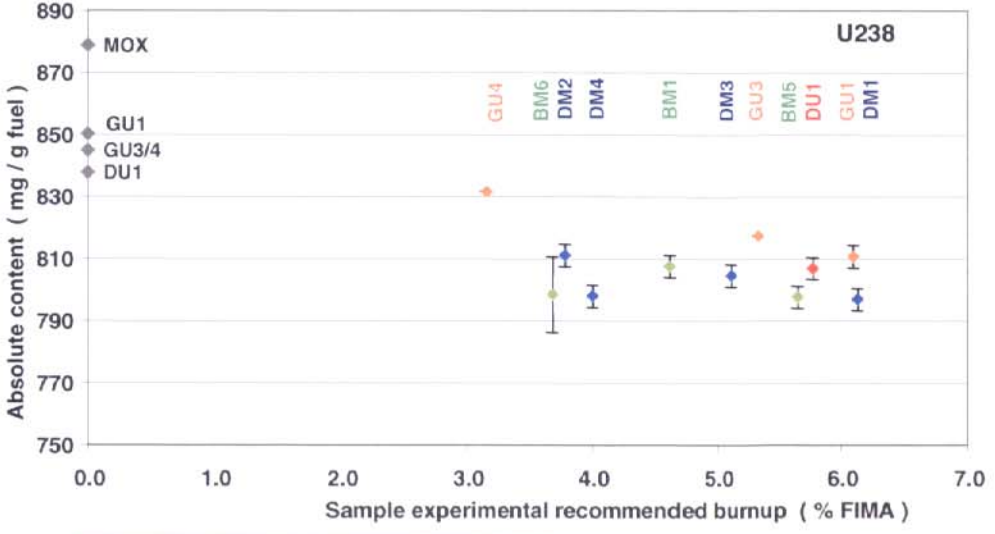
value is maintained

results are within uncertainties and combined

Table 5.3 / 4 - Results analysis and recommended values - U238

U238

Sample	Burnup	At analysis (*) content x	At analysis (*) 95% uncertainty Δx	At analysis (*) Δx / x	At analysis (*) $x_S-x_{P/I}/x_S$	at EOL (=at analysis) content x	at EOL (=at analysis) 95% uncertainty Δx	at EOL (=at analysis) Δx / x	At last date (=at analysis) content x	At last date (=at analysis) 95% uncertainty Δx	At last date (=at analysis) Δx / x	At last date (=at analysis) $x_S-x_{P/I}/x_S$	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	8.08E+02	3.66E+00	0.45	0.77								≥ EOL	8.07E+02	3.64E+00	0.45
BM1 - P	4.62	8.01E+02	4.17E+01	5.20												
BM5 - S	5.66	7.98E+02	3.59E+00	0.45	-0.05								≥ EOL	7.98E+02	3.57E+00	0.45
BM5 -P	5.66	7.98E+02	3.34E+01	4.18												
DM1 - S	6.13	7.97E+02	3.59E+00	0.45	1.32								≥ EOL	7.97E+02	3.56E+00	0.45
DM1 - P	6.13	7.86E+02	2.78E+01	3.54												
DU1 - S	5.78	8.06E+02	3.65E+00	0.45	-0.71								≥ EOL	8.07E+02	3.47E+00	0.43
DU1 - P	5.78	8.12E+02	1.11E+01	1.37												
GU3 - S	5.35	8.16E+02	3.67E+00	0.45	-0.20								≥ EOL	8.17E+02	1.57E-01	0.02
GU3 - I	5.35	8.17E+02	1.57E-01	0.02												
DM2	3.78	8.11E+02	3.65E+00	0.45												
DM3	5.12	8.05E+02	3.62E+00	0.45												
DM4	4.00	7.98E+02	3.59E+00	0.45												
GU1	6.09	8.11E+02	3.67E+00	0.45												
BM6	3.69	7.98E+02	1.22E+01	1.53												
GU4	3.16	8.32E+02	1.51E-01	0.02												



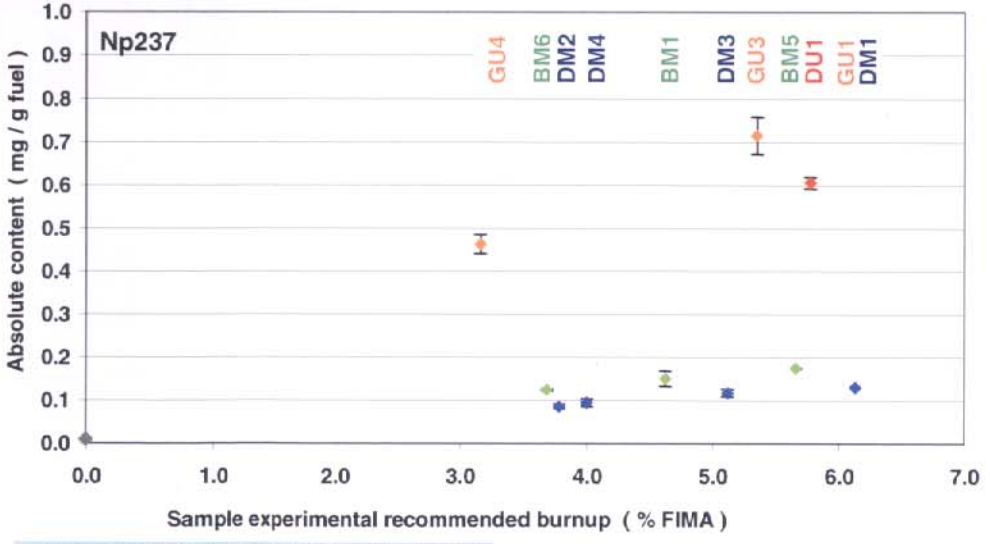
value is maintained

results are within uncertainties and combined

Table 5.3 / 5 - Results analysis and recommended values - Np237

Np237

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62															
BM1 - P	4.62	1.50E-01	1.81E-02	12.02												
BM5 - S	5.66	1.84E-01	2.01E-02	10.97	4.70								≥ EOL	1.75E-01	7.50E-04	0.43
BM5 -P	5.66	1.75E-01	7.51E-04	0.43												
DM1 - S	6.13	1.27E-01	1.02E-02	8.00	-2.72								≥ EOL	1.31E-01	1.38E-03	1.05
DM1 - P	6.13	1.31E-01	1.39E-03	1.06												
DU1 - S	5.78	6.24E-01	2.27E-02	3.65	4.51								≥ EOL	6.05E-01	1.34E-02	2.22
DU1 - P	5.78	5.95E-01	1.67E-02	2.80												
GU3 - S	5.35	7.09E-01	5.44E-02	7.68	-2.56								≥ EOL	7.15E-01	4.29E-02	6.00
GU3 - I	5.35	7.27E-01	6.98E-02	9.61												
DM2	3.78	8.63E-02	5.16E-03	5.98												
DM3	5.12	1.17E-01	8.96E-03	7.63												
DM4	4.00	9.47E-02	8.88E-03	9.37												
GU1	6.09															
BM6	3.69	1.25E-01	2.31E-03	1.85												
GU4	3.16	4.63E-01	2.22E-02	4.81												



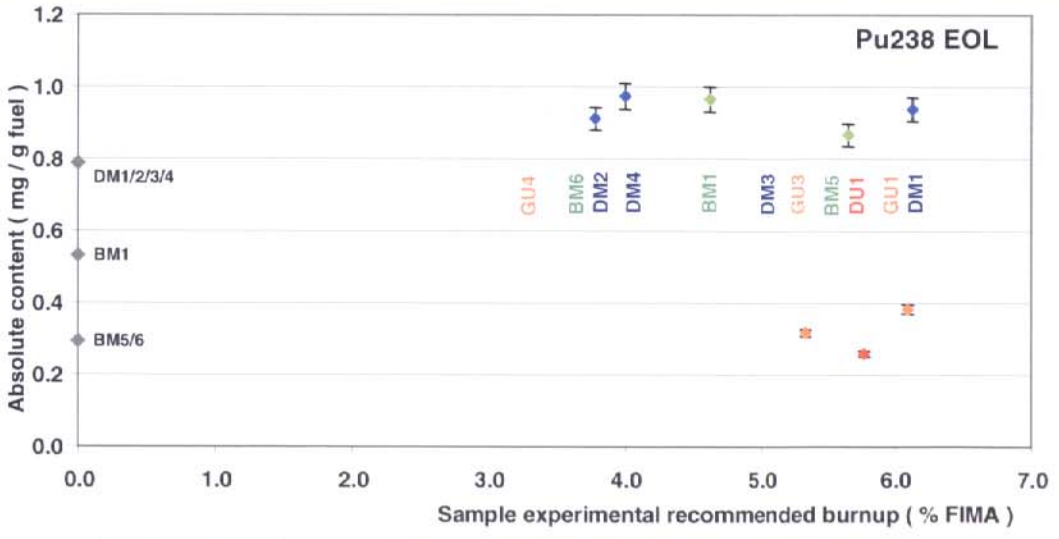
value is maintained

results are within uncertainties and combined

Table 5.3 / 6 - Results analysis and recommended values - Pu238

Pu238

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.11E+00	3.38E-02	3.05	10.32	9.65E-01	3.43E-02	3.56					analysis	1.11E+00	3.38E-02	3.05
BM1 - P	4.62	9.95E-01	3.89E-02	3.91												
BM5 - S	5.66	9.95E-01	3.03E-02	3.05	13.10	8.66E-01	3.08E-02	3.56					analysis	9.95E-01	3.03E-02	3.05
BM5 -P	5.66	8.65E-01	1.03E-01	11.89												
DM1 - S	6.13	1.06E+00	3.24E-02	3.05	2.74	9.37E-01	3.27E-02	3.49					analysis	1.06E+00	3.03E-02	2.86
DM1 - P	6.13	1.03E+00	8.62E-02	8.34												
DU1 - S	5.78	2.69E-01	8.16E-03	3.03	11.99	2.57E-01	8.25E-03	3.21					analysis	2.69E-01	8.16E-03	3.03
DU1 - P	5.78	2.37E-01	2.78E-03	1.17												
GU3 - S	5.35	3.32E-01	1.01E-02	3.05	1.25	3.15E-01	1.02E-02	3.23					analysis	3.28E-01	1.80E-03	0.55
GU3 - I	5.35	3.28E-01	1.83E-03	0.56												
DM2	3.78	1.01E+00	3.09E-02	3.05		9.11E-01	3.14E-02	3.45								
DM3	5.12	1.08E+00	3.30E-02	3.05		5.17E-01										
DM4	4.00	1.15E+00	3.50E-02	3.05		9.73E-01	3.67E-02	3.77								
GU1	6.09	4.00E-01	1.22E-02	3.05		3.81E-01	1.24E-02	3.24								
BM6	3.69	7.82E-01	5.84E-02	7.47												
GU4	3.16	9.80E-02	2.10E-03	2.15												

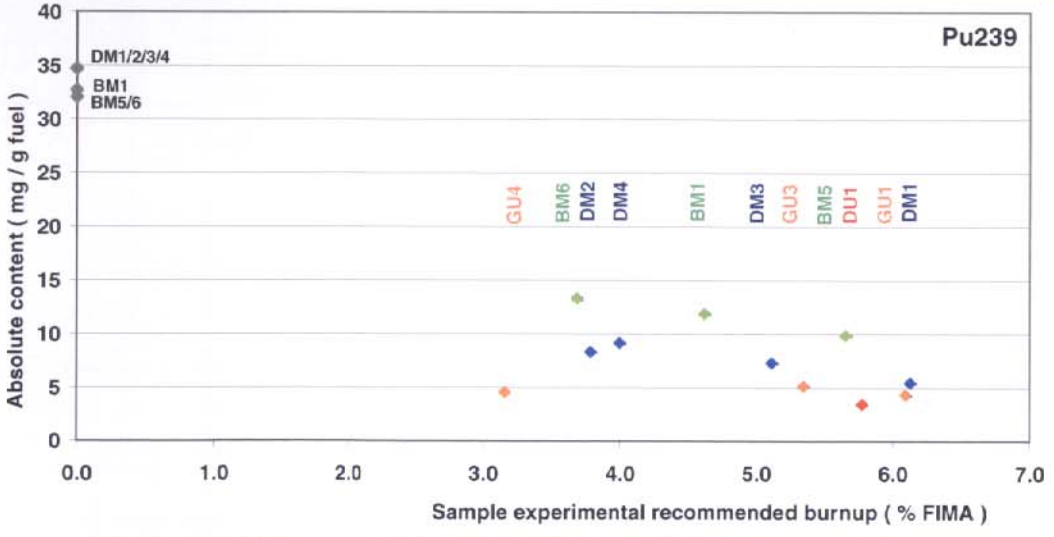


value is maintained value is dropped results are within uncertainties and combined

Table 5.3 / 7 - Results analysis and recommended values - Pu239

Pu239

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.19E+01	6.67E-02	0.56	7.11								≥ EOL	1.19E+01	6.67E-02	0.56
BM1 - P	4.62	1.10E+01	2.78E-01	2.52												
BM5 - S	5.66	9.80E+00	5.58E-02	0.57	5.57								≥ EOL	9.80E+00	5.58E-02	0.57
BM5 -P	5.66	9.25E+00	8.34E-02	0.90												
DM1 - S	6.13	5.43E+00	3.11E-02	0.57	-6.34								≥ EOL	5.43E+00	3.11E-02	0.57
DM1 - P	6.13	5.77E+00	5.56E-02	0.96												
DU1 - S	5.78	3.42E+00	1.70E-02	0.50	3.35								≥ EOL	3.42E+00	1.70E-02	0.50
DU1 - P	5.78	3.30E+00	2.78E-02	0.84												
GU3 - S	5.35	5.13E+00	2.92E-02	0.57	0.22								≥ EOL	5.12E+00	1.95E-02	0.38
GU3 - I	5.35	5.11E+00	2.62E-02	0.51												
DM2	3.78	8.27E+00	4.71E-02	0.57												
DM3	5.12	7.27E+00	4.15E-02	0.57												
DM4	4.00	9.13E+00	5.21E-02	0.57												
GU1	6.09	4.31E+00	2.48E-02	0.57												
BM6	3.69	1.33E+01	1.28E-01	0.96												
GU4	3.16	4.55E+00	2.12E-02	0.47												

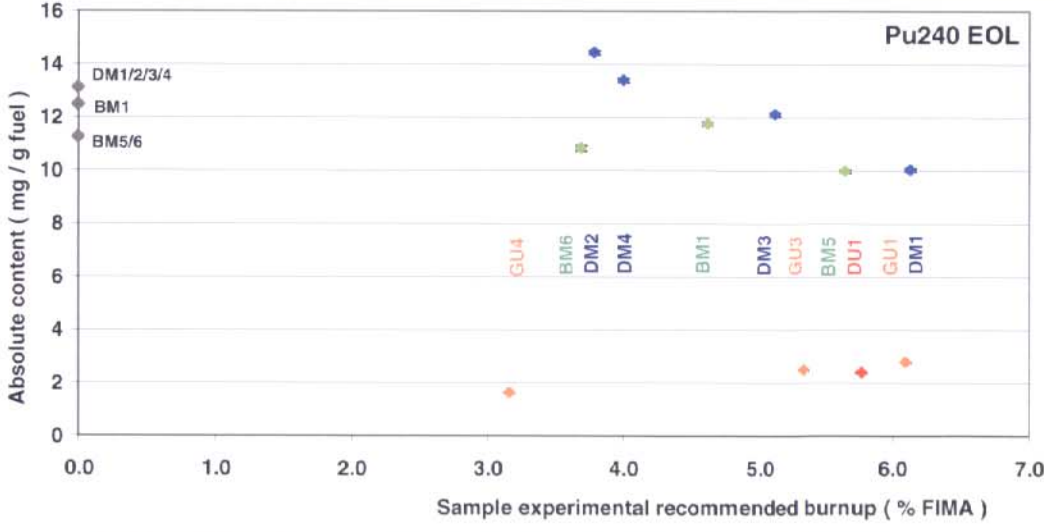


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 8 - Results analysis and recommended values - Pu240

Pu240

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.18E+01	6.65E-02	0.56	8.11	1.17E+01	6.61E-02	0.56	8.37				analysis	1.18E+01	6.65E-02	0.56
BM1 - P	4.62	1.09E+01	2.59E-01	2.38		1.08E+01	2.56E-01	2.38								
BM5 - S	5.66	1.01E+01	5.73E-02	0.57	4.65	9.97E+00	5.68E-02	0.57	4.65				analysis	1.01E+01	5.73E-02	0.57
BM5 -P	5.66	9.59E+00	9.45E-02	0.99		9.51E+00	9.37E-02	0.99								
DM1 - S	6.13	1.01E+01	5.80E-02	0.57	-8.19	1.00E+01	5.74E-02	0.57	-7.78				analysis	1.01E+01	5.80E-02	0.57
DM1 - P	6.13	1.10E+01	1.00E-01	0.91		1.08E+01	9.86E-02	0.91								
DU1 - S	5.78	2.39E+00	1.19E-02	0.50	5.41	2.39E+00	1.19E-02	0.50	5.61				analysis	2.39E+00	1.19E-02	0.50
DU1 - P	5.78	2.26E+00	2.78E-02	1.23		2.25E+00	2.77E-02	1.23								
GU3 - S	5.35	2.50E+00	1.42E-02	0.57	-0.07	2.49E+00	1.42E-02	0.57	-0.12				analysis	2.50E+00	7.44E-03	0.30
GU3 - I	5.35	2.50E+00	8.73E-03	0.35		2.49E+00	8.70E-03	0.35								
DM2	3.78	1.45E+01	8.23E-02	0.57		1.44E+01	8.21E-02	0.57								
DM3	5.12	1.22E+01	6.98E-02	0.57		1.21E+01	6.91E-02	0.57								
DM4	4.00	1.34E+01	7.67E-02	0.57		1.34E+01	7.64E-02	0.57								
GU1	6.09	2.80E+00	1.61E-02	0.57		2.77E+00	1.60E-02	0.57								
BM6	3.69	1.09E+01	1.06E-01	0.97		1.08E+01	1.05E-01	0.97								
GU4	3.16	1.62E+00	8.25E-03	0.51		1.62E+00	8.25E-03	0.51								

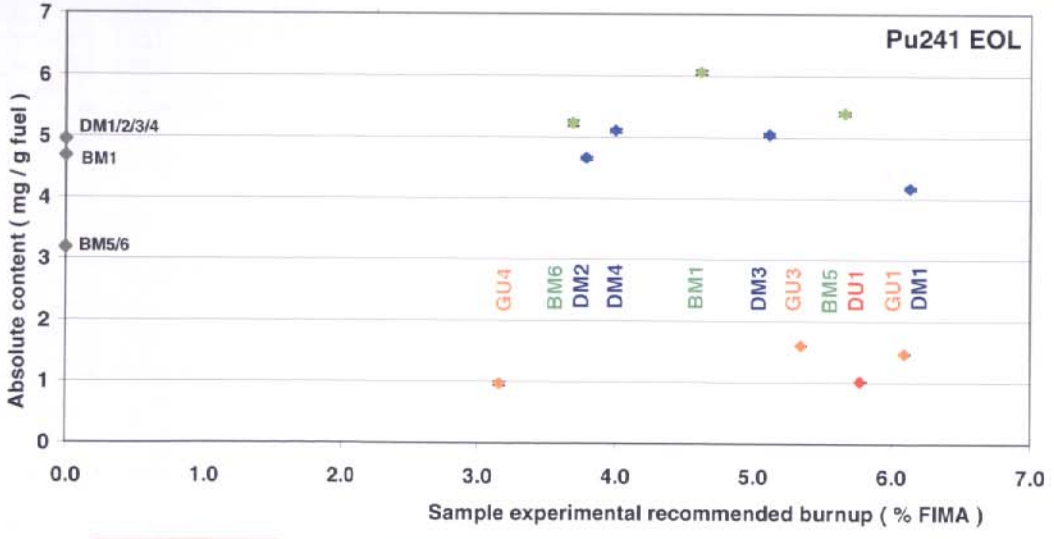


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 9 - Results analysis and recommended values - Pu241

Pu241

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	4.99E+00	2.81E-02	0.56	13.51	6.06E+00	3.41E-02	0.56	6.55				EOL	6.06E+00	3.41E-02	0.56
BM1 - P	4.62	4.32E+00	1.03E-01	2.38		5.66E+00	1.35E-01	2.38								
BM5 - S	5.66	4.60E+00	2.62E-02	0.57	2.90	5.39E+00	3.07E-02	0.57	4.93				EOL	5.39E+00	3.07E-02	0.57
BM5 -P	5.66	4.47E+00	4.73E-02	1.06		5.12E+00	5.42E-02	1.06								
DM1 - S	6.13	3.55E+00	2.04E-02	0.57	7.73	4.17E+00	2.39E-02	0.57	-5.47				EOL	4.17E+00	2.39E-02	0.57
DM1 - P	6.13	3.28E+00	3.89E-02	1.19		4.40E+00	5.22E-02	1.19								
DU1 - S	5.78	8.67E-01	4.32E-03	0.50	18.79	1.01E+00	5.06E-03	0.50	5.75				EOL	1.01E+00	5.06E-03	0.50
DU1 - P	5.78	7.04E-01	1.39E-02	1.97		9.56E-01	1.89E-02	1.97								
GU3 - S	5.35	1.43E+00	8.18E-03	0.57	-3.26	1.60E+00	9.15E-03	0.57	0.17				EOL	1.60E+00	8.92E-03	0.56
GU3 - I	5.35	1.48E+00	3.67E-02	2.48		1.60E+00	3.97E-02	2.48								
DM2	3.78	3.78E+00	2.15E-02	0.57		4.66E+00	2.65E-02	0.57								
DM3	5.12	3.79E+00	2.16E-02	0.57		5.04E+00	2.88E-02	0.57								
DM4	4.00	4.03E+00	2.30E-02	0.57		5.11E+00	2.91E-02	0.57								
GU1	6.09	1.27E+00	7.33E-03	0.57		1.46E+00	8.42E-03	0.57								
BM6	3.69	4.56E+00	4.17E-02	0.92		5.23E+00	4.78E-02	0.92								
GU4	3.16	8.70E-01	2.96E-02	3.40		9.67E-01	3.29E-02	3.40								

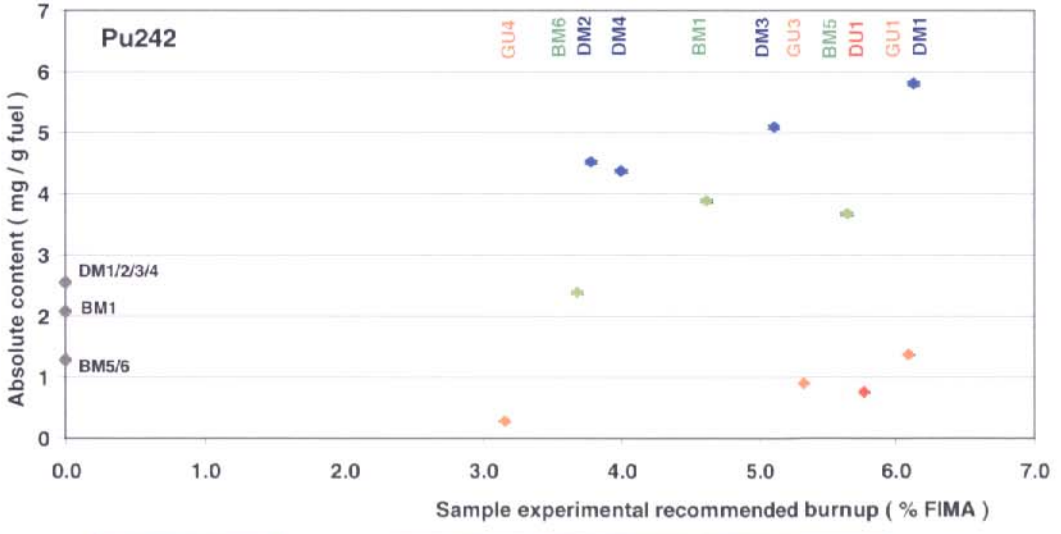


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 10 - Results analysis and recommended values - Pu242

Pu242

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.88E+00	2.18E-02	0.56	9.98								≥ EOL	3.88E+00	2.18E-02	0.56
BM1 - P	4.62	3.49E+00	8.62E-02	2.47												
BM5 - S	5.66	3.67E+00	2.09E-02	0.57	4.10								≥ EOL	3.67E+00	2.09E-02	0.57
BM5 -P	5.66	3.52E+00	4.45E-02	1.26												
DM1 - S	6.13	5.80E+00	3.32E-02	0.57	-7.53								≥ EOL	5.80E+00	3.32E-02	0.57
DM1 - P	6.13	6.24E+00	6.67E-02	1.07												
DU1 - S	5.78	7.53E-01	3.76E-03	0.50	6.51								≥ EOL	7.53E-01	3.76E-03	0.50
DU1 - P	5.78	7.04E-01	1.67E-02	2.37												
GU3 - S	5.35	8.93E-01	5.26E-03	0.59	-0.30								≥ EOL	8.95E-01	3.48E-04	0.04
GU3 - I	5.35	8.95E-01	3.49E-04	0.04												
DM2	3.78	4.52E+00	2.57E-02	0.57												
DM3	5.12	5.09E+00	2.90E-02	0.57												
DM4	4.00	4.37E+00	2.49E-02	0.57												
GU1	6.09	1.37E+00	7.85E-03	0.57												
BM6	3.69	2.38E+00	2.25E-02	0.94												
GU4	3.16	2.73E-01	1.51E-03	0.55												

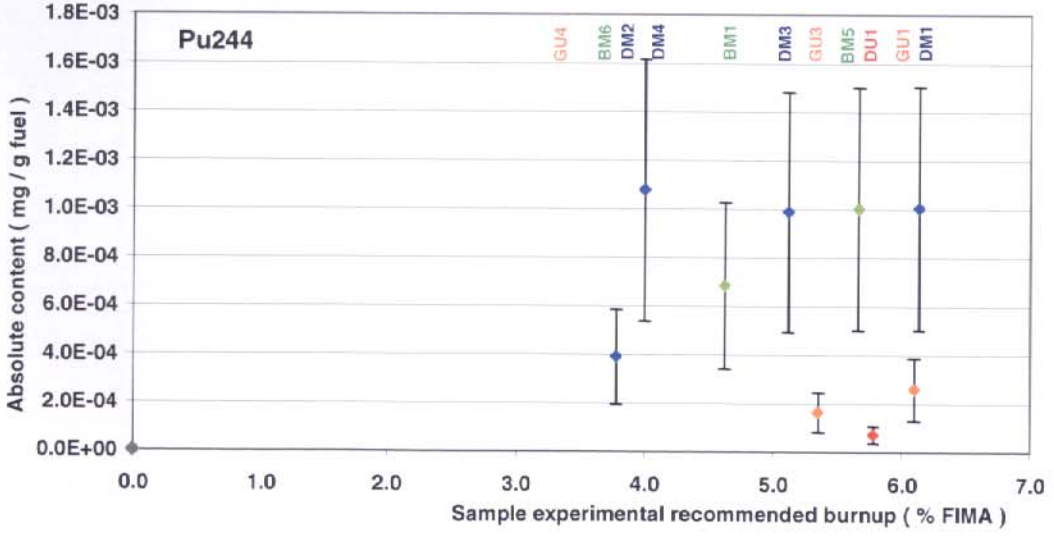


value is maintained value is dropped results are within uncertainties and combined

Table 5.3 / 11 - Results analysis and recommended values - Pu244

Pu244

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.85E-04	3.42E-04	50.00												
BM1 - P	4.62															
BM5 - S	5.66	1.00E-03	5.01E-04	50.00												
BM5 -P	5.66															
DM1 - S	6.13	1.00E-03	5.01E-04	50.00												
DM1 - P	6.13															
DU1 - S	5.78	7.05E-05	3.53E-05	50.00												
DU1 - P	5.78															
GU3 - S	5.35	1.63E-04	8.14E-05	50.00												
GU3 - I	5.35															
DM2	3.78	3.91E-04	1.95E-04	50.00												
DM3	5.12	9.88E-04	4.94E-04	50.00												
DM4	4.00	1.08E-03	5.39E-04	50.00												
GU1	6.09	2.58E-04	1.29E-04	50.00												
BM6	3.69															
GU4	3.16															

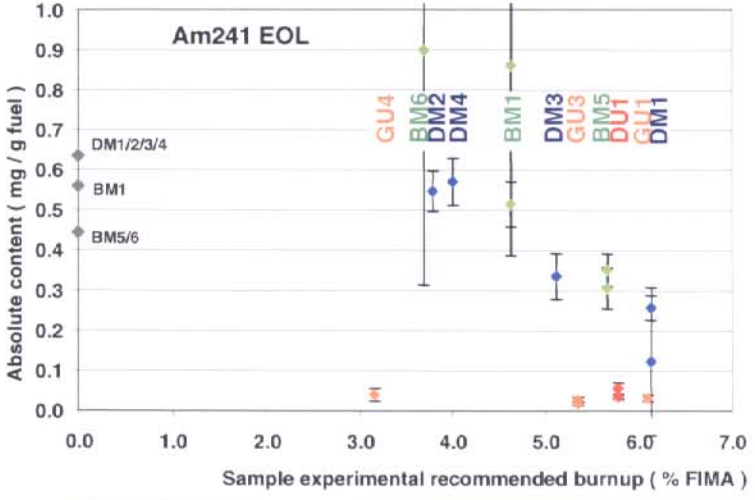


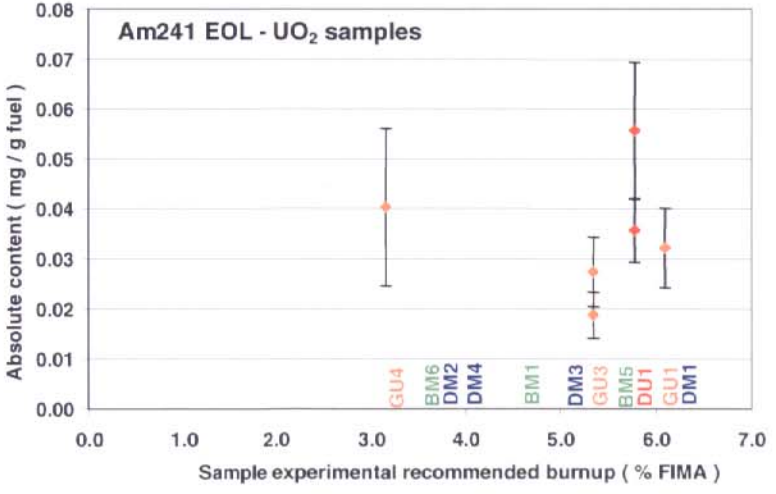
value is maintained

Table 5.3 / 12 - Results analysis and recommended values - Am241

Am241

Sample	Burnup	At analysis				at EOL				At last date (*)				(*)Recommended			
		content	95% uncertainty			content	95% uncertainty			content	95% uncertainty				content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.56E+00	5.55E-02	3.56	-53.88	5.14E-01	5.58E-02	10.87	-67.57	2.17E+00	5.56E-02	2.56	-10.47	last date	2.17E+00	5.52E-02	2.54
BM1 - P	4.62	2.40E+00	4.73E-01	19.72		8.61E-01	4.74E-01	55.02		2.40E+00	4.73E-01	19.72					
BM5 - S	5.66	1.13E+00	3.97E-02	3.51	4.62	3.50E-01	4.00E-02	11.40	12.72	1.13E+00	3.97E-02	3.51	3.41	last date	1.12E+00	3.11E-02	2.79
BM5 -P	5.66	1.08E+00	5.00E-02	4.64		3.06E-01	5.05E-02	16.52		1.09E+00	5.00E-02	4.58					
DM1 - S	6.13	8.65E-01	3.03E-02	3.50	-53.09	2.57E-01	3.05E-02	11.88	52.09	1.41E+00	3.04E-02	2.16	5.93	last date	1.41E+00	3.00E-02	2.14
DM1 - P	6.13	1.32E+00	1.83E-01	13.86		1.23E-01	1.84E-01	149.44		1.32E+00	1.83E-01	13.86					
DU1 - S	5.78	1.81E-01	6.31E-03	3.48	-78.53	3.56E-02	6.36E-03	17.85	-56.06	3.13E-01	6.34E-03	2.03	-3.43	last date	3.15E-01	5.68E-03	1.80
DU1 - P	5.78	3.24E-01	1.28E-02	3.95		5.56E-02	1.37E-02	24.69		3.24E-01	1.28E-02	3.95					
GU3 - S	5.35	1.97E-01	6.85E-03	3.48	15.08	2.74E-02	6.92E-03	25.30	31.65	1.97E-01	6.85E-03	3.48	-2.99	last date	2.01E-01	3.19E-03	1.58
GU3 - I	5.35	1.67E-01	3.49E-03	2.09		1.87E-02	4.61E-03	24.66		2.03E-01	3.60E-03	1.78					
DM2	3.78	1.41E+00	5.01E-02	3.55		5.47E-01	5.04E-02	9.21		1.41E+00	5.01E-02	3.55					
DM3	5.12	1.57E+00	5.60E-02	3.56		3.35E-01	5.64E-02	16.84		1.57E+00	5.60E-02	3.56					
DM4	4.00	1.64E+00	5.83E-02	3.56		5.70E-01	5.86E-02	10.27		1.64E+00	5.83E-02	3.56					
GU1	6.09	2.19E-01	7.81E-03	3.56		3.21E-02	7.88E-03	24.54		2.19E-01	7.81E-03	3.56					
BM6	3.69	1.68E+00	5.84E-01	34.65		8.99E-01	5.84E-01	64.96		1.68E+00	5.84E-01	34.65					
GU4	3.16	1.30E-01	1.54E-02	11.87		4.03E-02	1.58E-02	39.07		1.30E-01	1.54E-02	11.87					





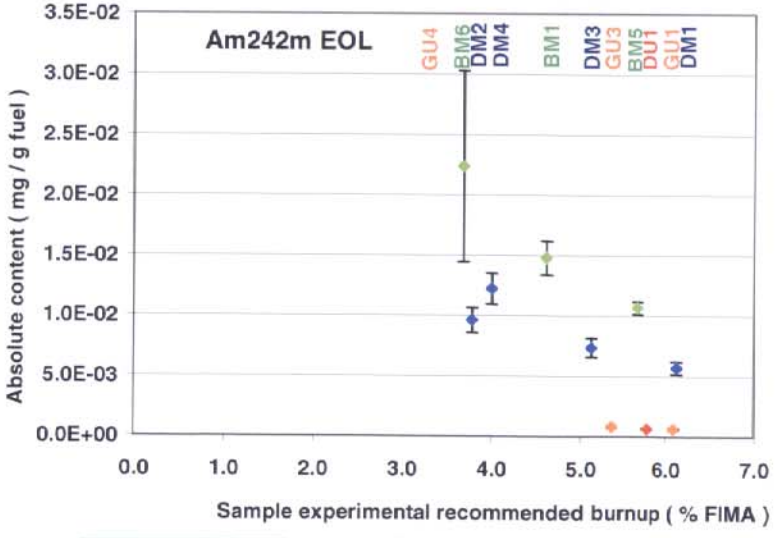
value is maintained

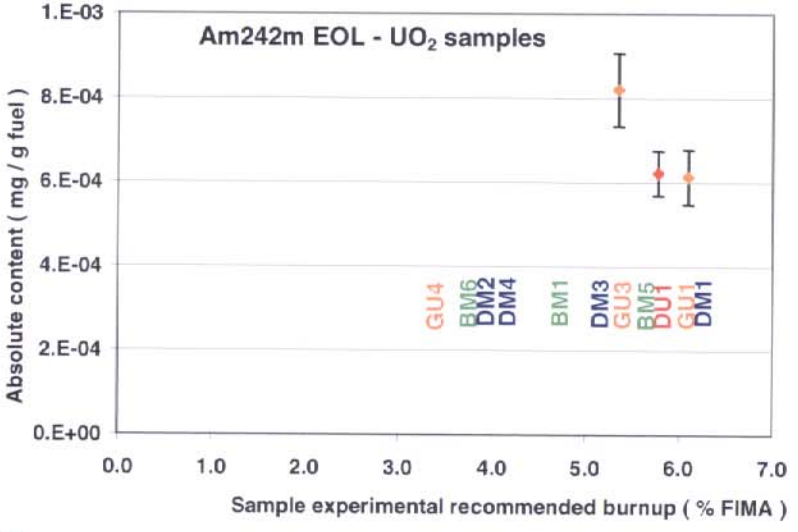
results are within uncertainties and combined

Table 5.3 / 13 - Results analysis and recommended values - Am242m

Am242m

Sample	Burnup	At analysis				at EOL (*)				At last date			(*)Recommended			
		content	95% uncertainty			content	95% uncertainty			content	95% uncertainty			content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.41E-02	1.50E-03	10.60	-13.93	1.44E-02	1.53E-03	10.60	-15.46				EOL	1.48E-02	1.40E-03	9.45
BM1 - P	4.62	1.61E-02	3.34E-03	20.71		1.66E-02	3.45E-03	20.71								
BM5 - S	5.66	1.06E-02	1.12E-03	10.59	1.81	1.08E-02	1.14E-03	10.59	1.84				EOL	1.06E-02	5.07E-04	4.76
BM5 -P	5.66	1.04E-02	5.56E-04	5.33		1.06E-02	5.65E-04	5.33								
DM1 - S	6.13	5.80E-03	6.14E-04	10.58	14.10	5.90E-03	6.25E-04	10.58	12.72				EOL	5.68E-03	5.26E-04	9.26
DM1 - P	6.13	4.98E-03	9.45E-04	18.97		5.15E-03	9.77E-04	18.97								
DU1 - S	5.78	6.01E-04	6.35E-05	10.58	-3.41	6.11E-04	6.46E-05	10.58	-5.18				EOL	6.21E-04	5.29E-05	8.51
DU1 - P	5.78	6.21E-04	8.90E-05	14.32		6.42E-04	9.20E-05	14.32								
GU3 - S	5.35	8.10E-04	8.57E-05	10.58		8.20E-04	8.67E-05	10.58								
GU3 - I	5.35															
DM2	3.78	9.41E-03	9.98E-04	10.60		9.62E-03	1.02E-03	10.60								
DM3	5.12	7.13E-03	7.56E-04	10.60		7.34E-03	7.78E-04	10.60								
DM4	4.00	1.19E-02	1.27E-03	10.60		1.22E-02	1.30E-03	10.60								
GU1	6.09	6.04E-04	6.41E-05	10.60		6.13E-04	6.50E-05	10.60								
BM6	3.69	2.20E-02	7.78E-03	35.40		2.24E-02	7.92E-03	35.40								
GU4	3.16															





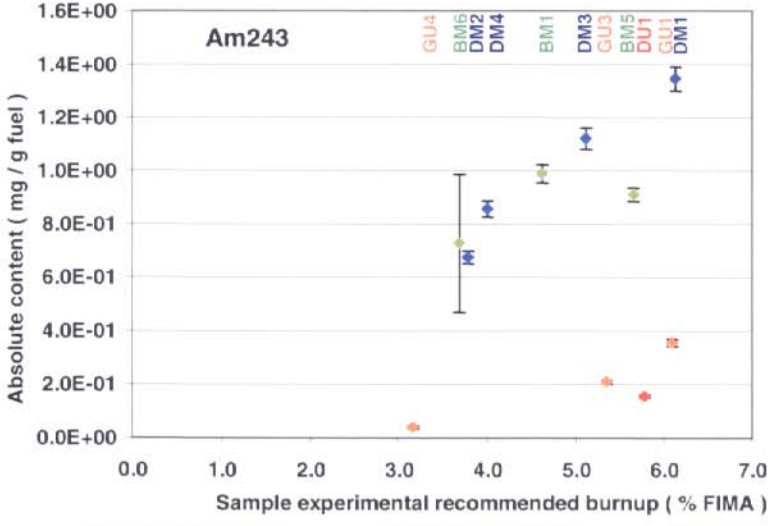
value is maintained

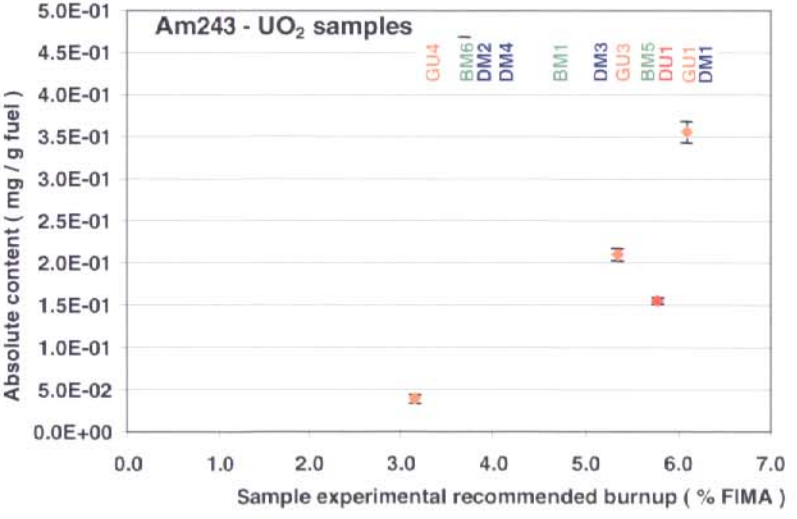
results are within uncertainties and combined

Table 5.3 / 14 - Results analysis and recommended values - Am243

Am243

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	9.84E-01	3.51E-02	3.56	-13.82								≥ EOL	9.87E-01	3.46E-02	3.51
BM1 - P	4.62	1.12E+00	2.25E-01	20.10												
BM5 - S	5.66	9.37E-01	3.29E-02	3.51	7.74								≥ EOL	9.09E-01	2.58E-02	2.84
BM5 -P	5.66	8.64E-01	4.17E-02	4.82												
DM1 - S	6.13	1.34E+00	4.70E-02	3.50	-5.06								≥ EOL	1.34E+00	4.56E-02	3.40
DM1 - P	6.13	1.41E+00	1.95E-01	13.82												
DU1 - S	5.78	1.52E-01	5.30E-03	3.48	-4.22								≥ EOL	1.55E-01	4.08E-03	2.64
DU1 - P	5.78	1.59E-01	6.39E-03	4.03												
GU3 - S	5.35	2.10E-01	7.30E-03	3.48	-12.80								≥ EOL	2.10E-01	7.30E-03	3.48
GU3 - I	5.35	2.36E-01	8.73E-03	3.69												
DM2	3.78	6.74E-01	2.39E-02	3.55												
DM3	5.12	1.12E+00	3.99E-02	3.56												
DM4	4.00	8.56E-01	3.05E-02	3.56												
GU1	6.09	3.55E-01	1.27E-02	3.56												
BM6	3.69	7.27E-01	2.59E-01	35.54												
GU4	3.16	3.86E-02	5.13E-03	13.29												



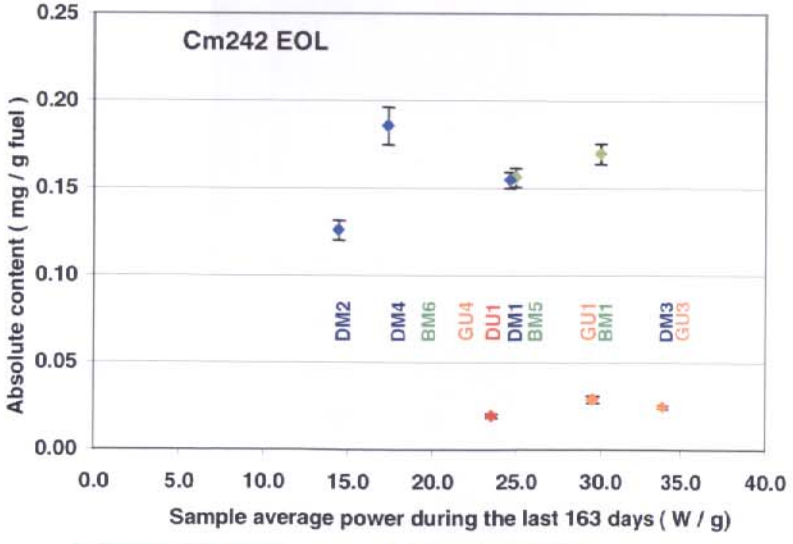


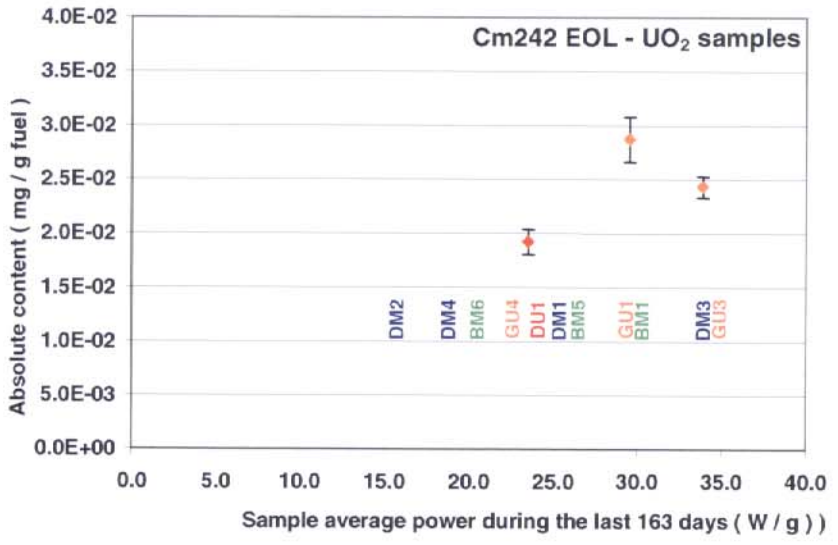
value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 15 - Results analysis and recommended values - Cm242

Cm242

Sample	Burnup	At analysis				at EOL				At last date			Recommended			
		content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	content x	95% uncertainty Δx	Δx / x	date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.01E-04	1.06E-05	3.50		1.70E-01	5.94E-03	3.50								
BM1 - P	4.62															
BM5 - S	5.66	1.49E-03	5.15E-05	3.46		1.56E-01	5.40E-03	3.46								
BM5 -P	5.66															
DM1 - S	6.13	7.51E-04	2.24E-05	2.99		1.55E-01	4.62E-03	2.99								
DM1 - P	6.13															
DU1 - S	5.78	9.29E-05	5.60E-06	6.02		1.92E-02	1.16E-03	6.02								
DU1 - P	5.78															
GU3 - S	5.35	9.82E-04	3.95E-05	4.03		2.43E-02	9.78E-04	4.03								
GU3 - I	5.35															
DM2	3.78	1.57E-04	6.92E-06	4.41		1.26E-01	5.55E-03	4.41								
DM3	5.12	7.54E-05				5.14E-01										
DM4	4.00	1.27E-04	7.42E-06	5.84		1.85E-01	1.08E-02	5.84								
GU1	6.09	2.72E-04	1.96E-05	7.22		2.87E-02	2.07E-03	7.22								
BM6	3.69															
GU4	3.16															



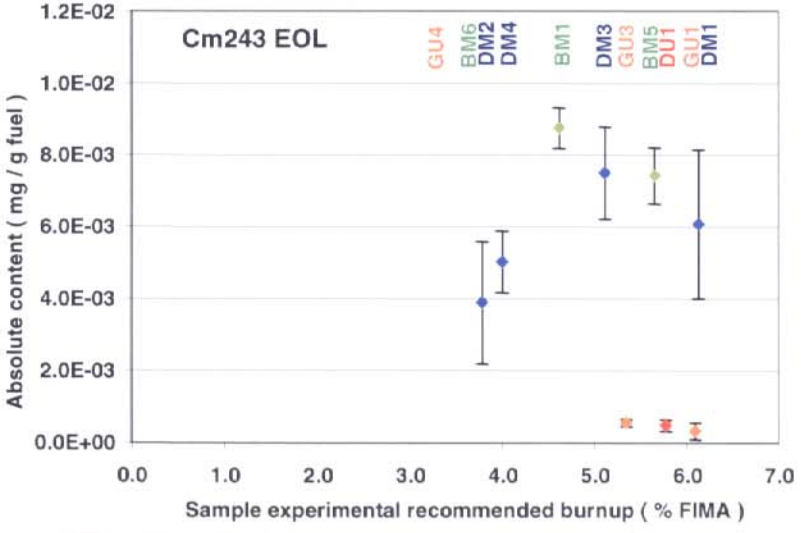


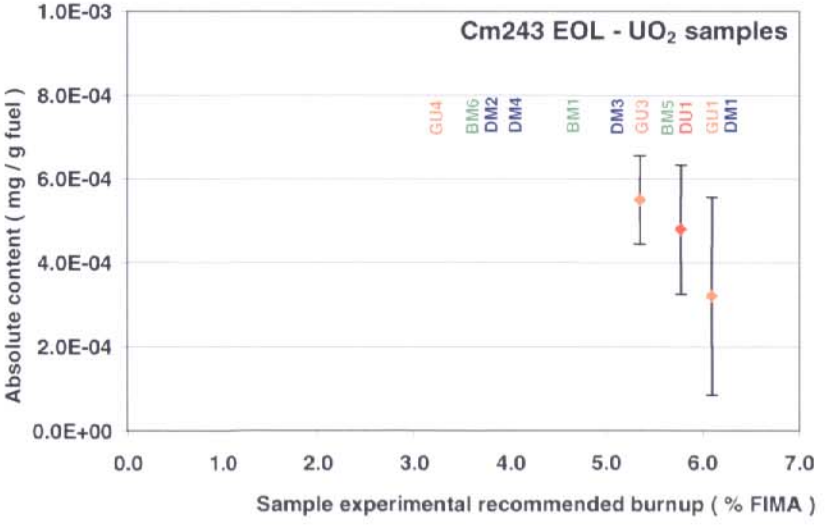
value is maintained value is dropped

Table 5.3 / 16 - Results analysis and recommended values - Cm243

Cm243

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	at EOL x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	Recommended date	Recommended content x	Recommended 95% uncertainty Δx	Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	7.91E-03	5.11E-04	6.46		8.74E-03	5.64E-04	6.46								
BM1 - P	4.62															
BM5 - S	5.66	6.90E-03	7.32E-04	10.60		7.42E-03	7.86E-04	10.60								
BM5 -P	5.66															
DM1 - S	6.13	5.59E-03	1.91E-03	34.11		6.07E-03	2.07E-03	34.11								
DM1 - P	6.13															
DU1 - S	5.78	4.41E-04	1.42E-04	32.21		4.79E-04	1.54E-04	32.21								
DU1 - P	5.78															
GU3 - S	5.35	5.23E-04	1.01E-04	19.21		5.50E-04	1.06E-04	19.21								
GU3 - I	5.35															
DM2	3.78	3.49E-03	1.53E-03	43.82		3.88E-03	1.70E-03	43.82								
DM3	5.12	6.51E-03	1.12E-03	17.18		7.49E-03	1.29E-03	17.18								
DM4	4.00	4.46E-03	7.64E-04	17.14		5.01E-03	8.59E-04	17.14								
GU1	6.09	2.98E-04	2.19E-04	73.49		3.21E-04	2.36E-04	73.49								
BM6	3.69															
GU4	3.16															



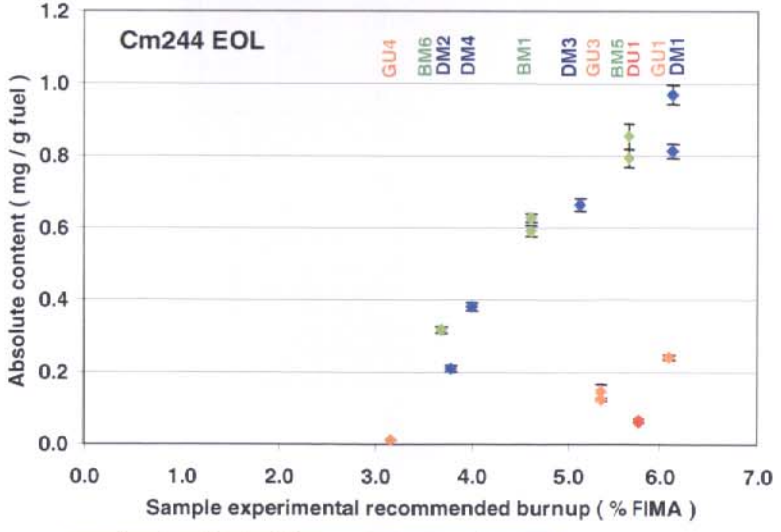


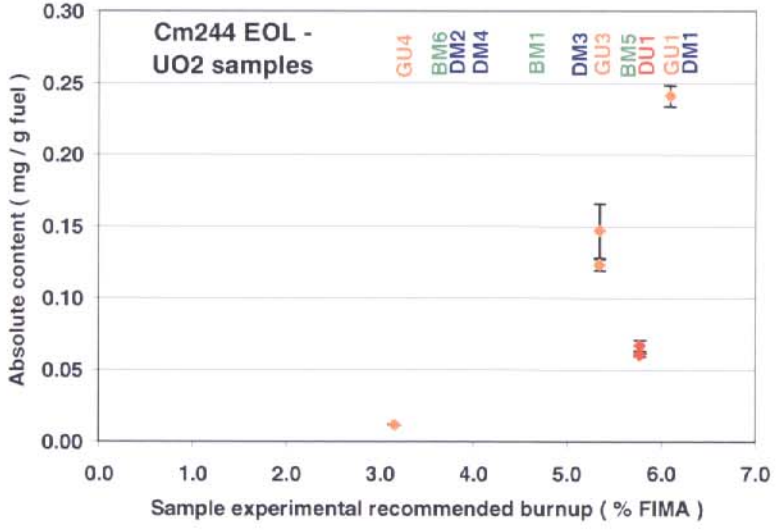
value is maintained

Table 5.3 / 17 - Results analysis and recommended values - Cm244

Cm244

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	at EOL x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	Recommended date	Recommended content x	Recommended 95% uncertainty Δx	Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	5.35E-01	9.64E-03	1.80	14.44	6.28E-01	1.13E-02	1.80	5.86							
BM1 - P	4.62	4.58E-01	1.20E-02	2.61		5.91E-01	1.54E-02	2.61								
BM5 - S	5.66	7.07E-01	2.21E-02	3.13	-5.95	7.93E-01	2.48E-02	3.13	-7.60							
BM5 -P	5.66	7.49E-01	3.06E-02	4.09		8.53E-01	3.48E-02	4.09								
DM1 - S	6.13	8.49E-01	2.35E-02	2.77	25.91	9.69E-01	2.69E-02	2.77	16.12							
DM1 - P	6.13	6.29E-01	1.53E-02	2.43		8.12E-01	1.97E-02	2.43								
DU1 - S	5.78	5.88E-02	3.31E-03	5.63	20.91	6.71E-02	3.78E-03	5.63	9.72							
DU1 - P	5.78	4.65E-02	8.34E-04	1.79		6.06E-02	1.09E-03	1.79								
GU3 - S	5.35	1.14E-01	3.68E-03	3.24	-19.39	1.23E-01	3.98E-03	3.24	-19.20							
GU3 - I	5.35	1.36E-01	1.75E-02	12.85		1.47E-01	1.89E-02	12.85								
DM2	3.78	1.77E-01	7.35E-03	4.15		2.10E-01	8.71E-03	4.15								
DM3	5.12	5.29E-01	1.40E-02	2.64		6.64E-01	1.75E-02	2.64								
DM4	4.00	3.16E-01	9.27E-03	2.93		3.82E-01	1.12E-02	2.93								
GU1	6.09	2.15E-01	6.48E-03	3.02		2.41E-01	7.26E-03	3.02								
BM6	3.69	2.78E-01	7.78E-03	2.80		3.17E-01	8.87E-03	2.80								
GU4	3.16	1.09E-02	3.42E-04	3.13		1.18E-02	3.70E-04	3.13								



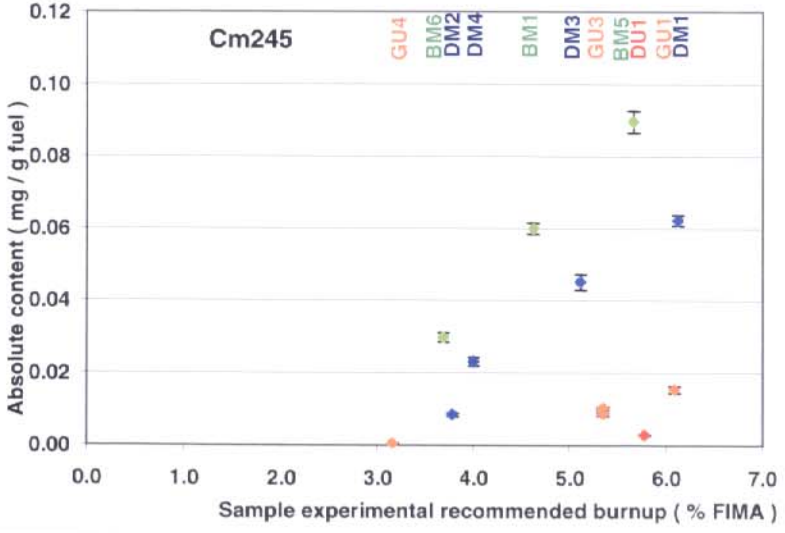


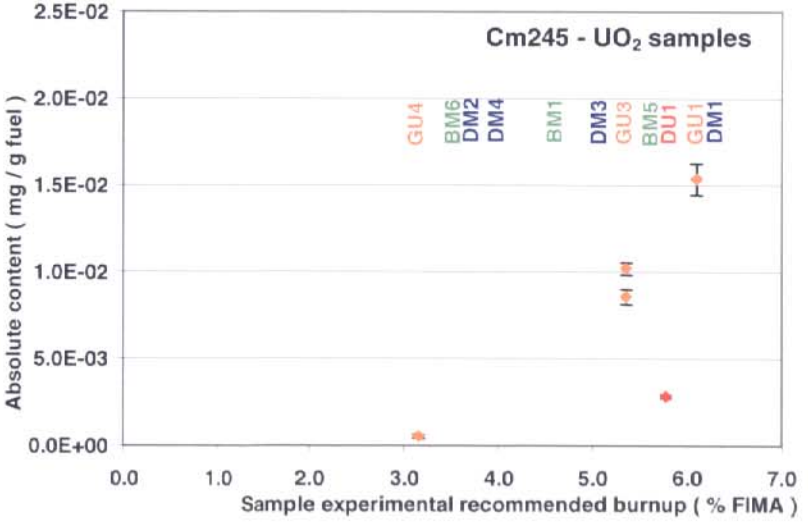
value is maintained but no recommendation

Table 5.3 / 18 - Results analysis and recommended values - Cm245

Cm245

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.44E-02	3.47E-03	5.39	8.59								≥ EOL	5.99E-02	1.54E-03	2.58
BM1 - P	4.62	5.88E-02	1.72E-03	2.93												
BM5 - S	5.66	8.76E-02	4.50E-03	5.13	-4.26								≥ EOL	8.96E-02	3.06E-03	3.41
BM5 -P	5.66	9.13E-02	4.17E-03	4.57												
DM1 - S	6.13	6.49E-02	3.18E-03	4.90	5.10								≥ EOL	6.22E-02	1.44E-03	2.31
DM1 - P	6.13	6.16E-02	1.61E-03	2.62												
DU1 - S	5.78	2.95E-03	2.04E-04	6.92	6.69								≥ EOL	2.81E-03	1.05E-04	3.74
DU1 - P	5.78	2.75E-03	1.22E-04	4.44												
GU3 - S	5.35	8.54E-03	4.42E-04	5.17	-19.22											
GU3 - I	5.35	1.02E-02	3.49E-04	3.43												
DM2	3.78	8.39E-03	4.85E-04	5.78												
DM3	5.12	4.51E-02	2.17E-03	4.83												
DM4	4.00	2.30E-02	1.15E-03	4.99												
GU1	6.09	1.54E-02	9.05E-04	5.89												
BM6	3.69	2.97E-02	1.25E-03	4.21												
GU4	3.16	5.06E-04	1.03E-04	20.29												





value is maintained

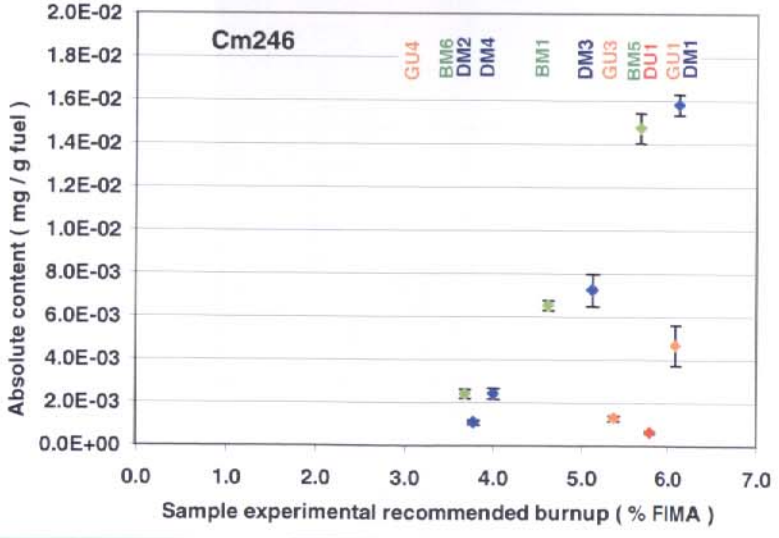
value is maintained but no recommendation

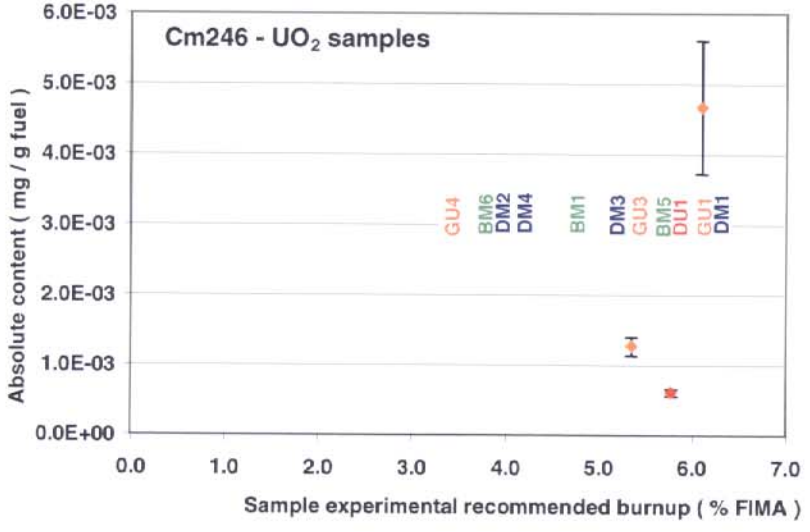
results are within uncertainties and combined

Table 5.3 / 19 - Results analysis and recommended values - Cm246

Cm246

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	7.02E-03	1.41E-03	20.10	7.23								≥ EOL	6.52E-03	2.33E-04	3.57
BM1 - P	4.62	6.51E-03	2.36E-04	3.63												
BM5 - S	5.66	1.40E-02	1.47E-03	10.50	-6.51								≥ EOL	1.47E-02	6.88E-04	4.68
BM5 -P	5.66	1.49E-02	7.78E-04	5.22												
DM1 - S	6.13	1.62E-02	1.68E-03	10.39	2.50								≥ EOL	1.58E-02	4.80E-04	3.03
DM1 - P	6.13	1.58E-02	5.00E-04	3.17												
DU1 - S	5.78	6.52E-04	7.49E-05	11.49	11.82								≥ EOL	6.09E-04	4.98E-05	8.18
DU1 - P	5.78	5.75E-04	6.67E-05	11.60												
GU3 - S	5.35	1.27E-03	1.33E-04	10.52												
GU3 - I	5.35															
DM2	3.78	1.07E-03	1.16E-04	10.84												
DM3	5.12	7.23E-03	7.49E-04	10.36												
DM4	4.00	2.42E-03	2.52E-04	10.43												
GU1	6.09	4.66E-03	9.44E-04	20.24												
BM6	3.69	2.41E-03	2.14E-04	8.89												
GU4	3.16															





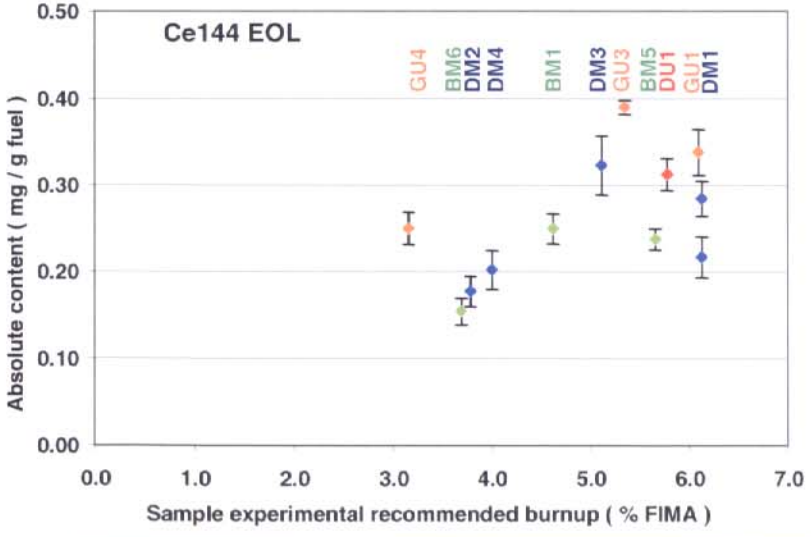
value is maintained

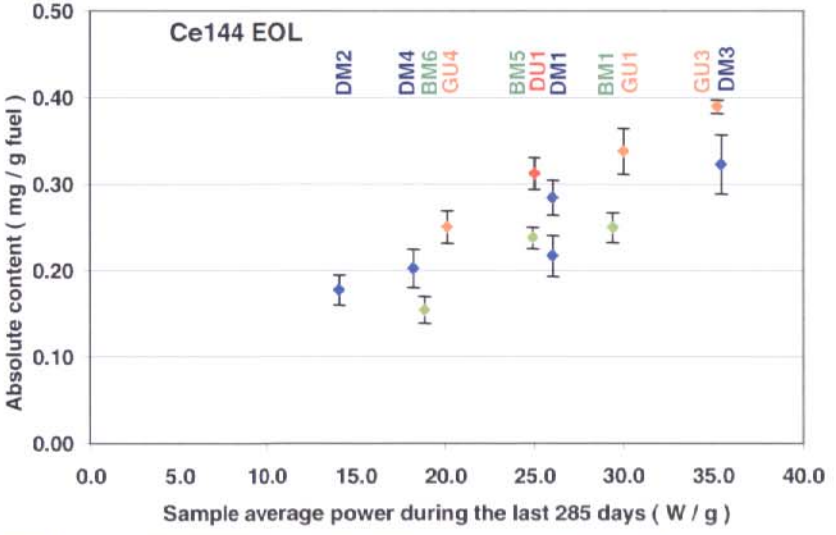
results are within uncertainties and combined

Table 5.3 / 20 - Results analysis and recommended values - Ce144

Ce144

Sample	Burnup	At analysis				at EOL (*)				At last date			(*)Recommended				
		content	95% uncertainty			content	95% uncertainty			content	95% uncertainty			content	95% uncertainty		
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	date	x	Δx	Δx / x	
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%	
BM1 - S	4.62	8.02E-03	7.23E-04	9.02	90.63	2.59E-01	2.34E-02	9.02	8.01				EOL	2.50E-01	1.72E-02	6.91	
BM1 - P	4.62	7.51E-04	8.06E-05	10.73		2.38E-01	2.56E-02	10.73									
BM5 - S	5.66	1.68E-02	1.00E-03	5.94	26.12	2.43E-01	1.45E-02	5.94	8.26				EOL	2.38E-01	1.22E-02	5.15	
BM5 -P	5.66	1.24E-02	1.28E-03	10.28		2.23E-01	2.29E-02	10.28									
DM1 - S	6.13	1.69E-02	1.20E-03	7.09	95.93	2.84E-01	2.01E-02	7.09	23.69								
DM1 - P	6.13	6.87E-04	7.51E-05	10.92		2.17E-01	2.37E-02	10.92									
DU1 - S	5.78	1.87E-02	1.31E-03	6.99	95.75	3.15E-01	2.21E-02	6.99	3.32				EOL	3.12E-01	1.83E-02	5.88	
DU1 - P	5.78	7.95E-04	8.62E-05	10.83		3.05E-01	3.30E-02	10.83									
GU3 - S	5.35	6.32E-02	2.22E-03	3.51	-12.85	3.95E-01	1.39E-02	3.51	2.24				EOL	3.89E-01	7.82E-03	2.01	
GU3 - I	5.35	7.13E-02	1.75E-03	2.45		3.87E-01	9.46E-03	2.45									
DM2	3.78	4.35E-03	4.26E-04	9.78		1.77E-01	1.73E-02	9.78									
DM3	5.12	1.79E-03	1.90E-04	10.58		3.22E-01	3.41E-02	10.58									
DM4	4.00	2.72E-03	3.00E-04	11.06		2.02E-01	2.24E-02	11.06									
GU1	6.09	2.97E-02	2.33E-03	7.84		3.38E-01	2.65E-02	7.84									
BM6	3.69	8.63E-03	8.62E-04	9.99		1.54E-01	1.54E-02	9.99									
GU4	3.16	3.20E-02	2.40E-03	7.49		2.50E-01	1.87E-02	7.49									



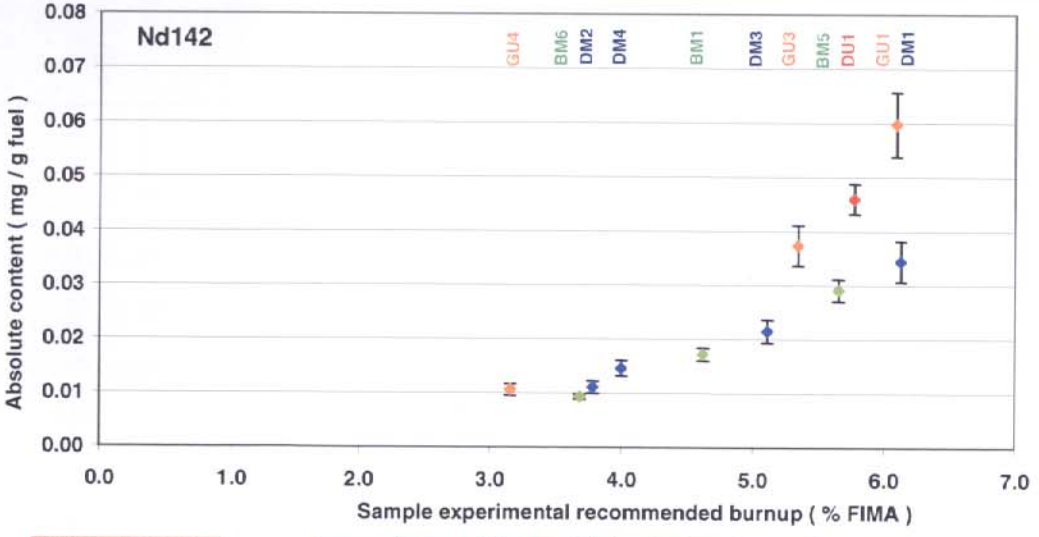


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 21 - Results analysis and recommended values - Nd142

Nd142

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.80E-02	1.80E-03	10.01	8.16								≥ EOL	1.72E-02	1.20E-03	6.99
BM1 - P	4.62	1.65E-02	1.61E-03	9.74												
BM5 - S	5.66	2.97E-02	2.98E-03	10.01	4.17								≥ EOL	2.91E-02	2.04E-03	7.03
BM5 -P	5.66	2.85E-02	2.81E-03	9.86												
DM1 - S	6.13	5.11E-02	5.12E-03	10.01	32.72								≥ EOL	3.44E-02	3.75E-03	10.92
DM1 - P	6.13	3.44E-02	3.75E-03	10.92												
DU1 - S	5.78	4.95E-02	4.96E-03	10.01	10.68								≥ EOL	4.59E-02	2.78E-03	6.07
DU1 - P	5.78	4.42E-02	3.36E-03	7.61												
GU3 - S	5.35	3.73E-02	3.74E-03	10.01	14.44								≥ EOL	3.73E-02	3.74E-03	10.01
GU3 - I	5.35	3.19E-02	5.24E-04	1.64												
DM2	3.78	1.11E-02	1.11E-03	10.01												
DM3	5.12	2.15E-02	2.15E-03	10.01												
DM4	4.00	1.46E-02	1.47E-03	10.01												
GU1	6.09	5.97E-02	5.97E-03	10.01												
BM6	3.69	9.34E-03	4.73E-04	5.06												
GU4	3.16	1.06E-02	1.08E-03	10.18												

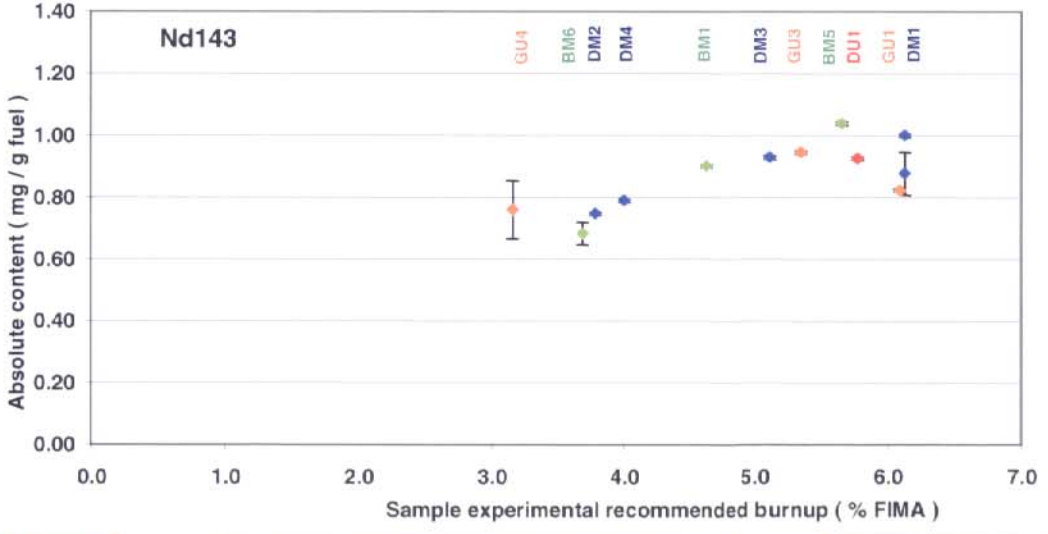


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 22 - Results analysis and recommended values - Nd143

Nd143

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	9.00E-01	5.04E-03	0.56	2.27								≥ EOL	9.00E-01	5.03E-03	0.56
BM1 - P	4.62	8.80E-01	8.62E-02	9.79												
BM5 - S	5.66	1.04E+00	5.81E-03	0.56	7.57								≥ EOL	1.04E+00	5.79E-03	0.56
BM5 -P	5.66	9.60E-01	6.39E-02	6.66												
DM1 - S	6.13	9.99E-01	5.64E-03	0.56	12.32											
DM1 - P	6.13	8.76E-01	6.95E-02	7.93												
DU1 - S	5.78	9.26E-01	5.25E-03	0.57	6.60								≥ EOL	9.26E-01	5.23E-03	0.57
DU1 - P	5.78	8.65E-01	6.67E-02	7.71												
GU3 - S	5.35	9.45E-01	5.31E-03	0.56	7.26								≥ EOL	9.45E-01	5.31E-03	0.56
GU3 - I	5.35	8.76E-01	3.49E-02	3.98												
DM2	3.78	7.47E-01	4.17E-03	0.56												
DM3	5.12	9.28E-01	5.19E-03	0.56												
DM4	4.00	7.89E-01	4.41E-03	0.56												
GU1	6.09	8.22E-01	4.68E-03	0.57												
BM6	3.69	6.83E-01	3.61E-02	5.29												
GU4	3.16	7.60E-01	9.36E-02	12.32												

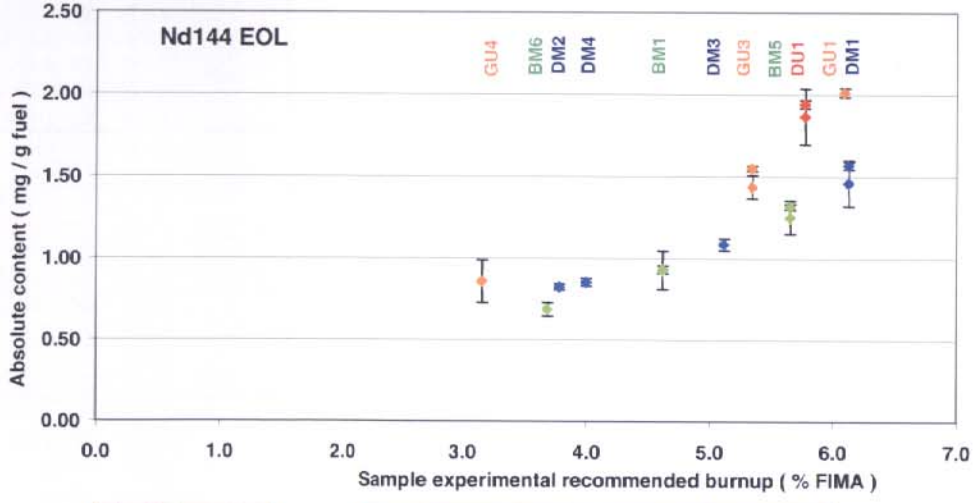


value is maintained | value is dropped | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 23 - Results analysis and recommended values - Nd144

Nd144

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	at EOL x_S-$x_{P/I}$ /x_S	At last date (*) content x	At last date (*) 95% uncertainty Δx	At last date (*) Δx / x	At last date (*) x_S-$x_{P/I}$ /x_S	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.18E+00	6.61E-03	0.56	1.54	9.31E-01	2.36E-02	2.53	0.38	1.19E+00	6.64E-03	0.56	2.03	last date	1.19E+00	6.63E-03	0.56
BM1 - P	4.62	1.16E+00	1.14E-01	9.79		9.27E-01	1.17E-01	12.59		1.16E+00	1.14E-01	9.79					
BM5 - S	5.66	1.55E+00	8.65E-03	0.56	5.69	1.31E+00	1.60E-02	1.22	4.88	1.55E+00	8.65E-03	0.56	5.31	last date	1.54E+00	8.62E-03	0.56
BM5 -P	5.66	1.46E+00	9.73E-02	6.68		1.25E+00	9.97E-02	7.97		1.46E+00	9.73E-02	6.65					
DM1 - S	6.13	1.84E+00	1.04E-02	0.56	8.90	1.57E+00	2.16E-02	1.38	6.94	1.85E+00	1.03E-02	0.56	9.34	last date	1.85E+00	1.03E-02	0.56
DM1 - P	6.13	1.67E+00	1.36E-01	8.13		1.46E+00	1.38E-01	9.48		1.67E+00	1.36E-01	8.13					
DU1 - S	5.78	2.24E+00	1.27E-02	0.57	3.26	1.94E+00	2.43E-02	1.25	3.93	2.25E+00	1.28E-02	0.57	3.69	last date	2.25E+00	1.28E-02	0.57
DU1 - P	5.78	2.17E+00	1.67E-01	7.69		1.87E+00	1.70E-01	9.12		2.17E+00	1.67E-01	7.69					
GU3 - S	5.35	1.89E+00	1.07E-02	0.56	7.89	1.55E+00	1.58E-02	1.02	7.20	1.89E+00	1.07E-02	0.56	6.05	last date	1.89E+00	1.07E-02	0.56
GU3 - I	5.35	1.75E+00	6.98E-02	4.00		1.44E+00	7.02E-02	4.89		1.78E+00	6.98E-02	3.92					
DM2	3.78	9.97E-01	5.57E-03	0.56		8.24E-01	1.78E-02	2.16		9.97E-01	5.57E-03	0.56					
DM3	5.12	1.41E+00	7.86E-03	0.56		1.08E+00	3.48E-02	3.21		1.41E+00	7.86E-03	0.56					
DM4	4.00	1.05E+00	5.88E-03	0.56		8.53E-01	2.28E-02	2.68		1.05E+00	5.88E-03	0.56					
GU1	6.09	2.32E+00	1.32E-02	0.57		2.01E+00	2.75E-02	1.37		2.32E+00	1.32E-02	0.57					
BM6	3.69	8.29E-01	3.89E-02	4.69		6.87E-01	4.15E-02	6.05		8.29E-01	3.89E-02	4.69					
GU4	3.16	1.08E+00	1.28E-01	11.89		8.58E-01	1.29E-01	15.03		1.08E+00	1.28E-01	11.89					

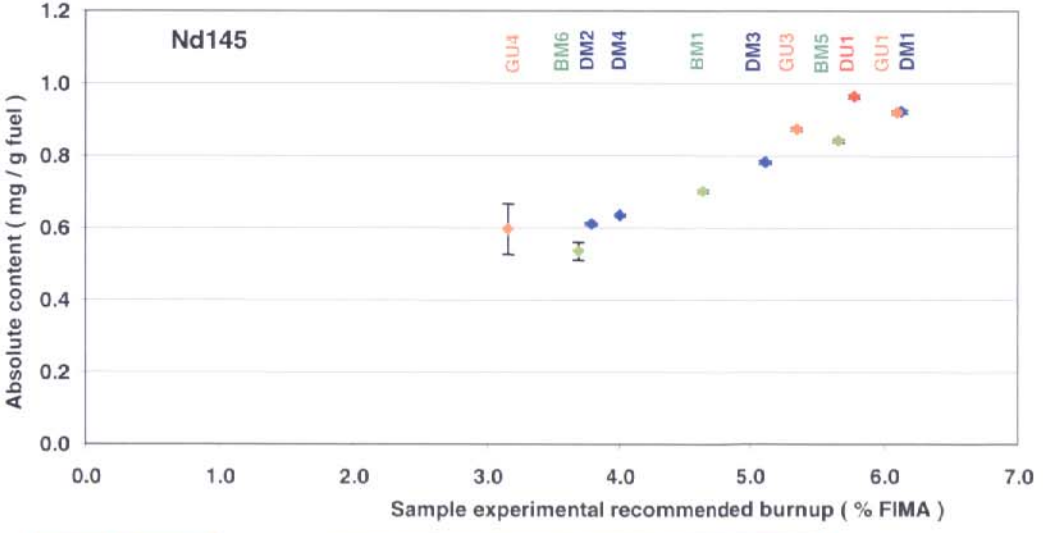


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 24 - Results analysis and recommended values - Nd145

Nd145

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	7.01E-01	3.92E-03	0.56	0.11								≥ EOL	7.01E-01	3.91E-03	0.56
BM1 - P	4.62	7.00E-01	6.95E-02	9.93												
BM5 - S	5.66	8.41E-01	4.71E-03	0.56	3.88								≥ EOL	8.40E-01	4.69E-03	0.56
BM5 -P	5.66	8.08E-01	5.56E-02	6.88												
DM1 - S	6.13	9.21E-01	5.20E-03	0.56	6.66								≥ EOL	9.21E-01	5.19E-03	0.56
DM1 - P	6.13	8.60E-01	6.95E-02	8.08												
DU1 - S	5.78	9.63E-01	5.45E-03	0.57	1.16								≥ EOL	9.63E-01	5.44E-03	0.56
DU1 - P	5.78	9.52E-01	7.23E-02	7.60												
GU3 - S	5.35	8.72E-01	4.90E-03	0.56	5.79								≥ EOL	8.72E-01	4.90E-03	0.56
GU3 - I	5.35	8.22E-01	3.49E-02	4.25												
DM2	3.78	6.11E-01	3.41E-03	0.56												
DM3	5.12	7.81E-01	4.37E-03	0.56												
DM4	4.00	6.35E-01	3.54E-03	0.56												
GU1	6.09	9.18E-01	5.23E-03	0.57												
BM6	3.69	5.35E-01	2.50E-02	4.67												
GU4	3.16	5.96E-01	7.02E-02	11.78												

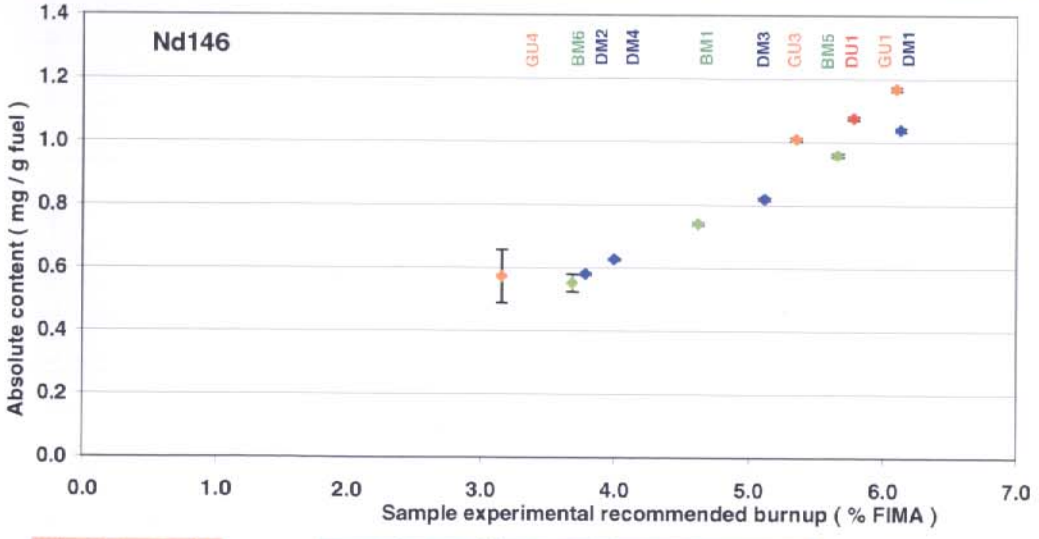


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 25 - Results analysis and recommended values - Nd146

Nd146

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	7.40E-01	4.14E-03	0.56	-0.78								≥ EOL	7.40E-01	4.13E-03	0.56
BM1 - P	4.62	7.46E-01	7.23E-02	9.69												
BM5 - S	5.66	9.58E-01	5.36E-03	0.56	1.74								≥ EOL	9.58E-01	5.34E-03	0.56
BM5 -P	5.66	9.41E-01	6.39E-02	6.79												
DM1 - S	6.13	1.04E+00	5.85E-03	0.56	4.78								≥ EOL	1.04E+00	5.84E-03	0.56
DM1 - P	6.13	9.88E-01	8.06E-02	8.16												
DU1 - S	5.78	1.07E+00	6.09E-03	0.57	-0.93								≥ EOL	1.07E+00	6.07E-03	0.57
DU1 - P	5.78	1.08E+00	8.34E-02	7.69												
GU3 - S	5.35	1.01E+00	5.67E-03	0.56	5.00								≥ EOL	1.01E+00	5.67E-03	0.56
GU3 - I	5.35	9.58E-01	3.49E-02	3.65												
DM2	3.78	5.81E-01	3.24E-03	0.56												
DM3	5.12	8.19E-01	4.58E-03	0.56												
DM4	4.00	6.27E-01	3.50E-03	0.56												
GU1	6.09	1.17E+00	6.64E-03	0.57												
BM6	3.69	5.52E-01	2.78E-02	5.04												
GU4	3.16	5.73E-01	8.44E-02	14.73												

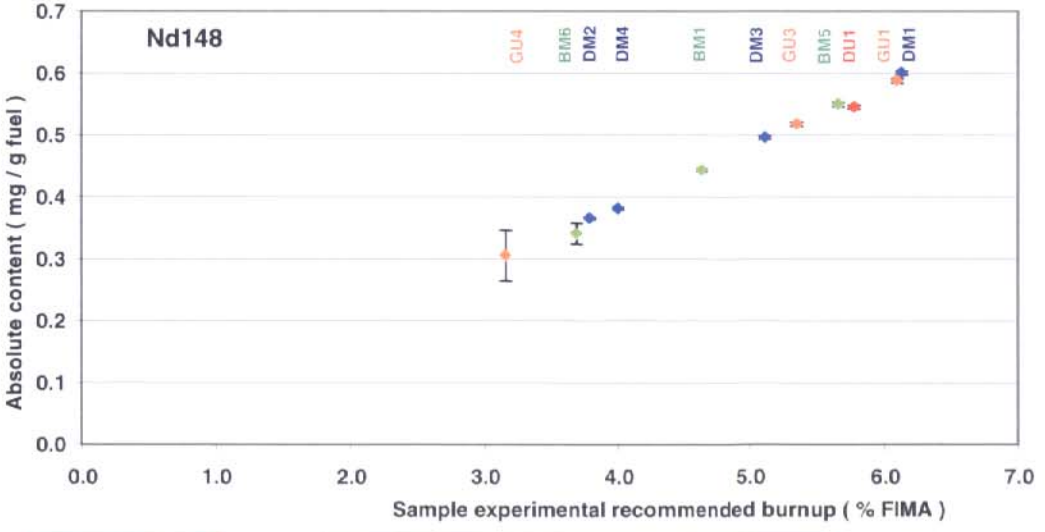


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 26 - Results analysis and recommended values - Nd148

Nd148

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	4.43E-01	2.48E-03	0.56	-1.79								≥ EOL	4.43E-01	2.48E-03	0.56
BM1 - P	4.62	4.51E-01	4.45E-02	9.86												
BM5 - S	5.66	5.49E-01	3.07E-03	0.56	1.01								≥ EOL	5.49E-01	3.06E-03	0.56
BM5 -P	5.66	5.43E-01	3.61E-02	6.65												
DM1 - S	6.13	6.00E-01	3.39E-03	0.56	3.72								≥ EOL	6.00E-01	3.38E-03	0.56
DM1 - P	6.13	5.78E-01	4.73E-02	8.18												
DU1 - S	5.78	5.45E-01	3.19E-03	0.59	-0.58								≥ EOL	5.45E-01	3.18E-03	0.58
DU1 - P	5.78	5.48E-01	4.45E-02	8.12												
GU3 - S	5.35	5.17E-01	3.01E-03	0.58	4.55								≥ EOL	5.17E-01	3.01E-03	0.58
GU3 - I	5.35	4.94E-01	1.22E-02	2.47												
DM2	3.78	3.66E-01	2.04E-03	0.56												
DM3	5.12	4.96E-01	2.77E-03	0.56												
DM4	4.00	3.82E-01	2.13E-03	0.56												
GU1	6.09	5.87E-01	3.46E-03	0.59												
BM6	3.69	3.41E-01	1.67E-02	4.89												
GU4	3.16	3.06E-01	4.10E-02	13.40												

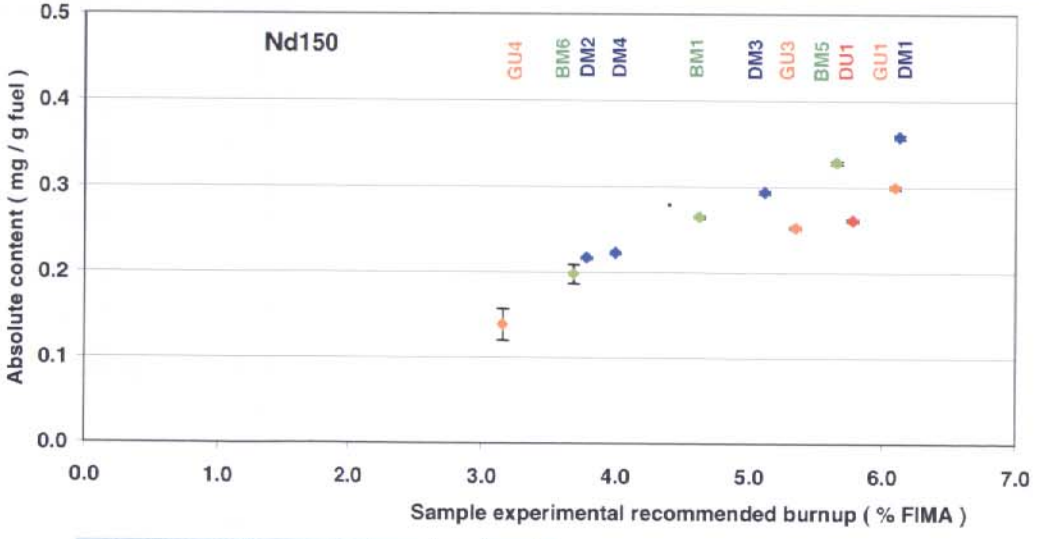


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 27 - Results analysis and recommended values - Nd150

Nd150

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	2.65E-01	1.53E-03	0.58	-2.41								≥ EOL	2.65E-01	1.53E-03	0.58
BM1 - P	4.62	2.71E-01	2.78E-02	10.26												
BM5 - S	5.66	3.28E-01	1.90E-03	0.58	2.54								≥ EOL	3.28E-01	1.89E-03	0.58
BM5 -P	5.66	3.20E-01	2.22E-02	6.96												
DM1 - S	6.13	3.58E-01	2.09E-03	0.58	4.80								≥ EOL	3.58E-01	2.08E-03	0.58
DM1 - P	6.13	3.41E-01	2.78E-02	8.16												
DU1 - S	5.78	2.61E-01	1.53E-03	0.59	4.85								≥ EOL	2.61E-01	1.52E-03	0.58
DU1 - P	5.78	2.48E-01	1.95E-02	7.84												
GU3 - S	5.35	2.52E-01	1.46E-03	0.58	-0.86								≥ EOL	2.52E-01	1.43E-03	0.57
GU3 - I	5.35	2.54E-01	6.98E-03	2.75												
DM2	3.78	2.17E-01	1.25E-03	0.58												
DM3	5.12	2.93E-01	1.70E-03	0.58												
DM4	4.00	2.22E-01	1.29E-03	0.58												
GU1	6.09	2.99E-01	1.76E-03	0.59												
BM6	3.69	1.98E-01	1.11E-02	5.62												
GU4	3.16	1.39E-01	1.88E-02	13.55												



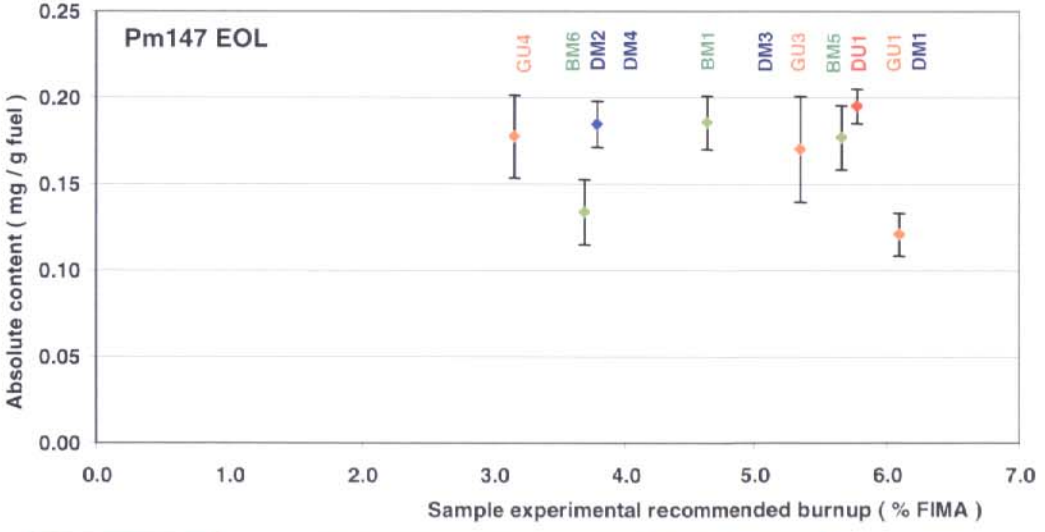
value is maintained

results are within uncertainties and combined

Table 5.3 / 28 - Results analysis and recommended values - Pm147

Pm147

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ / x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ / x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.41E-02	5.39E-03	8.41		1.85E-01	1.56E-02	8.41								
BM1 - P	4.62															
BM5 - S	5.66	7.32E-02	1.17E-02	16.01	8.93	1.94E-01	3.10E-02	16.01	13.49				EOL	1.77E-01	1.85E-02	10.46
BM5 -P	5.66	6.67E-02	9.17E-03	13.76		1.67E-01	2.30E-02	13.76								
DM1 - S	6.13															
DM1 - P	6.13															
DU1 - S	5.78	6.83E-02	3.76E-03	5.51	60.31	2.00E-01	1.10E-02	5.51	14.80				EOL	1.95E-01	1.00E-02	5.15
DU1 - P	5.78	2.71E-02	3.89E-03	14.36		1.70E-01	2.45E-02	14.36								
GU3 - S	5.35	8.25E-02	1.48E-02	18.01	-70.48	1.70E-01	3.06E-02	18.01	-36.83				EOL	1.70E-01	3.06E-02	18.01
GU3 - I	5.35	1.41E-01	3.49E-03	2.48		2.33E-01	5.78E-03	2.48								
DM2	3.78	4.85E-02	3.51E-03	7.24		1.85E-01	1.34E-02	7.24								
DM3	5.12															
DM4	4.00															
GU1	6.09	5.61E-02	5.75E-03	10.25		1.21E-01	1.24E-02	10.25								
BM6	3.69	5.32E-02	7.51E-03	14.10		1.34E-01	1.89E-02	14.10								
GU4	3.16	9.63E-02	1.30E-02	13.51		1.78E-01	2.40E-02	13.51								

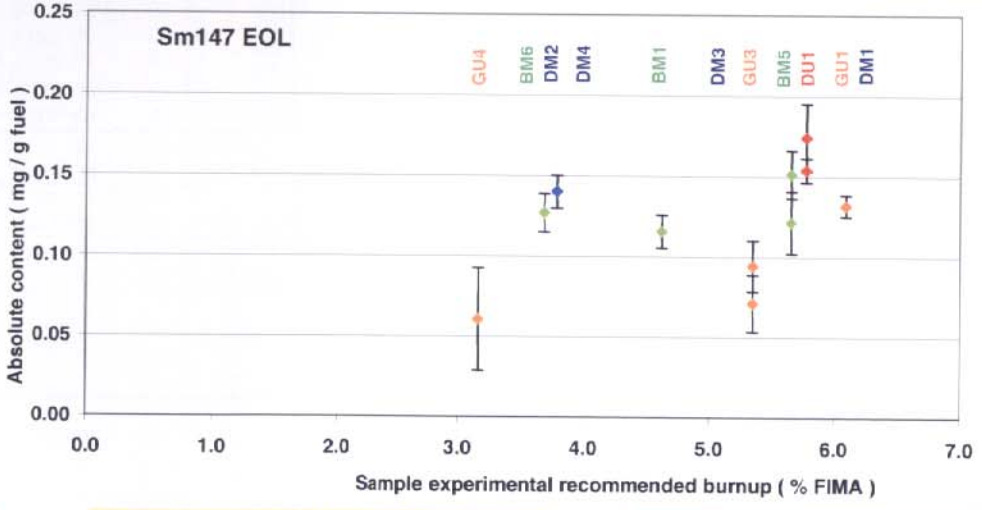


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 29 - Results analysis and recommended values - Sm147

Sm147

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	at EOL x_S-$x_{P/I}$ /x_S	At last date (*) content x	At last date (*) 95% uncertainty Δx	At last date (*) Δx / x	At last date (*) x_S-$x_{P/I}$ /x_S	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	2.37E-01	1.52E-03	0.64	-9.47	1.16E-01	1.03E-02	8.92		2.66E-01	2.86E-03	1.08	2.44	last date	2.65E-01	2.78E-03	1.05
BM1 - P	4.62	2.59E-01	1.17E-02	4.51						2.59E-01	1.17E-02	4.51					
BM5 - S	5.66	2.34E-01	1.50E-03	0.64	-4.77	1.21E-01	1.93E-02	15.93	-24.52	2.34E-01	1.50E-03	0.64	-7.51				
BM5 -P	5.66	2.45E-01	5.00E-03	2.04		1.51E-01	1.47E-02	9.76		2.51E-01	5.08E-03	2.02					
DM1 - S	6.13	2.89E-01	1.85E-03	0.64	-14.18												
DM1 - P	6.13	3.30E-01	1.64E-02	4.97													
DU1 - S	5.78	2.73E-01	1.88E-03	0.69	-15.04	1.54E-01	7.49E-03	4.87	-13.24	3.10E-01	2.76E-03	0.89	-1.47	last date	3.12E-01	2.19E-03	0.70
DU1 - P	5.78	3.15E-01	3.61E-03	1.15		1.74E-01	2.09E-02	12.00		3.15E-01	3.61E-03	1.15					
GU3 - S	5.35	1.73E-01	1.11E-03	0.64	5.74	9.42E-02	1.58E-02	16.76	24.68	1.73E-01	1.11E-03	0.64	-6.37	last date	1.73E-01	1.11E-03	0.64
GU3 - I	5.35	1.63E-01	1.75E-02	10.71		7.10E-02	1.76E-02	24.80		1.84E-01	1.75E-02	9.49					
DM2	3.78	2.68E-01	1.84E-03	0.69		1.40E-01	1.00E-02	7.16		2.68E-01	1.84E-03	0.69					
DM3	5.12	3.00E-01	1.93E-03	0.64						3.00E-01	1.93E-03	0.64					
DM4	4.00	2.65E-01	1.70E-03	0.64						2.65E-01	1.70E-03	0.64					
GU1	6.09	1.96E-01	1.26E-03	0.64		1.32E-01	6.75E-03	5.12		1.96E-01	1.26E-03	0.64					
BM6	3.69	2.02E-01	3.34E-03	1.65		1.27E-01	1.18E-02	9.32		2.02E-01	3.34E-03	1.65					
GU4	3.16	1.42E-01	3.00E-02	21.14		6.08E-02	3.20E-02	52.59		1.42E-01	3.00E-02	21.14					



value is maintained

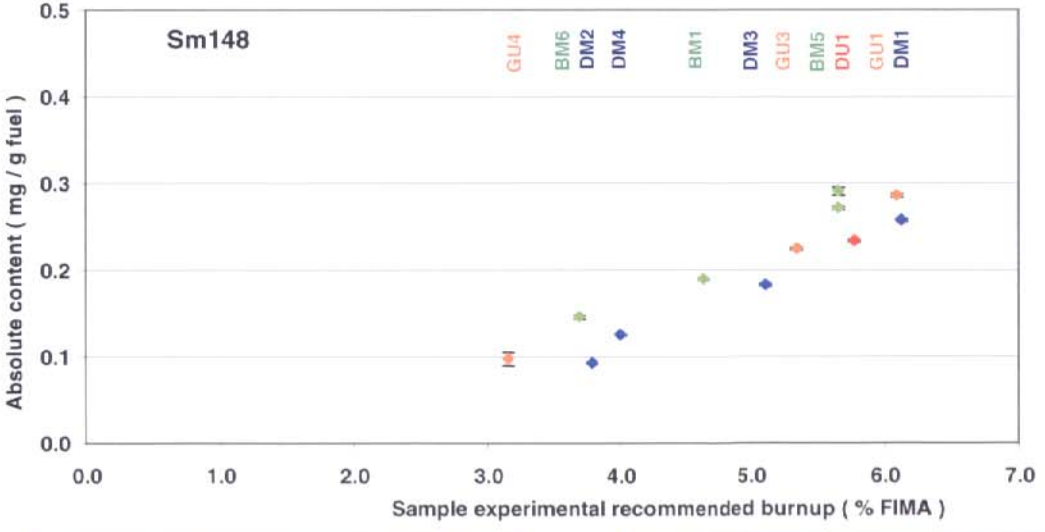
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 30 - Results analysis and recommended values - Sm148

Sm148

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.89E-01	1.22E-03	0.64	-2.16								≥ EOL	1.89E-01	1.20E-03	0.64
BM1 - P	4.62	1.93E-01	7.78E-03	4.03												
BM5 - S	5.66	2.71E-01	1.74E-03	0.64	-7.09											
BM5 -P	5.66	2.90E-01	4.45E-03	1.53												
DM1 - S	6.13	2.57E-01	1.65E-03	0.64	-0.98								≥ EOL	2.57E-01	1.64E-03	0.64
DM1 - P	6.13	2.60E-01	1.22E-02	4.71												
DU1 - S	5.78	2.33E-01	1.60E-03	0.69	-1.71								≥ EOL	2.33E-01	1.46E-03	0.63
DU1 - P	5.78	2.37E-01	3.61E-03	1.53												
GU3 - S	5.35	2.24E-01	1.44E-03	0.64	-3.11								≥ EOL	2.24E-01	1.43E-03	0.64
GU3 - I	5.35	2.31E-01	1.75E-02	7.56												
DM2	3.78	9.28E-02	6.36E-04	0.69												
DM3	5.12	1.82E-01	1.17E-03	0.64												
DM4	4.00	1.25E-01	8.04E-04	0.64												
GU1	6.09	2.86E-01	1.84E-03	0.64												
BM6	3.69	1.46E-01	2.22E-03	1.53												
GU4	3.16	9.74E-02	7.80E-03	8.01												

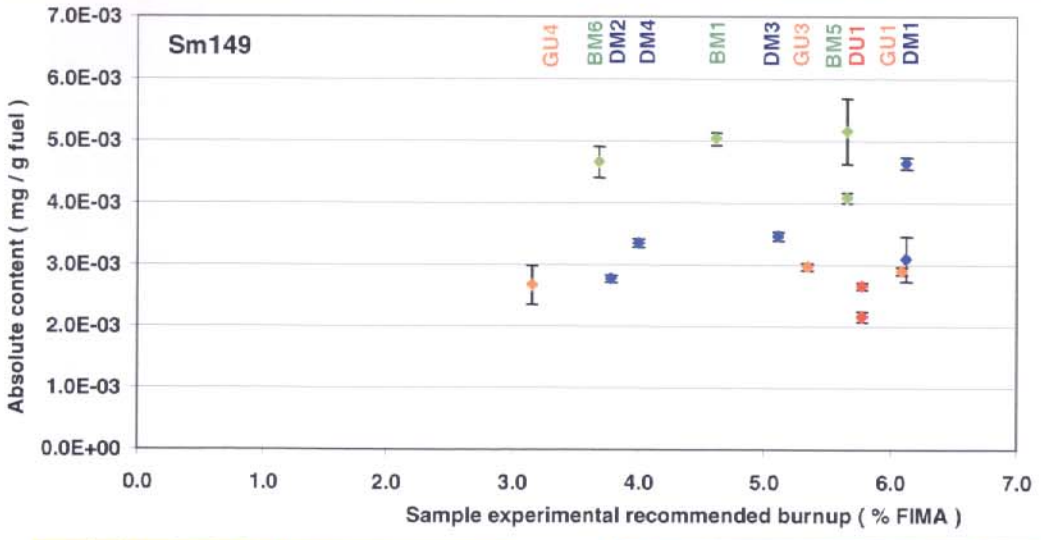


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 31 - Results analysis and recommended values - Sm149

Sm149

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	5.03E-03	1.05E-04	2.09	0.33								≥ EOL	5.03E-03	1.03E-04	2.06
BM1 - P	4.62	5.02E-03	5.56E-04	11.08												
BM5 - S	5.66	4.08E-03	8.53E-05	2.09	-26.39											
BM5 -P	5.66	5.15E-03	5.28E-04	10.25												
DM1 - S	6.13	4.64E-03	9.70E-05	2.09	33.44											
DM1 - P	6.13	3.09E-03	3.61E-04	11.71												
DU1 - S	5.78	2.65E-03	5.58E-05	2.11	18.85											
DU1 - P	5.78	2.15E-03	8.34E-05	3.88												
GU3 - S	5.35	2.96E-03	6.20E-05	2.09	-37.52								≥ EOL	2.96E-03	6.19E-05	2.09
GU3 - I	5.35	4.07E-03	1.75E-03	42.83												
DM2	3.78	2.77E-03	5.83E-05	2.10												
DM3	5.12	3.46E-03	7.23E-05	2.09												
DM4	4.00	3.35E-03	7.00E-05	2.09												
GU1	6.09	2.89E-03	6.05E-05	2.09												
BM6	3.69	4.66E-03	2.50E-04	5.37												
GU4	3.16	2.66E-03	3.13E-04	11.76												

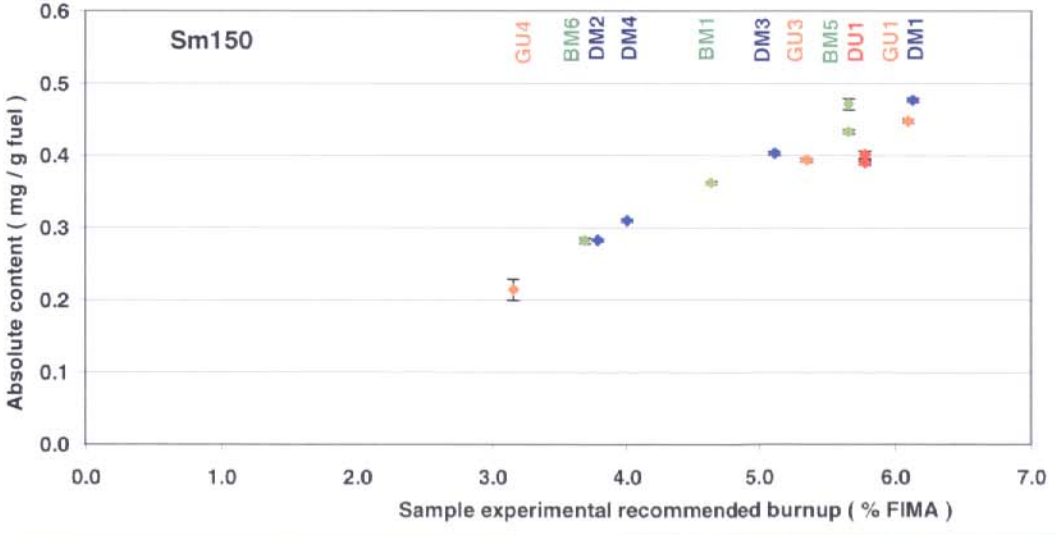


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 32 - Results analysis and recommended values - Sm150

Sm150

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.62E-01	2.33E-03	0.64	-2.07								≥ EOL	3.62E-01	2.30E-03	0.64
BM1 - P	4.62	3.69E-01	1.56E-02	4.22												
BM5 - S	5.66	4.33E-01	2.78E-03	0.64	-8.82											
BM5 -P	5.66	4.71E-01	7.78E-03	1.65												
DM1 - S	6.13	4.76E-01	3.06E-03	0.64	-2.45								≥ EOL	4.76E-01	3.02E-03	0.63
DM1 - P	6.13	4.88E-01	1.89E-02	3.88												
DU1 - S	5.78	3.90E-01	2.68E-03	0.69	-2.83											
DU1 - P	5.78	4.01E-01	5.00E-03	1.25												
GU3 - S	5.35	3.93E-01	2.53E-03	0.64	-0.11								≥ EOL	3.93E-01	2.50E-03	0.64
GU3 - I	5.35	3.94E-01	1.75E-02	4.43												
DM2	3.78	2.82E-01	1.94E-03	0.69												
DM3	5.12	4.03E-01	2.58E-03	0.64												
DM4	4.00	3.10E-01	1.99E-03	0.64												
GU1	6.09	4.48E-01	2.89E-03	0.64												
BM6	3.69	2.82E-01	3.89E-03	1.38												
GU4	3.16	2.14E-01	1.47E-02	6.87												

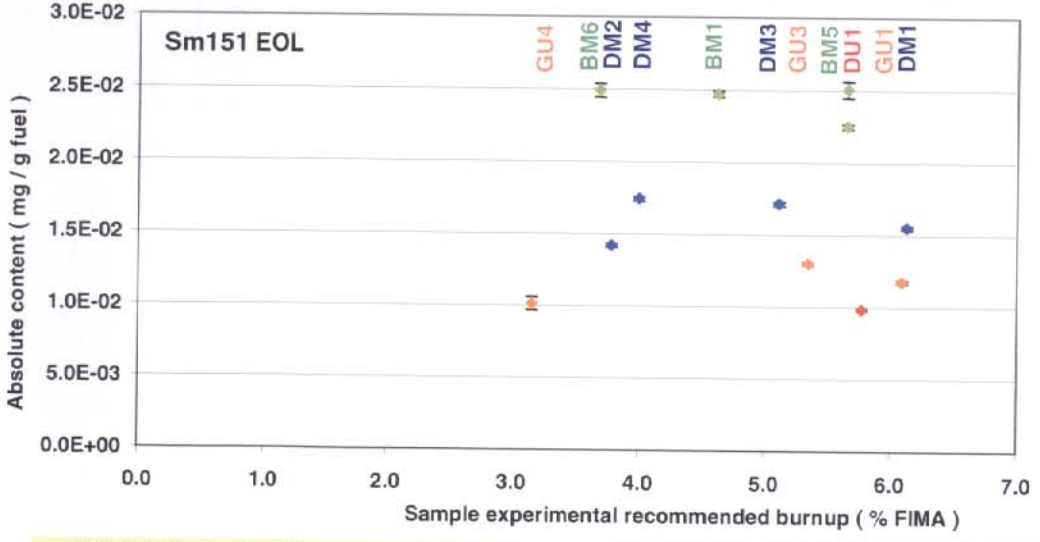


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 33 - Results analysis and recommended values - Sm151

Sm151

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	2.39E-02	1.89E-04	0.79	0.89	2.47E-02	2.07E-04	0.84	-0.87				EOL	2.47E-02	2.04E-04	0.82
BM1 - P	4.62	2.37E-02	1.11E-03	4.69		2.49E-02	1.17E-03	4.71								
BM5 - S	5.66	2.19E-02	1.73E-04	0.79	-11.60	2.25E-02	1.85E-04	0.82	-11.31							
BM5 -P	5.66	2.44E-02	5.56E-04	2.28		2.50E-02	5.72E-04	2.29								
DM1 - S	6.13	1.50E-02	1.18E-04	0.79	-1.25	1.55E-02	1.29E-04	0.83	-3.20				EOL	1.55E-02	1.27E-04	0.82
DM1 - P	6.13	1.52E-02	7.51E-04	4.94		1.60E-02	7.92E-04	4.96								
DU1 - S	5.78	9.50E-03	7.85E-05	0.83	0.19	9.79E-03	8.50E-05	0.87	-1.91				EOL	9.83E-03	7.36E-05	0.75
DU1 - P	5.78	9.48E-03	1.33E-04	1.41		9.97E-03	1.47E-04	1.48								
GU3 - S	5.35	1.27E-02	1.01E-04	0.79	-1.20	1.30E-02	1.05E-04	0.81	-0.73				EOL	1.30E-02	1.05E-04	0.81
GU3 - I	5.35	1.29E-02	8.73E-03	67.63		1.31E-02	8.86E-03	67.63								
DM2	3.78	1.37E-02	1.13E-04	0.82		1.42E-02	1.26E-04	0.89								
DM3	5.12	1.63E-02	1.29E-04	0.79		1.71E-02	1.53E-04	0.89								
DM4	4.00	1.68E-02	1.32E-04	0.79		1.74E-02	1.50E-04	0.86								
GU1	6.09	1.15E-02	9.09E-05	0.79		1.18E-02	9.58E-05	0.82								
BM6	3.69	2.43E-02	4.45E-04	1.83		2.49E-02	4.59E-04	1.84								
GU4	3.16	9.94E-03	4.38E-04	4.41		1.01E-02	4.46E-04	4.41								



value is maintained

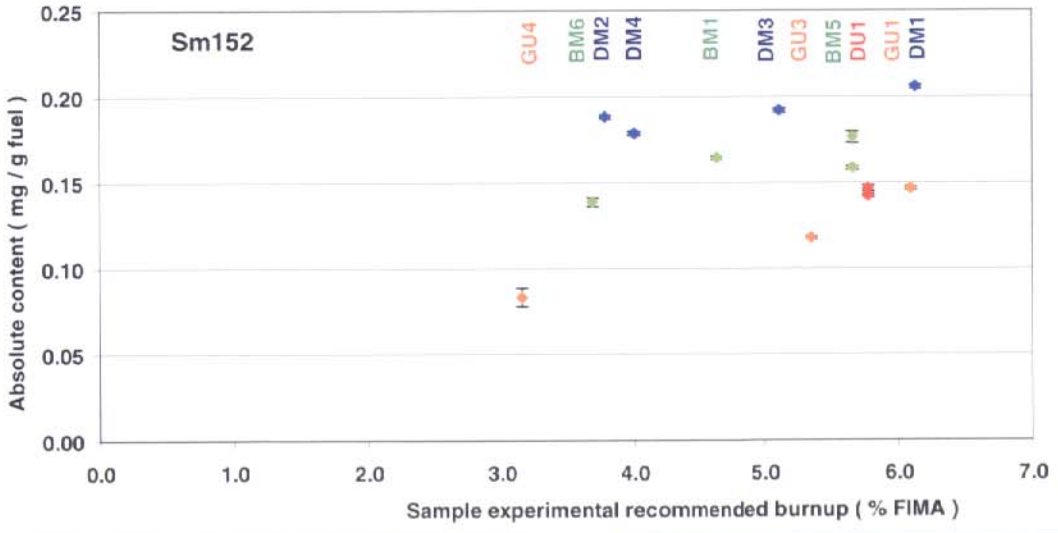
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 34 - Results analysis and recommended values - Sm152

Sm152

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.64E-01	1.06E-03	0.64	2.36								≥ EOL	1.64E-01	1.04E-03	0.64
BM1 - P	4.62	1.60E-01	6.39E-03	3.99												
BM5 - S	5.66	1.58E-01	1.02E-03	0.64	-11.45											
BM5 -P	5.66	1.76E-01	3.34E-03	1.89												
DM1 - S	6.13	2.06E-01	1.32E-03	0.64	-0.19								≥ EOL	2.06E-01	1.31E-03	0.64
DM1 - P	6.13	2.06E-01	1.08E-02	5.26												
DU1 - S	5.78	1.42E-01	9.78E-04	0.69	-3.00											
DU1 - P	5.78	1.47E-01	1.64E-03	1.12												
GU3 - S	5.35	1.18E-01	7.57E-04	0.64	1.98								≥ EOL	1.18E-01	7.49E-04	0.64
GU3 - I	5.35	1.15E-01	5.24E-03	4.54												
DM2	3.78	1.88E-01	1.29E-03	0.69												
DM3	5.12	1.92E-01	1.23E-03	0.64												
DM4	4.00	1.79E-01	1.15E-03	0.64												
GU1	6.09	1.46E-01	9.43E-04	0.64												
BM6	3.69	1.39E-01	2.50E-03	1.80												
GU4	3.16	8.34E-02	5.34E-03	6.41												

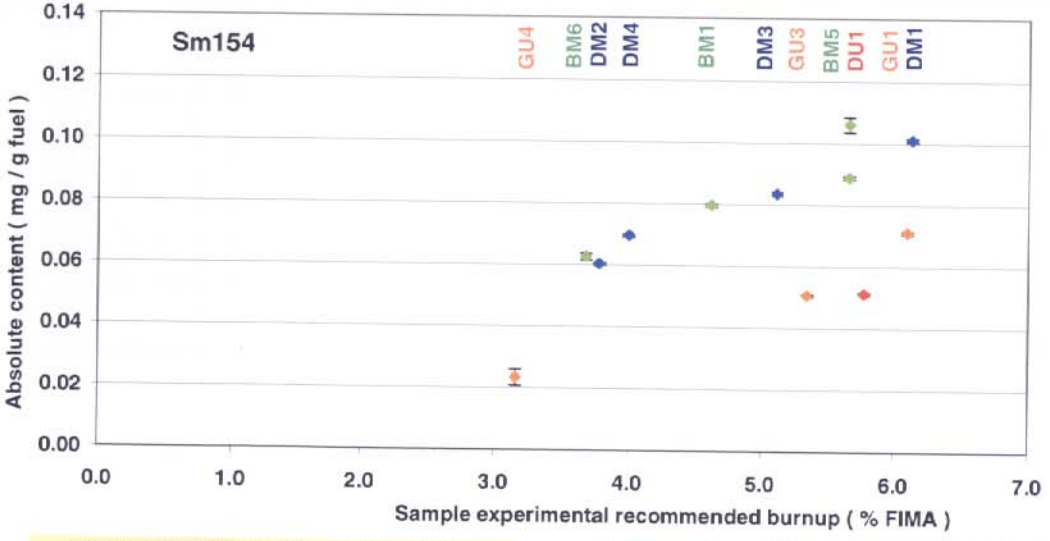


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 35 - Results analysis and recommended values - Sm154

Sm154

Sample	Burnup	At analysis (*) content	95% uncertainty			at EOL (=at analysis) content	95% uncertainty			At last date (=at analysis) content	95% uncertainty		(*)Recommended	content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	7.95E-02	5.26E-04	0.66	-1.44								≥ EOL	7.95E-02	5.19E-04	0.65
BM1 - P	4.62	8.06E-02	3.34E-03	4.14												
BM5 - S	5.66	8.87E-02	5.85E-04	0.66	-19.34											
BM5 -P	5.66	1.06E-01	2.39E-03	2.26												
DM1 - S	6.13	1.01E-01	6.65E-04	0.66	-3.92								≥ EOL	1.01E-01	6.62E-04	0.66
DM1 - P	6.13	1.05E-01	7.23E-03	6.89												
DU1 - S	5.78	5.08E-02	3.58E-04	0.70	-2.33								≥ EOL	5.11E-02	3.12E-04	0.61
DU1 - P	5.78	5.20E-02	6.39E-04	1.23												
GU3 - S	5.35	5.06E-02	3.34E-04	0.66	7.31								≥ EOL	5.05E-02	3.32E-04	0.66
GU3 - I	5.35	4.69E-02	3.49E-03	7.45												
DM2	3.78	6.03E-02	4.23E-04	0.70												
DM3	5.12	8.34E-02	5.50E-04	0.66												
DM4	4.00	6.95E-02	4.58E-04	0.66												
GU1	6.09	7.09E-02	4.69E-04	0.66												
BM6	3.69	6.26E-02	1.20E-03	1.91												
GU4	3.16	2.33E-02	2.64E-03	11.30												



value is maintained

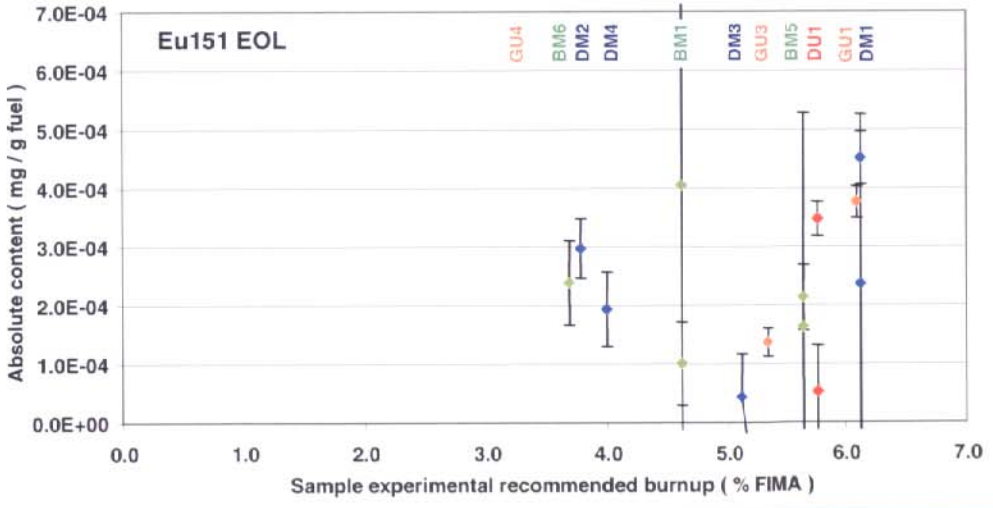
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 36 - Results analysis and recommended values - Eu151

Eu151

Sample	Burnup	At analysis				at EOL				At last date (*)				(*)Recommended			
		content	95% uncertainty			content	95% uncertainty			content	95% uncertainty				content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	8.50E-04	1.78E-05	2.10	-87.13	1.00E-04	7.09E-05	70.61	-302.65	1.27E-03	4.20E-05	3.32	-25.68	last date	1.27E-03	4.20E-05	3.32
BM1 - P	4.62	1.59E-03	9.45E-04	59.43		4.04E-04	9.53E-04	235.64		1.59E-03	9.45E-04	59.43					
BM5 - S	5.66	7.76E-04	1.63E-05	2.10	2.65	2.13E-04	5.59E-05	26.26	23.62	7.94E-04	1.64E-05	2.06	4.86	last date	7.94E-04	1.64E-05	2.06
BM5 -P	5.66	7.55E-04	3.61E-04	47.84		1.62E-04	3.66E-04	225.04		7.55E-04	3.61E-04	47.84					
DM1 - S	6.13	8.57E-04	1.78E-05	2.07	-16.81	4.51E-04	4.50E-05	9.99	47.63	1.17E-03	3.36E-05	2.88	14.16	last date	1.16E-03	3.33E-05	2.86
DM1 - P	6.13	1.00E-03	2.78E-04	27.76		2.36E-04	2.90E-04	122.75		1.00E-03	2.78E-04	27.76					
DU1 - S	5.78	6.04E-04	1.27E-05	2.10	9.57	3.47E-04	2.91E-05	8.38	84.93	8.00E-04	2.20E-05	2.76	31.71				
DU1 - P	5.78	5.46E-04	6.39E-05	11.70		5.23E-05	7.85E-05	150.21		5.46E-04	6.39E-05	11.70					
GU3 - S	5.35	3.70E-04	7.77E-06	2.10		1.37E-04	2.38E-05	17.38		3.70E-04	7.77E-06	2.10					
GU3 - I	5.35																
DM2	3.78	7.75E-04	1.61E-05	2.08		2.97E-04	5.06E-05	17.01		7.75E-04	1.61E-05	2.08					
DM3	5.12	8.07E-04	1.69E-05	2.10		4.34E-05	7.34E-05	169.01		8.07E-04	1.69E-05	2.10					
DM4	4.00	8.43E-04	1.77E-05	2.10		1.94E-04	6.35E-05	32.78		8.43E-04	1.77E-05	2.10					
GU1	6.09	6.33E-04	1.33E-05	2.10		3.76E-04	2.68E-05	7.13		6.33E-04	1.33E-05	2.10					
BM6	3.69	8.30E-04	4.73E-05	5.69		2.39E-04	7.19E-05	30.13		8.30E-04	4.73E-05	5.69					
GU4	3.16																

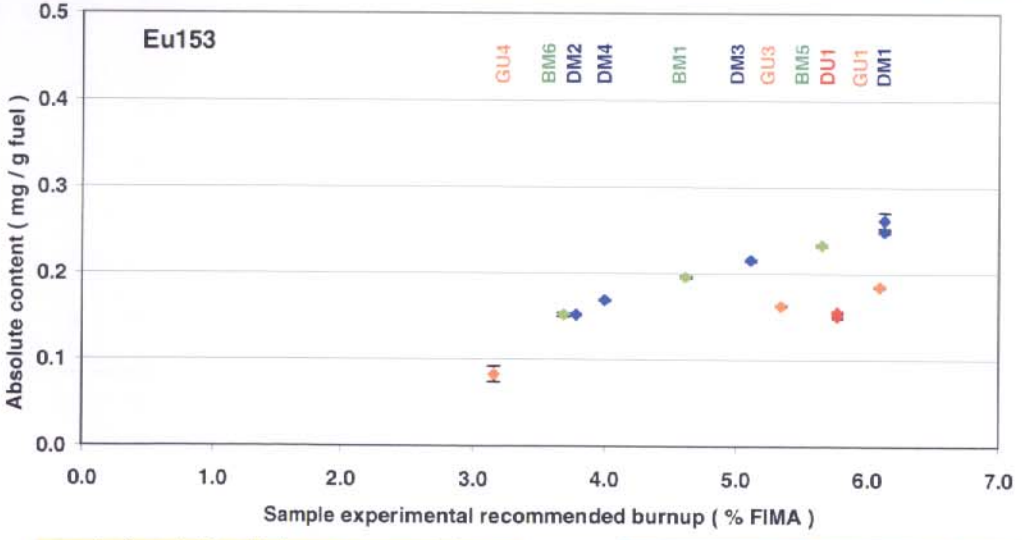


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 37 - Results analysis and recommended values - Eu153

Eu153

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.96E-01	1.31E-03	0.67	0.95								≥ EOL	1.96E-01	1.29E-03	0.66
BM1 - P	4.62	1.94E-01	7.51E-03	3.87												
BM5 - S	5.66	2.33E-01	1.55E-03	0.67	0.27								≥ EOL	2.32E-01	1.47E-03	0.63
BM5 -P	5.66	2.32E-01	4.73E-03	2.04												
DM1 - S	6.13	2.48E-01	1.45E-03	0.59	-5.26											
DM1 - P	6.13	2.61E-01	9.45E-03	3.62												
DU1 - S	5.78	1.55E-01	1.04E-03	0.67	3.24											
DU1 - P	5.78	1.50E-01	2.25E-03	1.50												
GU3 - S	5.35	1.62E-01	1.08E-03	0.67	-1.61								≥ EOL	1.62E-01	1.07E-03	0.66
GU3 - I	5.35	1.65E-01	6.98E-03	4.23												
DM2	3.78	1.52E-01	9.07E-04	0.60												
DM3	5.12	2.15E-01	1.43E-03	0.67												
DM4	4.00	1.69E-01	1.12E-03	0.66												
GU1	6.09	1.85E-01	1.23E-03	0.67												
BM6	3.69	1.52E-01	2.25E-03	1.48												
GU4	3.16	8.28E-02	9.08E-03	10.97												

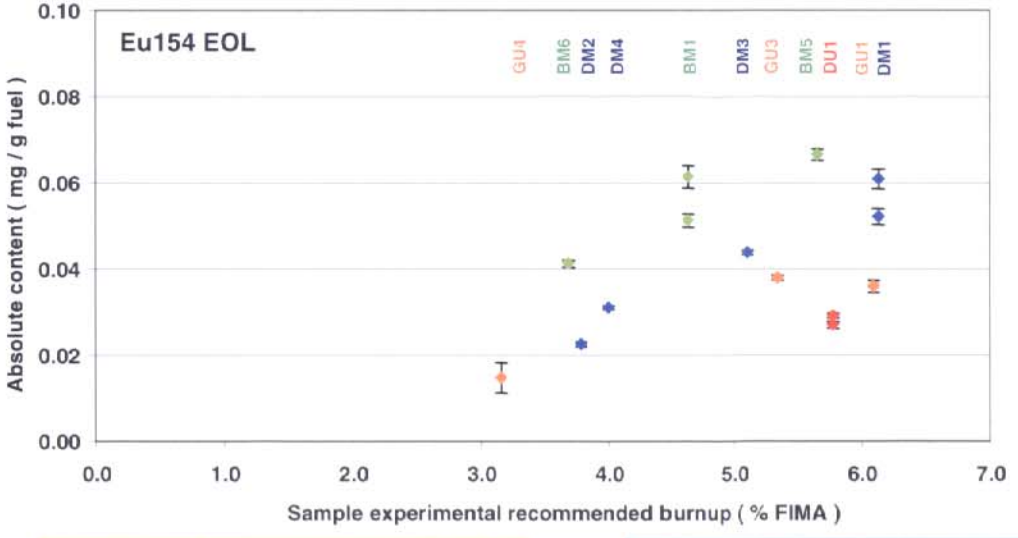


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 38 - Results analysis and recommended values - Eu154

Eu154

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.69E-02	1.11E-03	3.01	0.36	5.13E-02	1.54E-03	3.01	-19.80							
BM1 - P	4.62	3.68E-02	1.58E-03	4.31		6.14E-02	2.65E-03	4.31								
BM5 - S	5.66	5.06E-02	1.52E-03	3.01	-4.62	6.45E-02	1.94E-03	3.01	-5.53				EOL	6.65E-02	1.29E-03	1.93
BM5 -P	5.66	5.29E-02	1.33E-03	2.52		6.81E-02	1.72E-03	2.52								
DM1 - S	6.13	3.80E-02	1.35E-03	3.56	4.42	5.22E-02	1.86E-03	3.56	-16.77							
DM1 - P	6.13	3.63E-02	1.36E-03	3.75		6.09E-02	2.28E-03	3.75								
DU1 - S	5.78	1.96E-02	5.64E-04	2.87	13.14	2.69E-02	7.73E-04	2.87	-8.13							
DU1 - P	5.78	1.71E-02	3.06E-04	1.79		2.91E-02	5.22E-04	1.79								
GU3 - S	5.35	3.06E-02	1.62E-03	5.29	-6.88	3.61E-02	1.91E-03	5.29	-5.52				EOL	3.79E-02	5.82E-04	1.53
GU3 - I	5.35	3.27E-02	5.24E-04	1.60		3.81E-02	6.11E-04	1.60								
DM2	3.78	1.50E-02	3.83E-04	2.56		2.25E-02	5.75E-04	2.56								
DM3	5.12	2.68E-02	3.31E-04	1.23		4.38E-02	5.40E-04	1.23								
DM4	4.00	2.06E-02	2.79E-04	1.36		3.10E-02	4.21E-04	1.36								
GU1	6.09	2.84E-02	1.11E-03	3.89		3.59E-02	1.40E-03	3.89								
BM6	3.69	3.21E-02	6.39E-04	1.99		4.13E-02	8.23E-04	1.99								
GU4	3.16	1.22E-02	2.89E-03	23.73		1.47E-02	3.49E-03	23.73								

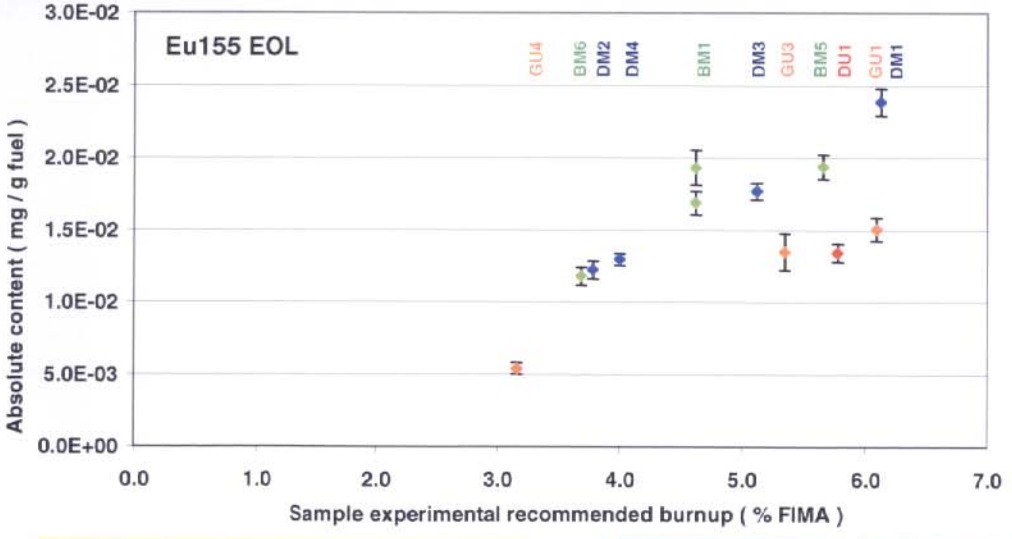


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 39 - Results analysis and recommended values - Eu155

Eu155

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis $x_S-x_{P/I}/x_S$	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) $x_S-x_{P/I}/x_S$	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	9.44E-03	4.30E-04	4.55	17.28	1.69E-02	8.18E-04	4.85	-14.51							
BM1 - P	4.62	7.81E-03	4.45E-04	5.70		1.93E-02	1.21E-03	6.27								
BM5 - S	5.66	1.35E-02	1.19E-03	8.81	9.88	2.08E-02	1.85E-03	8.90	8.49				EOL	1.94E-02	8.40E-04	4.34
BM5 -P	5.66	1.22E-02	5.84E-04	4.79		1.90E-02	9.43E-04	4.96								
DM1 - S	6.13	1.35E-02	7.28E-04	5.40	27.99	2.36E-02	1.33E-03	5.64	-2.53				EOL	2.39E-02	9.46E-04	3.97
DM1 - P	6.13	9.71E-03	4.73E-04	4.87		2.42E-02	1.35E-03	5.58								
DU1 - S	5.78	7.67E-03	3.68E-04	4.80	31.24	1.34E-02	6.77E-04	5.06	-1.21				EOL	1.34E-02	6.20E-04	4.63
DU1 - P	5.78	5.27E-03	5.84E-04	11.08		1.35E-02	1.54E-03	11.40								
GU3 - S	5.35	9.97E-03	9.80E-04	9.83	-9.01	1.34E-02	1.32E-03	9.87	-6.56				EOL	1.35E-02	1.27E-03	9.43
GU3 - I	5.35	1.09E-02	3.49E-03	32.13		1.43E-02	4.58E-03	32.13								
DM2	3.78	5.96E-03	2.75E-04	4.61		1.22E-02	6.17E-04	5.05								
DM3	5.12	7.42E-03	1.52E-04	2.05		1.77E-02	5.71E-04	3.23								
DM4	4.00	6.27E-03	1.49E-04	2.38		1.29E-02	4.10E-04	3.17								
GU1	6.09	9.95E-03	5.26E-04	5.28		1.50E-02	8.14E-04	5.42								
BM6	3.69	7.54E-03	3.89E-04	5.16		1.18E-02	6.26E-04	5.32								
GU4	3.16	3.88E-03	2.82E-04	7.28		5.41E-03	3.97E-04	7.35								



value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 40 - Results analysis and recommended values - Gd155

Gd155

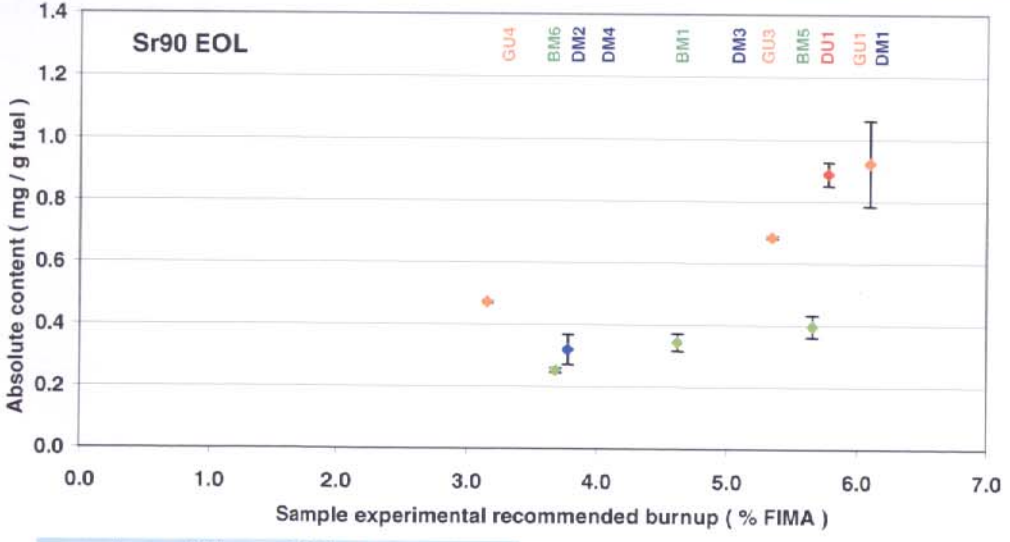
Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	x_S-$x_{P/I}$ / x_S	at EOL content x	at EOL 95% uncertainty Δx	at EOL Δx / x	At last date (*) content x	At last date (*) 95% uncertainty Δx	At last date (*) Δx / x		(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	mg/gfuel	mg/gfuel	%			mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.65E-03	3.33E-04	5.00	-40.76	Negative values			9.34E-03	3.76E-04	4.02	-0.24		1.69E-02	8.18E-04	4.85
BM1 - P	4.62	9.37E-03	3.34E-04	3.56					9.37E-03	3.34E-04	3.56					
BM5 - S	5.66	7.34E-03	1.54E-04	2.09	-11.32				7.34E-03	1.54E-04	2.09	-18.62				
BM5 -P	5.66	8.17E-03	5.56E-04	6.81					8.70E-03	5.57E-04	6.40					
DM1 - S	6.13	1.04E-02	5.18E-04	5.00	-18.21				1.56E-02	6.38E-04	4.10	21.32				
DM1 - P	6.13	1.22E-02	2.47E-04	2.02					1.22E-02	2.47E-04	2.02					
DU1 - S	5.78	4.98E-03	2.49E-04	5.00	-43.62				7.92E-03	3.18E-04	4.02	9.73				
DU1 - P	5.78	7.15E-03	2.31E-04	3.23					7.15E-03	2.31E-04	3.23					
GU3 - S	5.35	3.41E-03	7.15E-05	2.10	-7.47				3.41E-03	7.15E-05	2.10	-13.97				
GU3 - I	5.35	3.67E-03	2.27E-04	6.19					3.89E-03	2.38E-04	6.12					
DM2	3.78	5.07E-03	2.54E-04	5.00					5.07E-03	2.54E-04	5.00					
DM3	5.12															
DM4	4.00															
GU1	6.09	4.96E-03	2.48E-04	5.00					4.96E-03	2.48E-04	5.00					
BM6	3.69	4.39E-03	1.64E-04	3.74					4.39E-03	1.64E-04	3.74					
GU4	3.16	2.33E-03	3.19E-04	13.72					2.33E-03	3.19E-04	13.72					

value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 41 - Results analysis and recommended values - Sr90

Sr90

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.56E-01	5.34E-02	15.00	21.21	3.94E-01	5.91E-02	15.00	16.76				EOL	3.43E-01	2.85E-02	8.30
BM1 - P	4.62	2.81E-01	2.78E-02	9.91		3.28E-01	3.25E-02	9.91								
BM5 - S	5.66	3.14E-01	5.03E-02	16.01	-27.87	3.45E-01	5.52E-02	16.01	-26.01				EOL	3.96E-01	3.63E-02	9.16
BM5 -P	5.66	4.02E-01	4.45E-02	11.07		4.35E-01	4.81E-02	11.07								
DM1 - S	6.13															
DM1 - P	6.13															
DU1 - S	5.78	9.05E-01	1.36E-01	15.00	17.41	1.01E+00	1.51E-01	15.00	12.73				EOL	8.88E-01	3.80E-02	4.28
DU1 - P	5.78	7.48E-01	3.34E-02	4.46		8.79E-01	3.92E-02	4.46								
GU3 - S	5.35	6.30E-01	1.01E-01	16.01	-2.45	6.76E-01	1.08E-01	16.01	-0.96				EOL	6.83E-01	4.32E-03	0.63
GU3 - I	5.35	6.45E-01	4.08E-03	0.63		6.83E-01	4.32E-03	0.63								
DM2	3.78	2.80E-01	4.20E-02	15.00		3.19E-01	4.79E-02	15.00								
DM3	5.12															
DM4	4.00															
GU1	6.09	8.57E-01	1.29E-01	15.00		9.22E-01	1.38E-01	15.00								
BM6	3.69	2.33E-01	7.23E-03	3.10		2.53E-01	7.82E-03	3.10								
GU4	3.16	4.45E-01	3.42E-03	0.77		4.72E-01	3.63E-03	0.77								



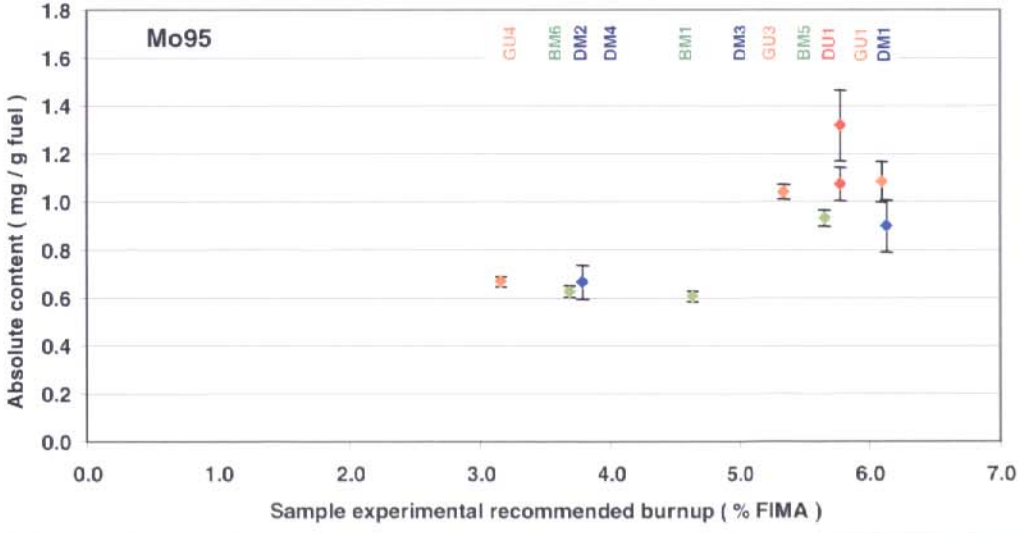
value is maintained

results are within uncertainties and combined

Table 5.3 / 42 - Results analysis and recommended values - Mo95

Mo95

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	5.96E-01	7.96E-02	13.34	-1.86								≥ EOL	6.06E-01	2.27E-02	3.74
BM1 - P	4.62	6.07E-01	2.37E-02	3.90												
BM5 - S	5.66	9.00E-01	8.73E-02	9.70	-4.17								≥ EOL	9.32E-01	3.36E-02	3.61
BM5 -P	5.66	9.37E-01	3.65E-02	3.89												
DM1 - S	6.13	8.98E-01	1.08E-01	12.0 (1)												
DM1 - P	6.13															
DU1 - S	5.78	1.32E+00	1.47E-01	11.19	18.49											
DU1 - P	5.78	1.07E+00	6.99E-02	6.51												
GU3 - S	5.35	1.15E+00	1.05E-01	9.14	10.21								≥ EOL	1.04E+00	3.06E-02	2.94
GU3 - I	5.35	1.03E+00	3.20E-02	3.11												
DM2	3.78	6.66E-01	7.03E-02	10.56												
DM3	5.12															
DM4	4.00															
GU1	6.09	1.08E+00	8.38E-02	7.74												
BM6	3.69	6.27E-01	2.43E-02	3.87												
GU4	3.16	6.68E-01	2.07E-02	3.11												



(1) Estimated uncertainty

value is maintained

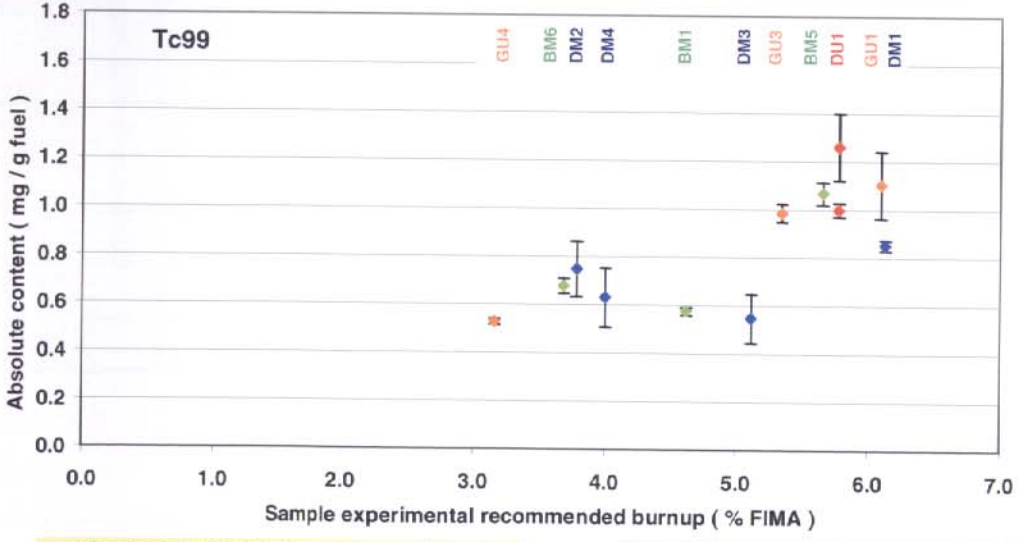
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 43 - Results analysis and recommended values - Tc99

Tc99

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	6.20E-01	1.69E-01	27.23	7.56								≥ EOL	5.74E-01	1.61E-02	2.81
BM1 - P	4.62	5.74E-01	1.62E-02	2.82												
BM5 - S	5.66	9.69E-01	1.89E-01	19.47	-10.64								≥ EOL	1.07E+00	4.71E-02	4.42
BM5 -P	5.66	1.07E+00	4.87E-02	4.54												
DM1 - S	6.13	9.59E-01	1.43E-01	14.96	11.57								≥ EOL	8.51E-01	2.23E-02	2.62
DM1 - P	6.13	8.48E-01	2.26E-02	2.67												
DU1 - S	5.78	1.26E+00	1.40E-01	11.11	20.76											
DU1 - P	5.78	9.98E-01	2.89E-02	2.89												
GU3 - S	5.35	1.14E+00	2.02E-01	17.70	14.49								≥ EOL	9.83E-01	3.81E-02	3.87
GU3 - I	5.35	9.77E-01	3.88E-02	3.97												
DM2	3.78	7.47E-01	1.13E-01	15.19												
DM3	5.12	5.45E-01	1.02E-01	18.65												
DM4	4.00	6.30E-01	1.22E-01	19.37												
GU1	6.09	1.10E+00	1.39E-01	12.60												
BM6	3.69	6.76E-01	3.05E-02	4.51												
GU4	3.16	5.28E-01	1.24E-02	2.35												



value is maintained

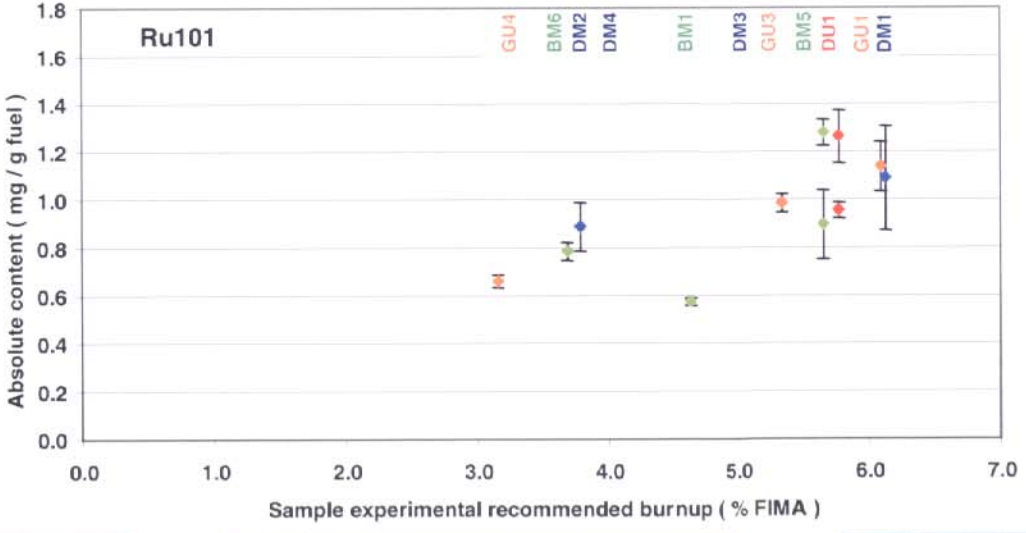
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 44 - Results analysis and recommended values - Ru101

Ru101

Sample	Burnup	At analysis (*) content x	At analysis (*) 95% uncertainty Δx	At analysis (*) Δx / x	At analysis (*) x_S-$x_{P/I}$ / x_S	at EOL (=at analysis) content x	at EOL (=at analysis) 95% uncertainty Δx	at EOL (=at analysis) Δx / x	at EOL (=at analysis) x_S-$x_{P/I}$ / x_S	At last date (=at analysis) content x	At last date (=at analysis) 95% uncertainty Δx	At last date (=at analysis) Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	5.28E-01	9.74E-02	18.45	8.21								≥ EOL	5.74E-01	1.61E-02	2.81
BM1 - P	4.62	4.85E-01	1.77E-02	3.64												
BM5 - S	5.66	8.94E-01	1.44E-01	16.13	-42.96											
BM5 -P	5.66	1.28E+00	5.45E-02	4.27												
DM1 - S	6.13	1.09E+00	2.17E-01	20.0 (1)												
DM1 - P	6.13															
DU1 - S	5.78	1.26E+00	1.10E-01	8.76	24.41											
DU1 - P	5.78	9.53E-01	3.27E-02	3.43												
GU3 - S	5.35	1.21E+00	2.96E-01	24.42	11.68								≥ EOL	9.83E-01	3.81E-02	3.87
GU3 - I	5.35	1.07E+00	3.78E-02	3.53												
DM2	3.78	8.87E-01	1.01E-01	11.42												
DM3	5.12															
DM4	4.00															
GU1	6.09	1.14E+00	1.04E-01	9.15												
BM6	3.69	7.84E-01	3.72E-02	4.74												
GU4	3.16	6.60E-01	2.64E-02	4.00												



(1) Estimated uncertainty

value is maintained

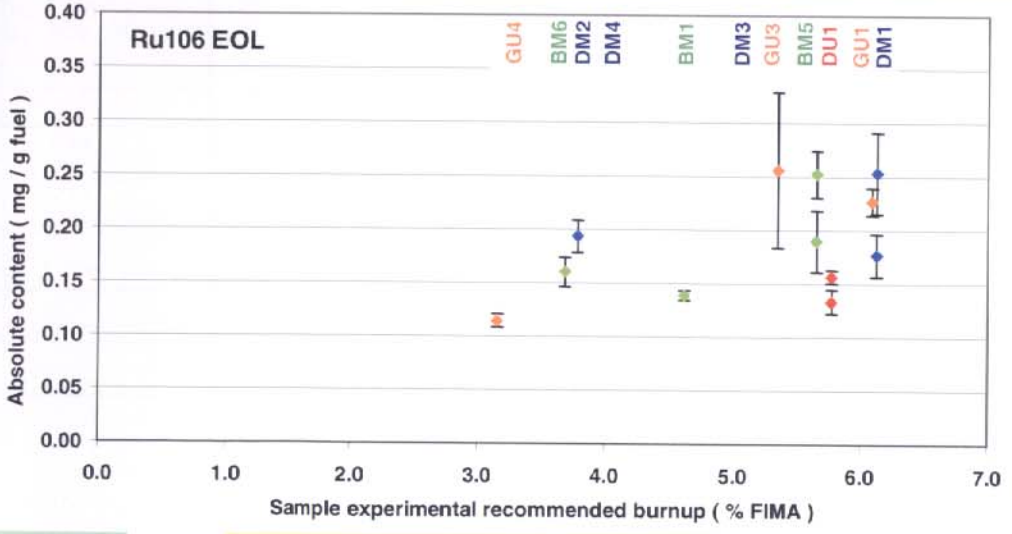
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 45 - Results analysis and recommended values - Ru106

Ru106

Sample	Burnup	At analysis				at EOL (*)				At last date				(*)Recommended			
		content	95% uncertainty			content	95% uncertainty			content	95% uncertainty				content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x		date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%			mg/gfuel	mg/gfuel	%
BM1 - S	4.62					1.38E-01	4.59E-03	3.31									
BM1 - P	4.62																
BM5 - S	5.66					1.89E-01	2.88E-02	15.24	-33.19								
BM5 -P	5.66					2.52E-01	2.19E-02	8.68									
DM1 - S	6.13					2.53E-01	3.80E-02	15.0 (1)									
DM1 - P	6.13					1.76E-01	1.99E-02	11.28									
DU1 - S	5.78					1.56E-01	6.18E-03	3.95	14.91								
DU1 - P	5.78					1.33E-01	1.11E-02	8.37									
GU3 - S	5.35					2.56E-01	7.27E-02	28.41	-71.77					EOL	2.56E-01	7.27E-02	28.41
GU3 - I	5.35					4.39E-01	3.14E-02	7.14									
DM2	3.78					1.93E-01	1.51E-02	7.83									
DM3	5.12																
DM4	4.00																
GU1	6.09					2.26E-01	1.28E-02	5.64									
BM6	3.69					1.60E-01	1.37E-02	8.53									
GU4	3.16					1.14E-01	6.14E-03	5.37									



(1) Estimated uncertainty

value is maintained

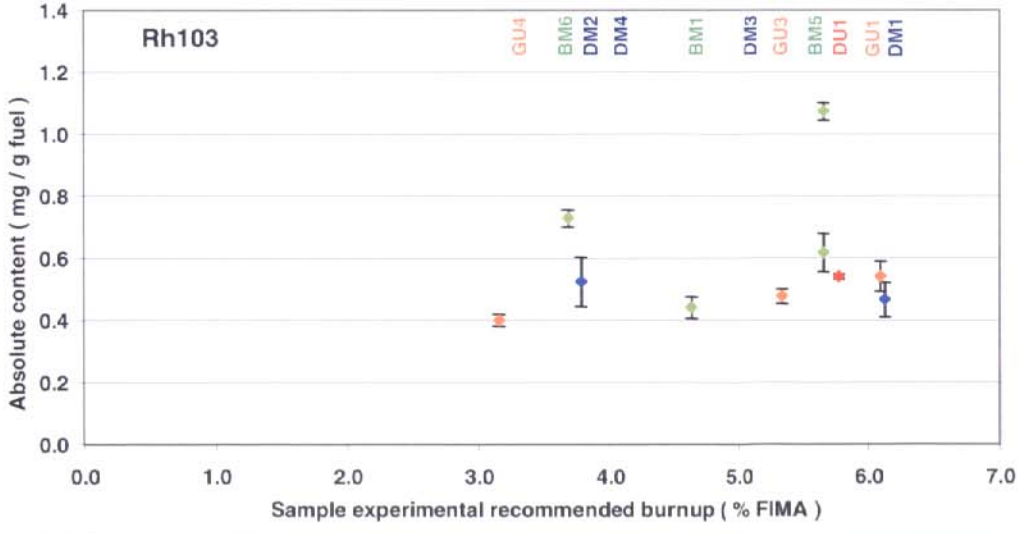
value is maintained but no recommendation

value is dropped

Table 5.3 / 46 - Results analysis and recommended values - Rh103

Rh103

Sample	Burnup	At analysis (*) content	95% uncertainty			at EOL (=at analysis) content	95% uncertainty			At last date (=at analysis) content	95% uncertainty		(*)Recommended	content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	4.41E-01	3.43E-02	7.77												
BM1 - P	4.62															
BM5 - S	5.66	6.16E-01	6.12E-02	9.93	-73.95											
BM5 -P	5.66	1.07E+00	2.80E-02	2.62												
DM1 - S	6.13	4.66E-01	5.59E-02	12.0 (1)												
DM1 - P	6.13															
DU1 - S	5.78	5.72E-01	5.74E-02	10.03	5.78								≥ EOL	5.40E-01	7.72E-03	1.43
DU1 - P	5.78	5.39E-01	7.79E-03	1.44												
GU3 - S	5.35	4.94E-01	4.82E-02	9.77	4.72								≥ EOL	4.76E-01	2.33E-02	4.88
GU3 - I	5.35	4.71E-01	2.65E-02	5.64												
DM2	3.78	5.23E-01	7.88E-02	15.07												
DM3	5.12															
DM4	4.00															
GU1	6.09	5.40E-01	4.85E-02	8.98												
BM6	3.69	7.28E-01	2.80E-02	3.84												
GU4	3.16	4.00E-01	1.88E-02	4.71												



(1) Estimated uncertainty

value is maintained

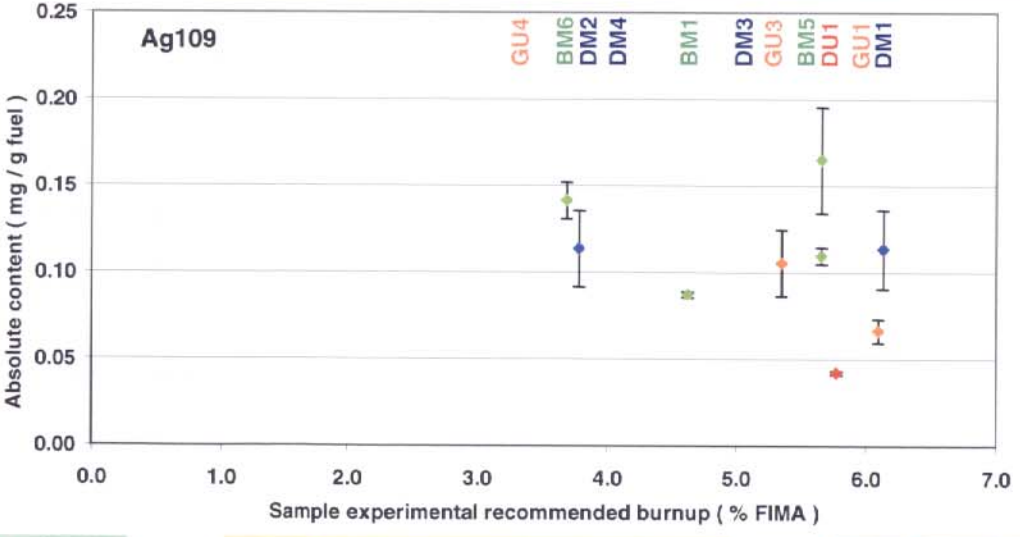
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 47 - Results analysis and recommended values - Ag109

Ag109

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	8.95E-02	1.49E-02	16.64	2.82								≥ EOL	8.70E-02	1.67E-03	1.92
BM1 - P	4.62	8.70E-02	1.68E-03	1.93												
BM5 - S	5.66	1.65E-01	3.06E-02	18.58	33.65											
BM5 -P	5.66	1.09E-01	4.79E-03	4.39												
DM1 - S	6.13	1.13E-01	2.26E-02	20.0 (1)												
DM1 - P	6.13															
DU1 - S	5.78	4.88E-02	9.42E-03	19.29	14.18								≥ EOL	4.20E-02	1.22E-03	2.90
DU1 - P	5.78	4.19E-02	1.23E-03	2.94												
GU3 - S	5.35	1.05E-01	1.91E-02	18.12												
GU3 - I	5.35															
DM2	3.78	1.13E-01	2.19E-02	19.30												
DM3	5.12															
DM4	4.00															
GU1	6.09	6.62E-02	6.85E-03	10.35												
BM6	3.69	1.41E-01	1.06E-02	7.48												
GU4	3.16															



(1) Estimated uncertainty

value is maintained

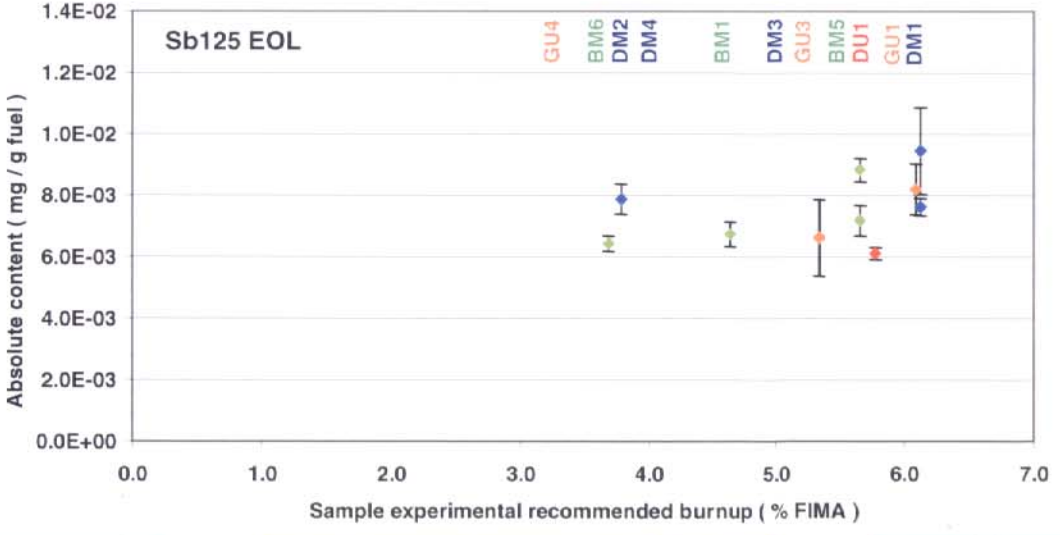
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 48 - Results analysis and recommended values - Sb125

Sb125

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62					6.73E-03	4.03E-04	5.99								
BM1 - P	4.62															
BM5 - S	5.66					7.18E-03	4.98E-04	6.93	-22.85							
BM5 -P	5.66					8.82E-03	3.82E-04	4.34								
DM1 - S	6.13					9.44E-03	1.42E-03	15.0 (1)								
DM1 - P	6.13					7.62E-03	2.79E-04	3.67								
DU1 - S	5.78					6.77E-03	5.72E-04	8.46	11.13				EOL	6.11E-03	1.98E-04	3.24
DU1 - P	5.78					6.02E-03	2.11E-04	3.51								
GU3 - S	5.35					6.61E-03	1.25E-03	18.85								
GU3 - I	5.35															
DM2	3.78					7.88E-03	4.88E-04	6.19								
DM3	5.12															
DM4	4.00															
GU1	6.09					8.19E-03	8.31E-04	10.14								
BM6	3.69					6.43E-03	2.52E-04	3.91								
GU4	3.16															



(1) Estimated uncertainty

value is maintained

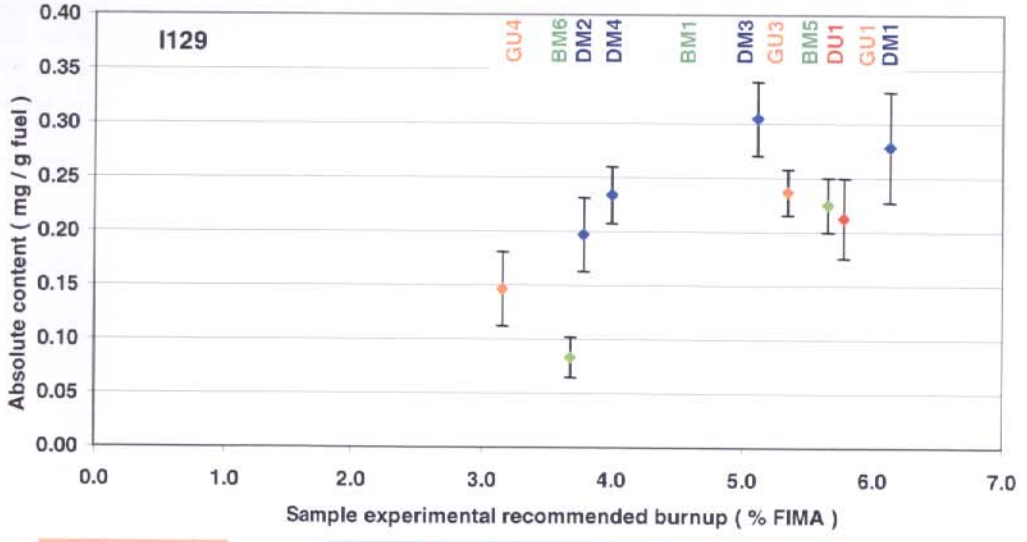
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 49 - Results analysis and recommended values - I129

I129

Sample	Burnup	At analysis (*) content	95% uncertainty			at EOL (=at analysis) content	95% uncertainty			At last date (=at analysis) content	95% uncertainty		(*)Recommended	content	95% uncertainty	
		x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	x_S-$x_{P/I}$ /x_S	x	Δx	Δx / x	date	x	Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62															
BM1 - P	4.62															
BM5 - S	5.66	2.24E-01	2.52E-02	11.24	60.71								≥ EOL	2.24E-01	2.52E-02	11.24
BM5 -P	5.66	8.82E-02	1.61E-02	18.28												
DM1 - S	6.13	2.78E-01	5.11E-02	18.40												
DM1 - P	6.13															
DU1 - S	5.78	2.12E-01	3.69E-02	17.40												
DU1 - P	5.78															
GU3 - S	5.35	2.39E-01	2.69E-02	11.24	3.56								≥ EOL	2.36E-01	2.13E-02	9.02
GU3 - I	5.35	2.31E-01	3.49E-02	15.12												
DM2	3.78	1.97E-01	3.42E-02	17.40												
DM3	5.12	3.04E-01	3.42E-02	11.24												
DM4	4.00	2.33E-01	2.62E-02	11.24												
GU1	6.09															
BM6	3.69	8.34E-02	1.86E-02	22.33												
GU4	3.16	1.46E-01	3.42E-02	23.36												

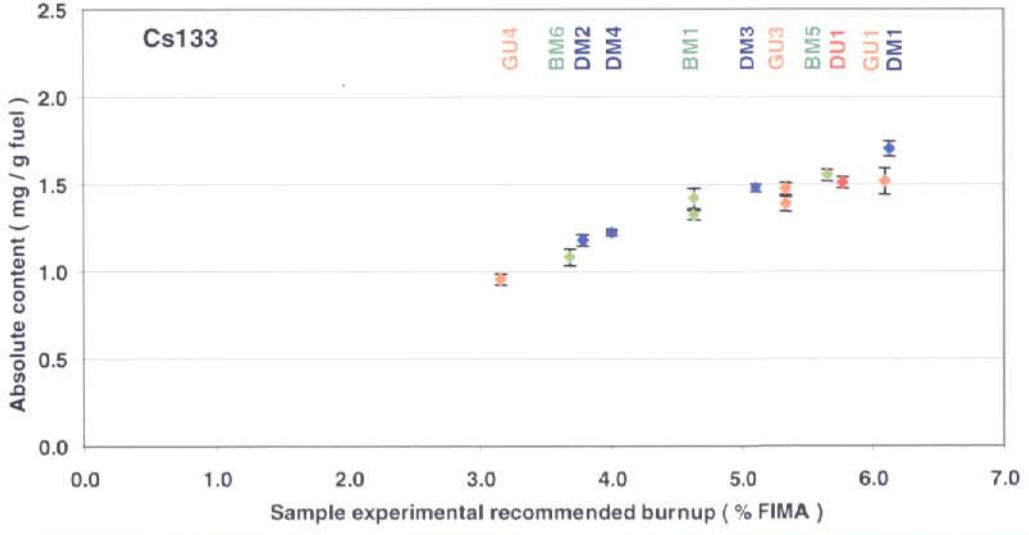


value is maintained | value is dropped | results are within uncertainties and combined

Table 5.3 / 50 - Results analysis and recommended values - Cs133

Cs133

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ /x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.32E+00	2.63E-02	1.99	-7.21											
BM1 - P	4.62	1.42E+00	5.84E-02	4.12												
BM5 - S	5.66	1.52E+00	4.65E-02	3.06	-4.01								≥ EOL	1.55E+00	3.31E-02	2.14
BM5 -P	5.66	1.58E+00	4.73E-02	2.99												
DM1 - S	6.13	1.69E+00	5.42E-02	3.22	-2.38								≥ EOL	1.70E+00	4.28E-02	2.51
DM1 - P	6.13	1.73E+00	6.95E-02	4.03												
DU1 - S	5.78	1.50E+00	4.23E-02	2.82	-1.50								≥ EOL	1.51E+00	3.15E-02	2.09
DU1 - P	5.78	1.52E+00	4.73E-02	3.11												
GU3 - S	5.35	1.39E+00	4.23E-02	3.06	-6.39											
GU3 - I	5.35	1.47E+00	3.49E-02	2.37												
DM2	3.78	1.18E+00	3.22E-02	2.73												
DM3	5.12	1.48E+00	2.26E-02	1.53												
DM4	4.00	1.22E+00	1.87E-02	1.53												
GU1	6.09	1.52E+00	7.45E-02	4.91												
BM6	3.69	1.08E+00	4.73E-02	4.37												
GU4	3.16	9.54E-01	3.11E-02	3.27												

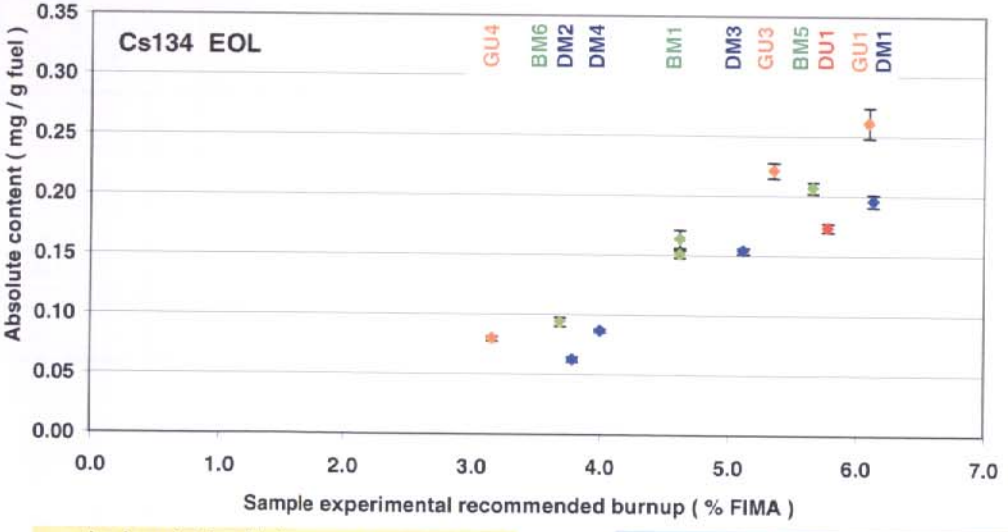


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 51 - Results analysis and recommended values - Cs134

Cs134

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis x_S-$x_{P/I}$ /x_S	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) x_S-$x_{P/I}$ /x_S	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	3.74E-02	7.63E-04	2.04	49.30	1.51E-01	3.08E-03	2.04	-8.31							
BM1 - P	4.62	1.89E-02	8.62E-04	4.55		1.64E-01	7.44E-03	4.55								
BM5 - S	5.66	7.40E-02	2.29E-03	3.09	1.95	2.03E-01	6.27E-03	3.09	-3.89				EOL	2.06E-01	4.73E-03	2.29
BM5 -P	5.66	7.26E-02	2.47E-03	3.41		2.11E-01	7.19E-03	3.41								
DM1 - S	6.13	5.71E-02	1.86E-03	3.25	61.97	2.00E-01	6.49E-03	3.25	5.72				EOL	1.96E-01	5.20E-03	2.66
DM1 - P	6.13	2.17E-02	1.00E-03	4.61		1.88E-01	8.67E-03	4.61								
DU1 - S	5.78	4.94E-02	1.41E-03	2.86	62.30	1.73E-01	4.94E-03	2.86	-0.79				EOL	1.73E-01	3.66E-03	2.11
DU1 - P	5.78	1.86E-02	5.84E-04	3.14		1.74E-01	5.46E-03	3.14								
GU3 - S	5.35	1.09E-01	3.34E-03	3.06	-16.85	2.18E-01	6.69E-03	3.06	-10.79				EOL	2.21E-01	6.34E-03	2.87
GU3 - I	5.35	1.28E-01	1.05E-02	8.20		2.42E-01	1.99E-02	8.20								
DM2	3.78	1.28E-02	4.33E-04	3.38		6.25E-02	2.11E-03	3.38								
DM3	5.12	2.16E-02	3.46E-04	1.60		1.54E-01	2.46E-03	1.60								
DM4	4.00	1.70E-02	2.71E-04	1.60		8.66E-02	1.38E-03	1.60								
GU1	6.09	9.56E-02	4.72E-03	4.94		2.61E-01	1.29E-02	4.94								
BM6	3.69	3.23E-02	1.31E-03	4.05		9.39E-02	3.80E-03	4.05								
GU4	3.16	3.65E-02	9.26E-04	2.54		7.97E-02	2.02E-03	2.54								



value is maintained

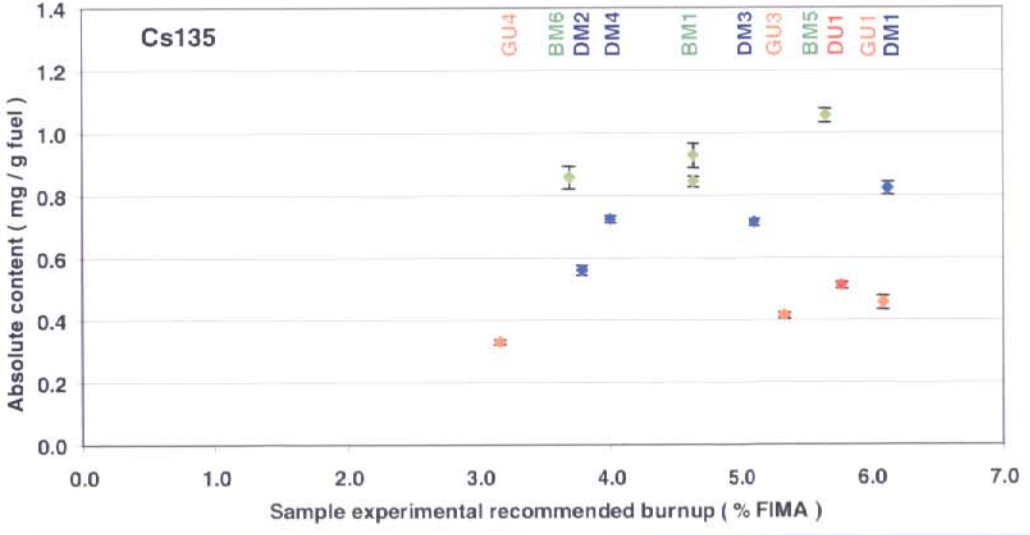
value is maintained but no recommendation

results are within uncertainties and combined

Table 5.3 / 52 - Results analysis and recommended values - Cs135

Cs135

Sample	Burnup	At analysis (*) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	at EOL (=at analysis) content x	95% uncertainty Δx	Δx / x	x_S-$x_{P/I}$ / x_S	At last date (=at analysis) content x	95% uncertainty Δx	Δx / x	(*)Recommended date	content x	95% uncertainty Δx	Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	8.45E-01	1.68E-02	1.99	-9.84											
BM1 - P	4.62	9.28E-01	3.89E-02	4.20												
BM5 - S	5.66	1.04E+00	3.17E-02	3.06	-3.41								≥ EOL	1.06E+00	2.20E-02	2.09
BM5 -P	5.66	1.07E+00	3.06E-02	2.85												
DM1 - S	6.13	8.15E-01	2.62E-02	3.22	-2.45								≥ EOL	8.23E-01	2.06E-02	2.51
DM1 - P	6.13	8.35E-01	3.34E-02	3.99												
DU1 - S	5.78	5.08E-01	1.43E-02	2.82	-0.94								≥ EOL	5.10E-01	1.06E-02	2.08
DU1 - P	5.78	5.13E-01	1.58E-02	3.09												
GU3 - S	5.35	4.05E-01	1.24E-02	3.06	-4.58								≥ EOL	4.13E-01	9.27E-03	2.24
GU3 - I	5.35	4.24E-01	1.40E-02	3.29												
DM2	3.78	5.60E-01	1.53E-02	2.73												
DM3	5.12	7.13E-01	1.09E-02	1.53												
DM4	4.00	7.24E-01	1.11E-02	1.53												
GU1	6.09	4.55E-01	2.24E-02	4.91												
BM6	3.69	8.58E-01	3.61E-02	4.21												
GU4	3.16	3.29E-01	7.92E-03	2.41												

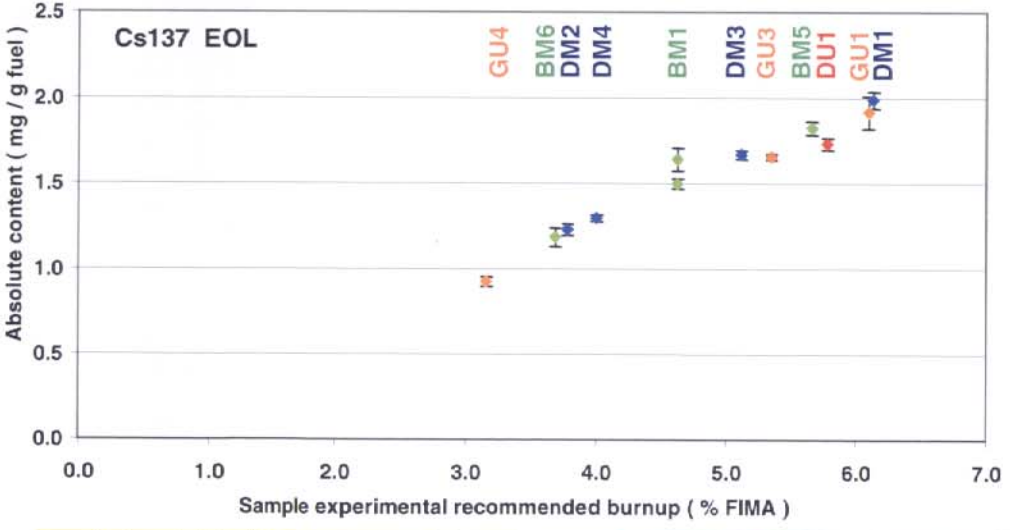


value is maintained | value is maintained but no recommendation | results are within uncertainties and combined

Table 5.3 / 53 - Results analysis and recommended values - Cs137

Cs137

Sample	Burnup	At analysis content x	At analysis 95% uncertainty Δx	At analysis Δx / x	At analysis $x_S-x_{P/I}/x_S$	at EOL (*) content x	at EOL (*) 95% uncertainty Δx	at EOL (*) Δx / x	at EOL (*) $x_S-x_{P/I}/x_S$	At last date content x	At last date 95% uncertainty Δx	At last date Δx / x	(*)Recommended date	(*)Recommended content x	(*)Recommended 95% uncertainty Δx	(*)Recommended Δx / x
	% FIMA	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%	%	mg/gfuel	mg/gfuel	%		mg/gfuel	mg/gfuel	%
BM1 - S	4.62	1.36E+00	2.67E-02	1.96	-3.94	1.50E+00	2.94E-02	1.96	-9.46							
BM1 - P	4.62	1.42E+00	5.84E-02	4.13		1.64E+00	6.76E-02	4.13								
BM5 - S	5.66	1.67E+00	5.07E-02	3.04	-3.76	1.79E+00	5.43E-02	3.04	-4.17				EOL	1.82E+00	3.93E-02	2.15
BM5 -P	5.66	1.73E+00	5.28E-02	3.05		1.86E+00	5.68E-02	3.05								
DM1 - S	6.13	1.81E+00	5.79E-02	3.20	4.18	1.97E+00	6.31E-02	3.20	-1.95				EOL	1.99E+00	4.97E-02	2.50
DM1 - P	6.13	1.73E+00	6.95E-02	4.01		2.01E+00	8.05E-02	4.01								
DU1 - S	5.78	1.57E+00	4.41E-02	2.80	4.78	1.71E+00	4.81E-02	2.80	-1.83				EOL	1.73E+00	3.52E-02	2.04
DU1 - P	5.78	1.50E+00	4.45E-02	2.97		1.75E+00	5.18E-02	2.97								
GU3 - S	5.35	1.59E+00	4.83E-02	3.04	0.36	1.66E+00	5.06E-02	3.04	0.72				EOL	1.65E+00	1.72E-02	1.04
GU3 - I	5.35	1.58E+00	1.75E-02	1.10		1.65E+00	1.82E-02	1.10								
DM2	3.78	1.10E+00	3.00E-02	2.71		1.23E+00	3.34E-02	2.71								
DM3	5.12	1.46E+00	2.18E-02	1.50		1.67E+00	2.49E-02	1.50								
DM4	4.00	1.16E+00	1.73E-02	1.49		1.30E+00	1.94E-02	1.49								
GU1	6.09	1.79E+00	8.76E-02	4.90		1.91E+00	9.38E-02	4.90								
BM6	3.69	1.10E+00	5.00E-02	4.54		1.19E+00	5.38E-02	4.54								
GU4	3.16	8.77E-01	2.63E-02	3.00		9.25E-01	2.78E-02	3.00								



value is maintained

value is maintained but no recommendation

results are within uncertainties and combined

Table 5.4 Sample burnup recommendation

	Sample		BM1	BM3	BM4-D	BM5	BM6
Calculated burnup	(GWd/tM)		47.02	48.48	37.94	58.85	39.57
Calculated burnup	(% FIMA)	(1)	4.75	4.90	3.83	5.94	4.00
CEN							
Experimental burnup(*)	(% FIMA)	(2)	4.56			5.68	
Comparison (1) - (2) / (2)	(%)		4.2			4.6	
PSI							
Experimental burnup(*)	(% FIMA)	(3)	4.68	4.76	4.29	5.63	3.69
Comparison (1) - (3) / (3)	(%)		1.4	2.9	-10.7	5.5	8.4
Comparison (2) - (3) / (2)	(%)		-2.7			0.9	
Recommended value	(% FIMA)		**4.6**			**5.7**	**3.7**

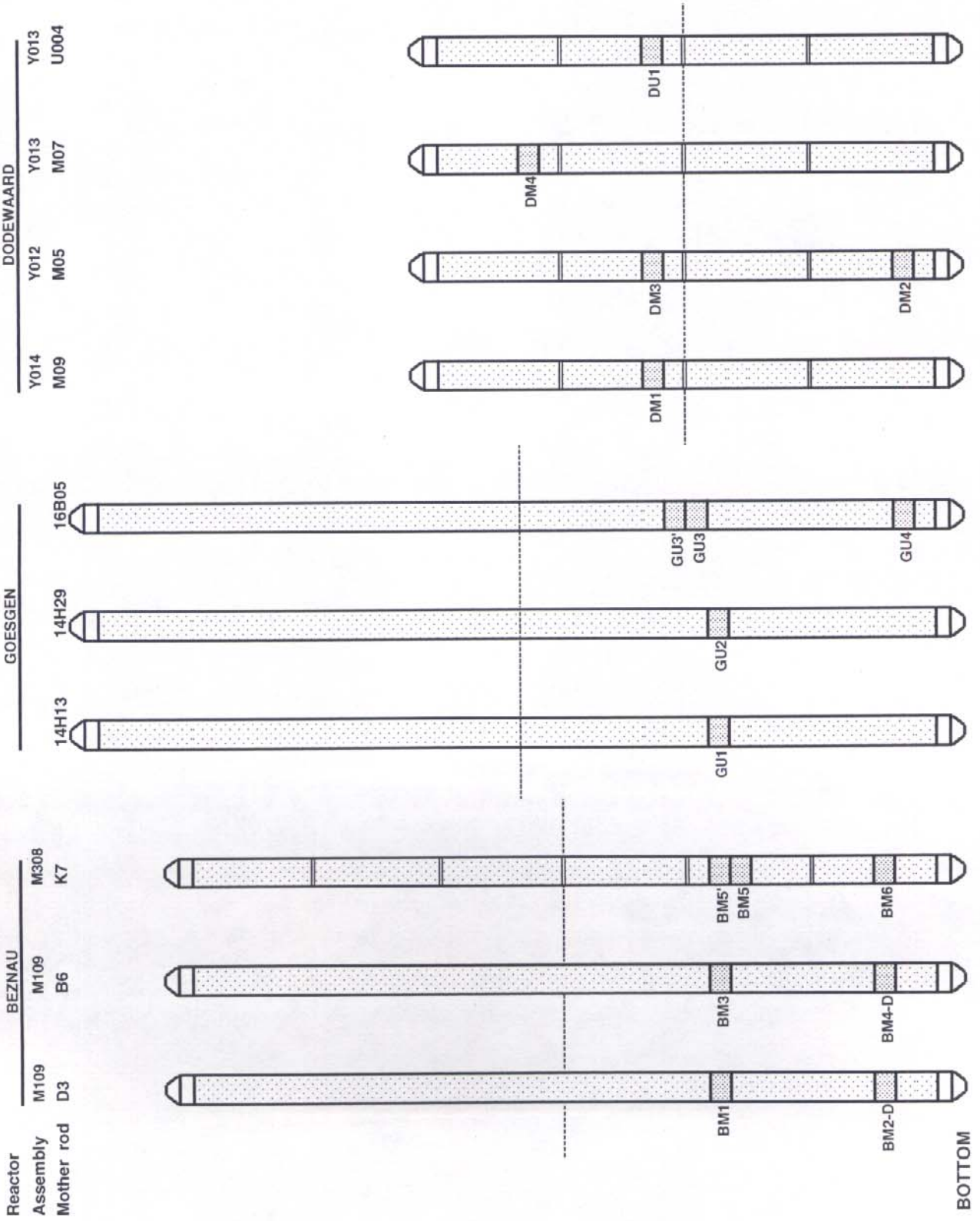
	Sample		DM1	DM2	DM3	DM4	DU1
Calculated burnup	(GWd/tM)		55.65	33.53	46.53	38.14	54.40
Calculated burnup	(% FIMA)	(1)	5.62	3.39	4.70	3.85	5.61
CEN							
Experimental burnup(*)	(% FIMA)	(2)	6.21	3.78	5.12	4.00	5.78
Comparison (1) - (2) / (2)	(%)		-9.5	-10.5	-8.1	-3.7	-2.9
PSI							
Experimental burnup(*)	(% FIMA)	(3)	6.05				5.77
Comparison (1) - (3) / (3)	(%)		-7.1				-2.8
Comparison (2) - (3) / (2)	(%)		2.6				0.1
Recommended value	(% FIMA)		**6.1**	**3.8**	**5.1**	**4.0**	**5.8**

	Sample		GU1	GU3	GU4
Calculated burnup	(GWd/tM)		59.66	52.50	29.07
Calculated burnup	(% FIMA)	(1)	6.15	5.41	3.00
CEN					
Experimental burnup(*)	(% FIMA)	(2)	6.09	5.35	
Comparison (1) - (2) / (2)	(%)		0.9	1.2	
ITU					
Experimental burnup(*)	(% FIMA)	(3)		5.11	3.16
Comparison (1) - (3) / (3)	(%)			6.0	-5.1
Comparison (2) - (3) / (2)	(%)			4.5	
Recommended value	(% FIMA)		**6.1**	**5.3**	**3.2**

(*) Burnup estimation : [measured Nd148 atoms / yield] / inferred initial metal atoms

Experimental average **ITU rejected**

Fig. 1.1 -- Cutting of the ARIANE samples



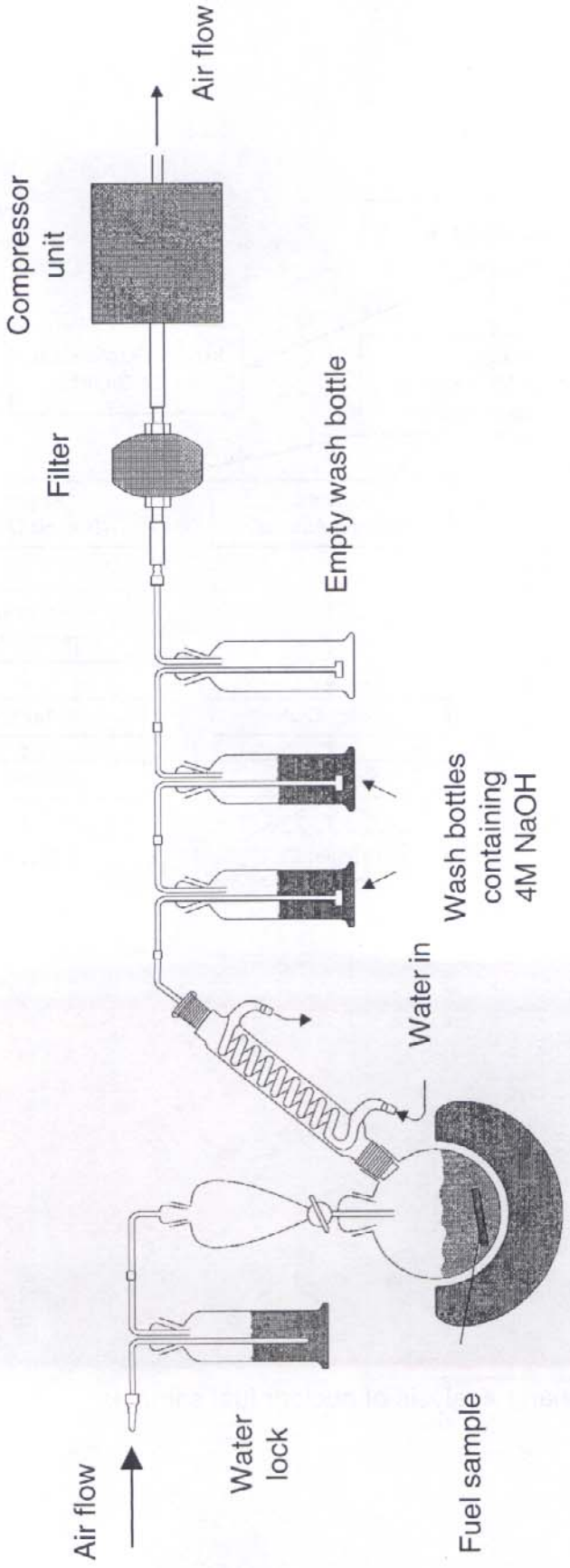


Figure 2.1 Iodine trapping system at PSI, based on SCK.CEN concept.

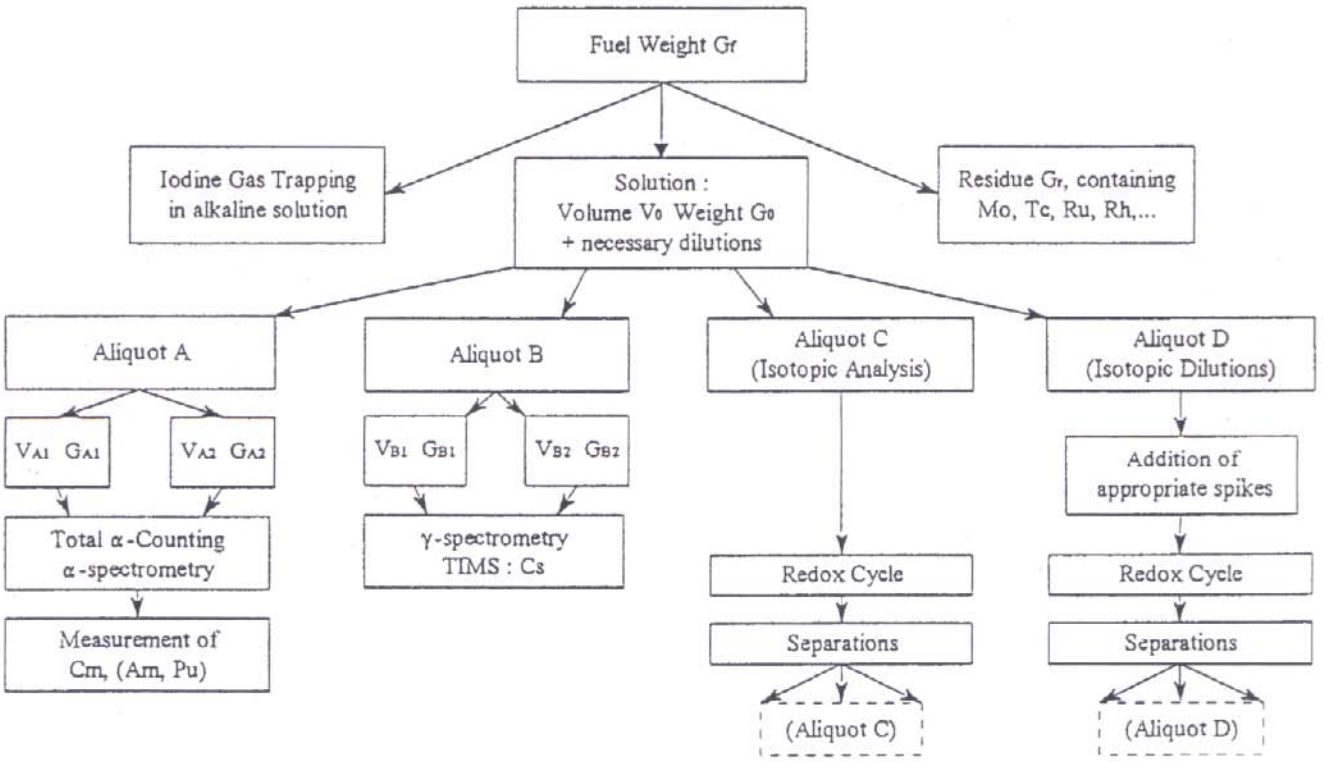
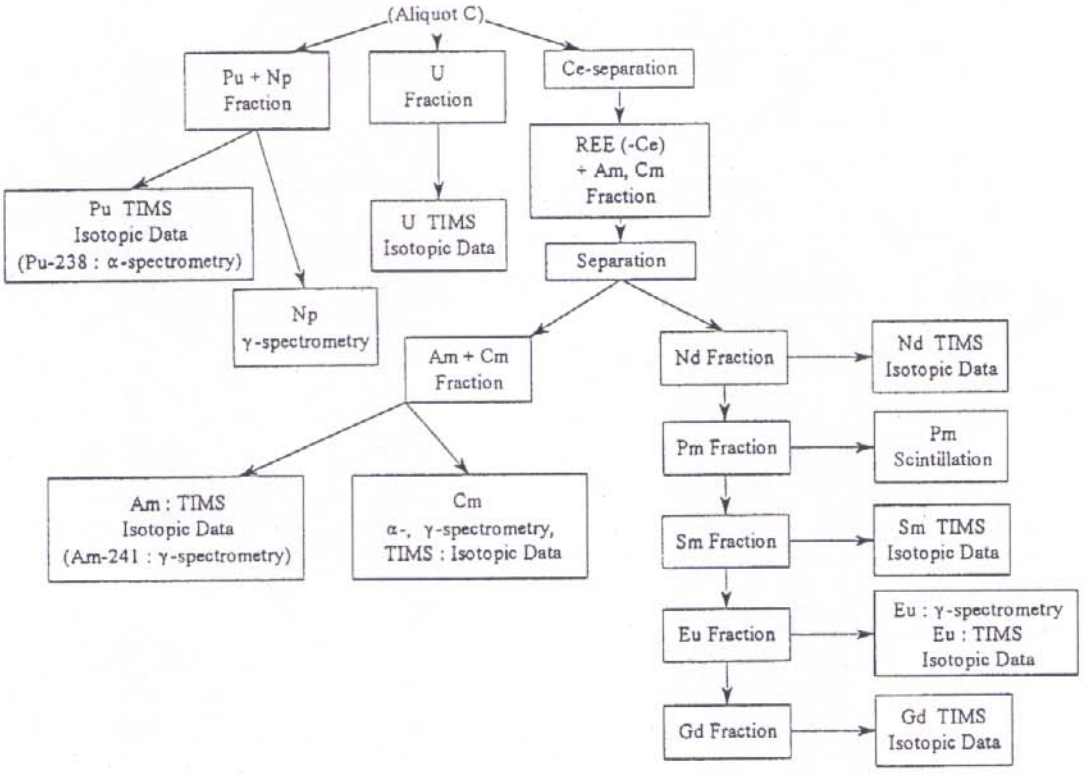


Figure 2.2 SCK.CEN flowchart : analysis of nuclear fuel samples



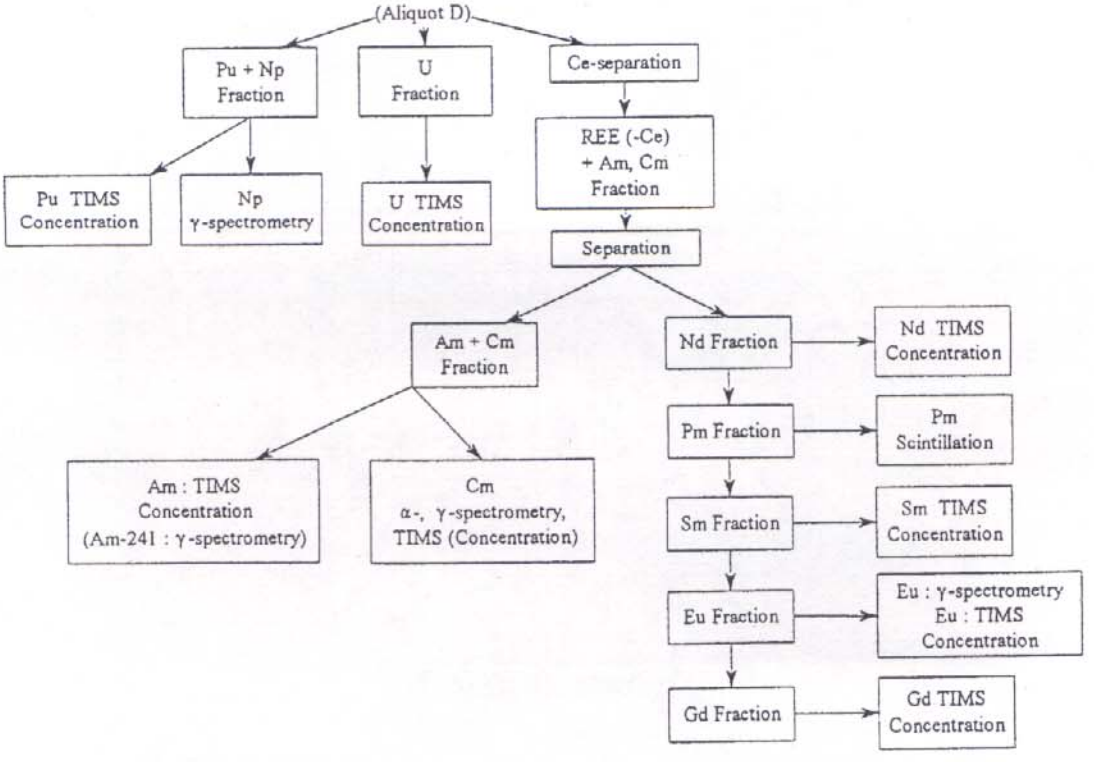


Figure 2.3 SCK.CEN flowchart of analysis of aliquots C and D

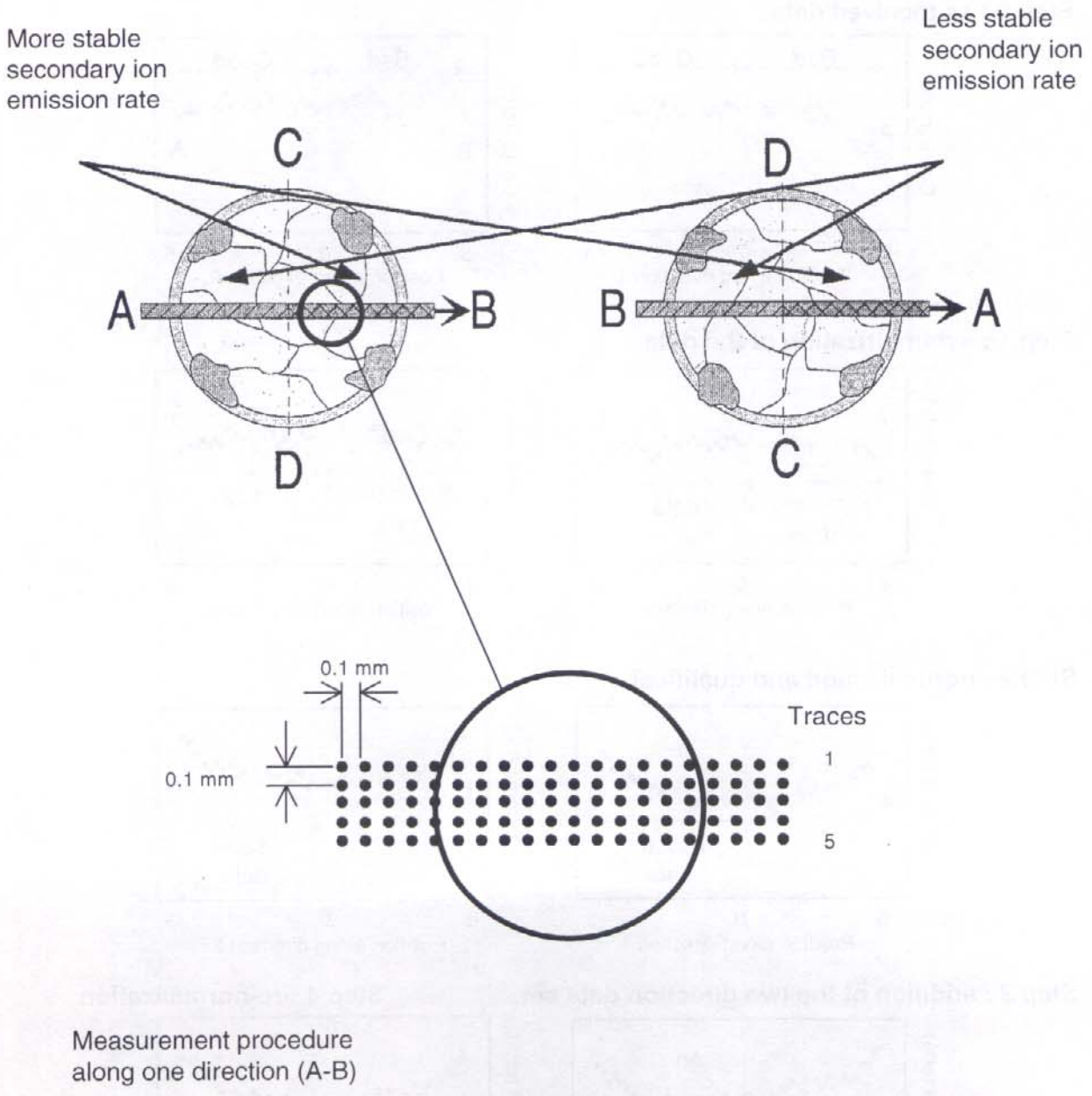


Figure 4.1 Secondary ion emission rate stability along a sample diameter. Local magnification illustrates the measurement procedure.

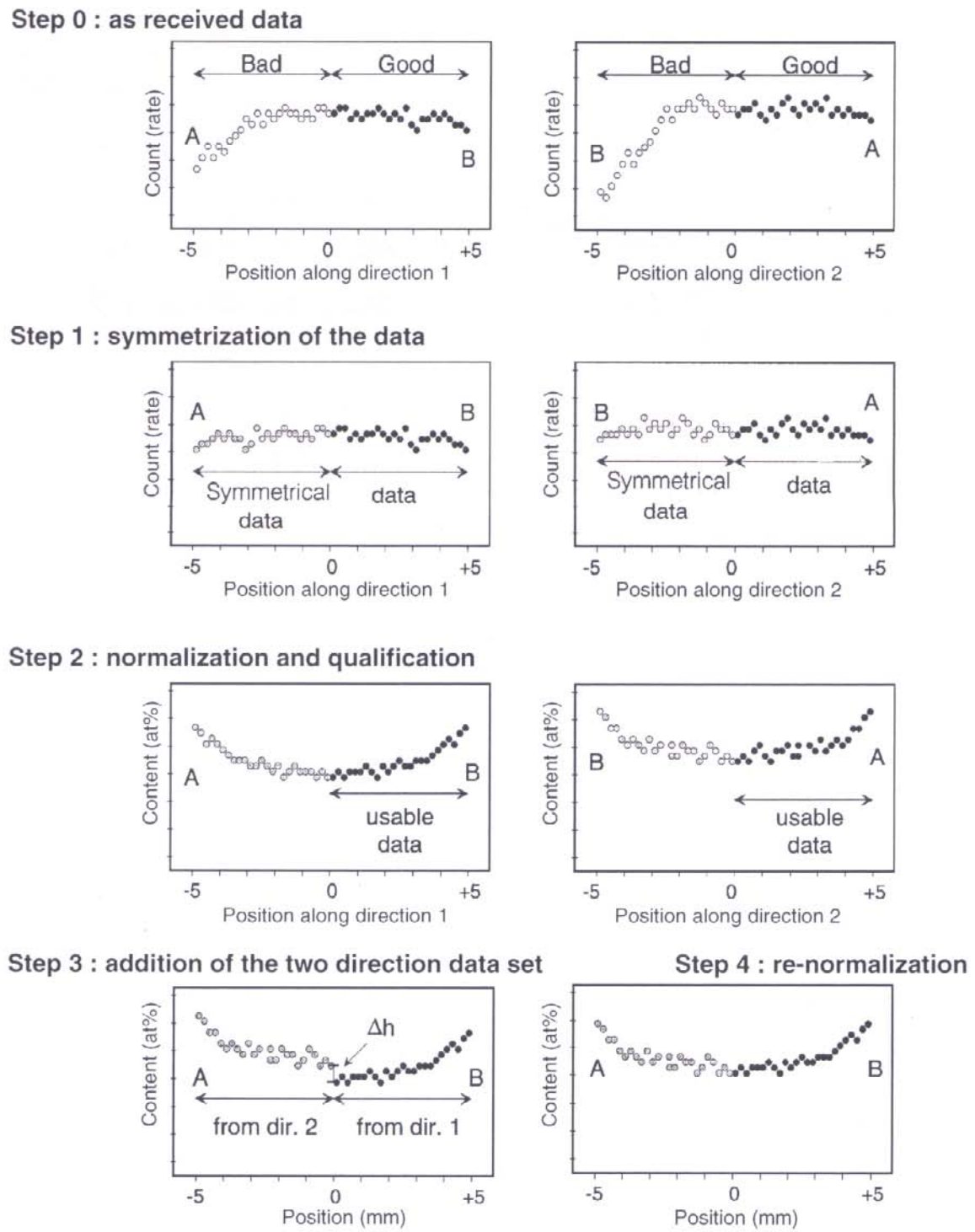


Figure 4.2 Data analysis procedure along reverse directions 1 and 2.

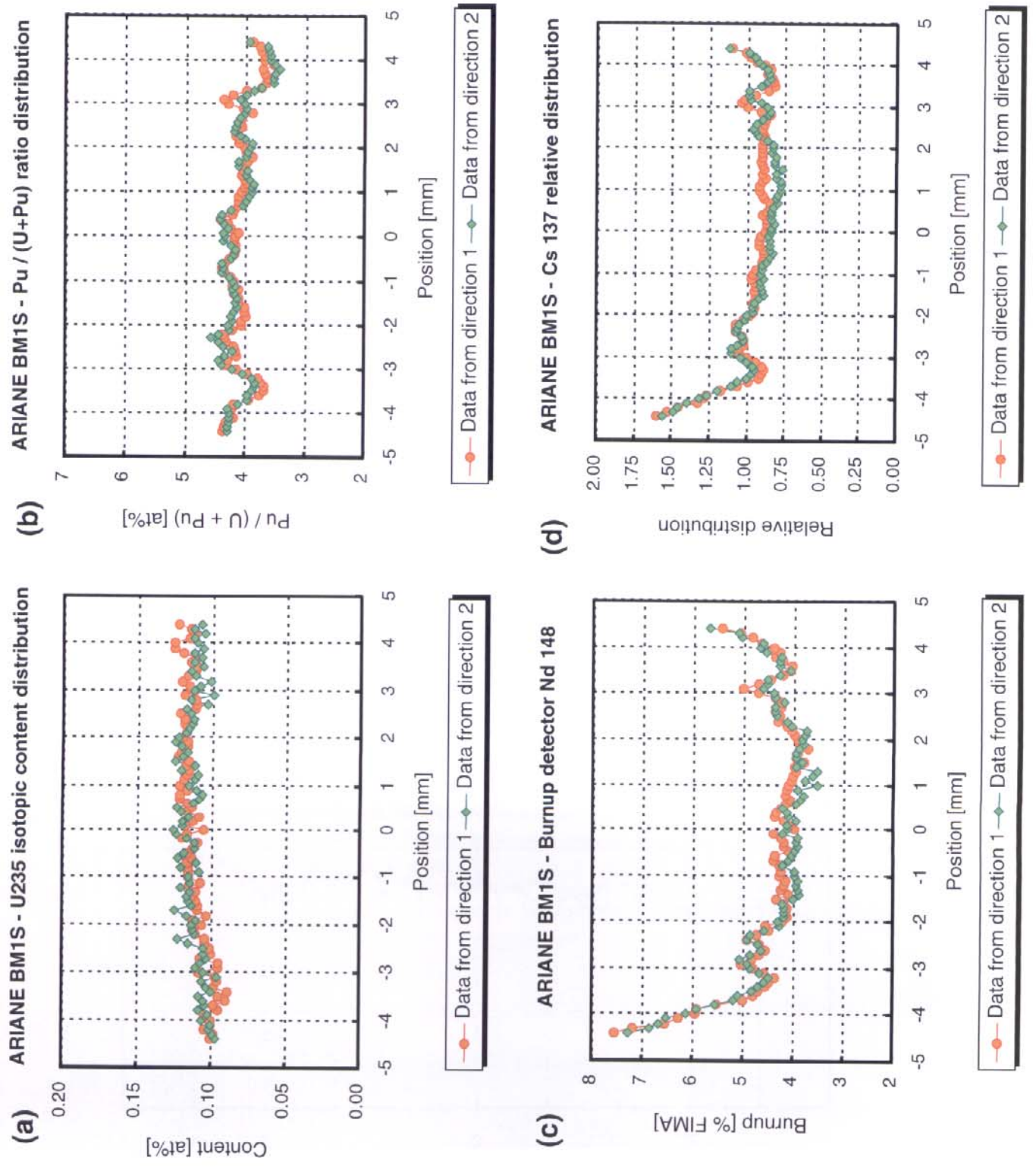


Fig. 4-3: Sample BM1S. Illustration of reproducibility of SIMS results for U 235, Pu / (U+Pu), burnup and Cs 137. Directions 1 and 2 are parallel and measurements are made in the same direction.

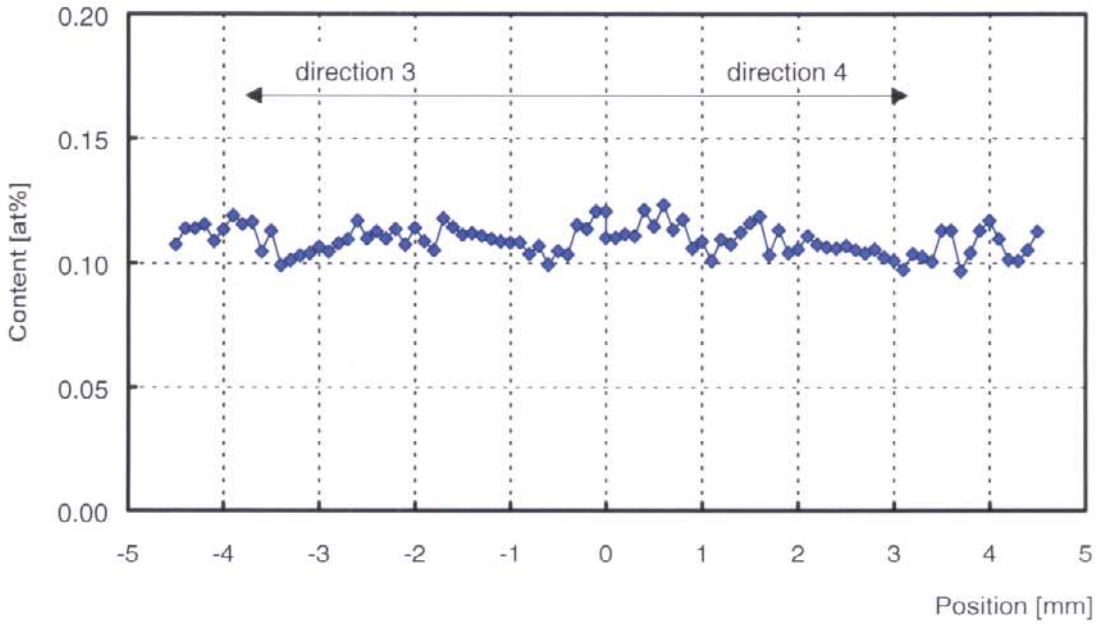


Fig. 4-4 Sample BM1S, local isotopic U235 distribution [at%] along directions 3 and 4

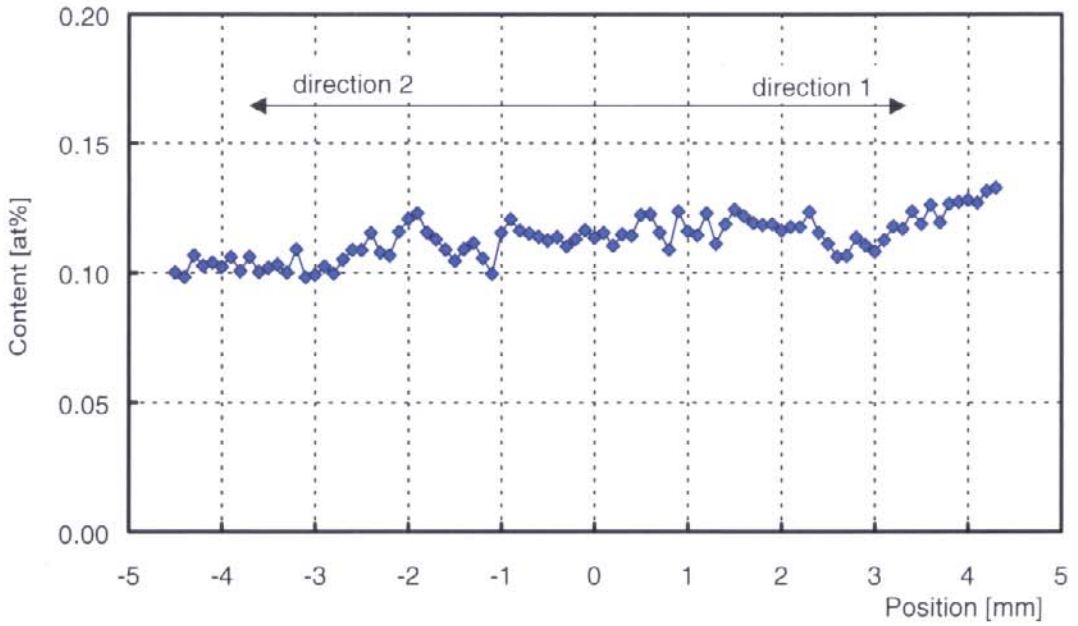


Fig. 4-5 Sample BM3S, local isotopic U235 distribution [at%] along directions 1 and 2

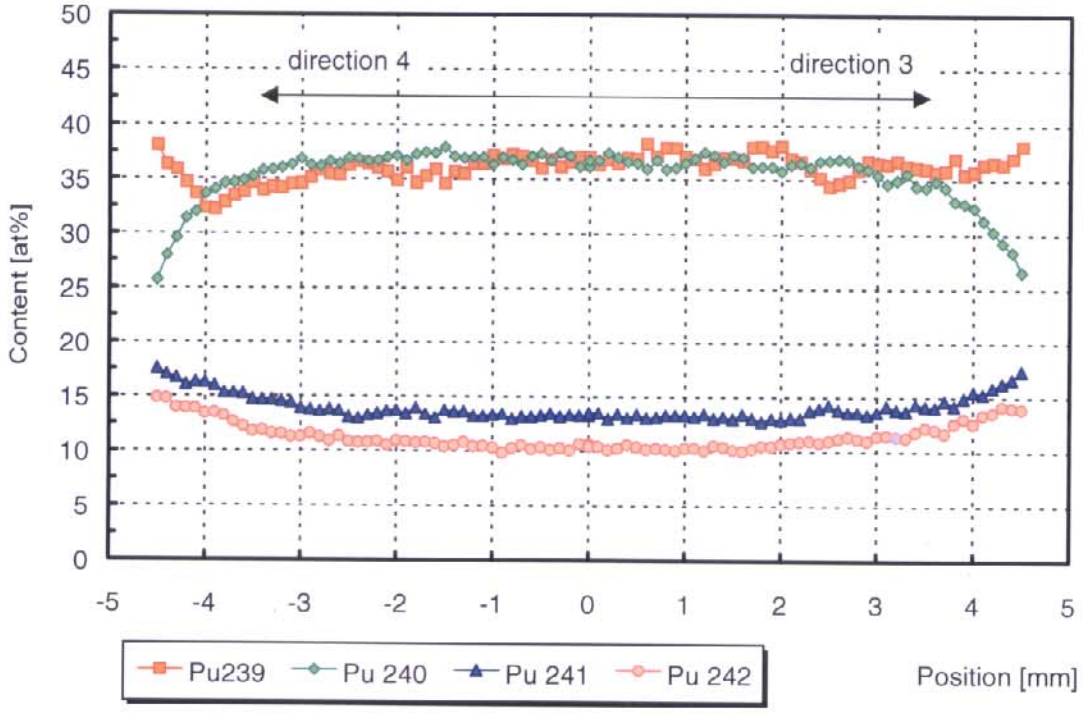


Fig. 4-6 Sample BM1S, local isotopic Pu distribution [at%] along directions 3 and 4

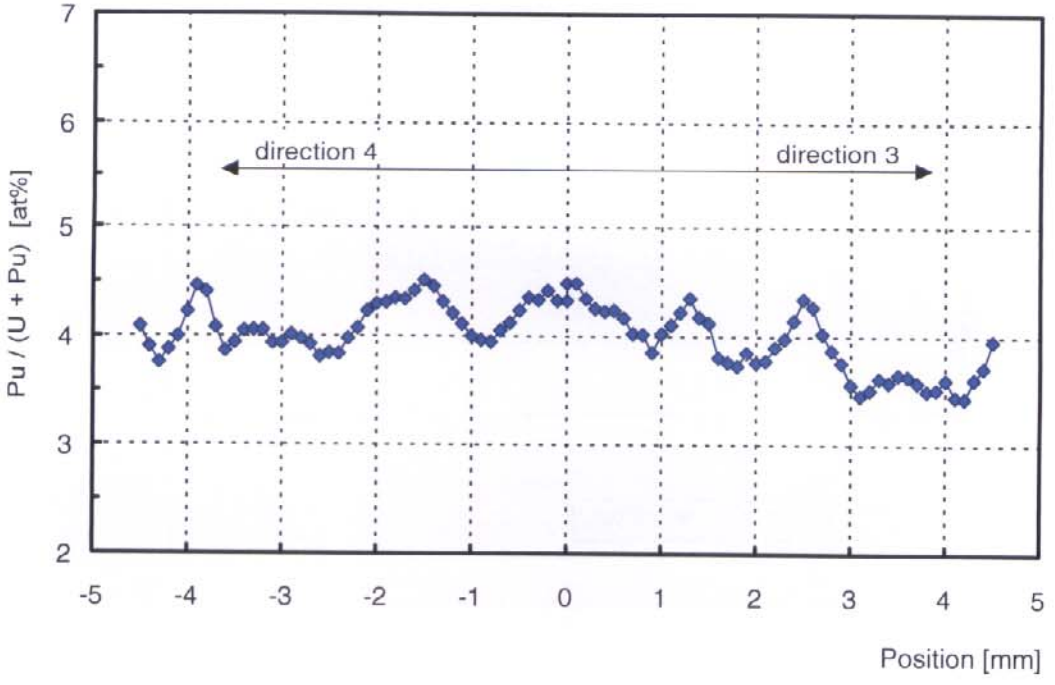


Fig. 4-7 -- Sample BM1S, Pu/(U+Pu) ratio distribution along directions 3 and 4

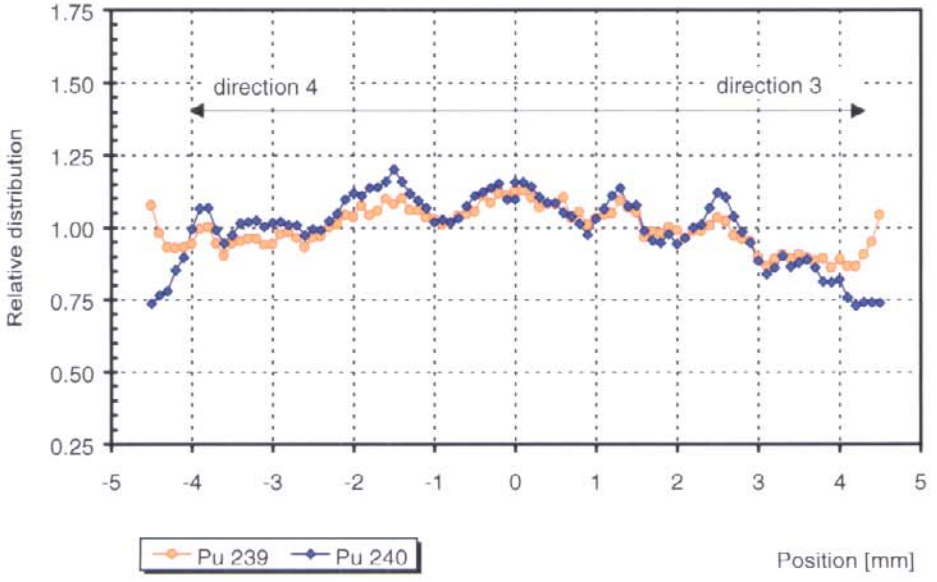


Fig. 4-8 -- Sample BM1S, Pu 239 and Pu 240 distribution (relative to average concentration) along directions 3 and 4

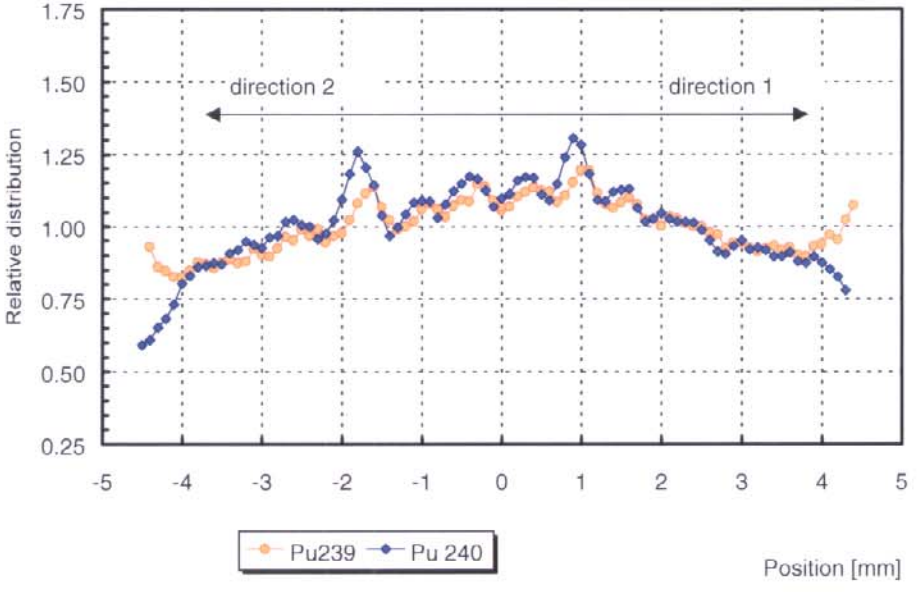


Fig. 4-9 -- Sample BM3S, PU 239 and Pu 240 distribution (relative to average concentration) along directions 1 and 2

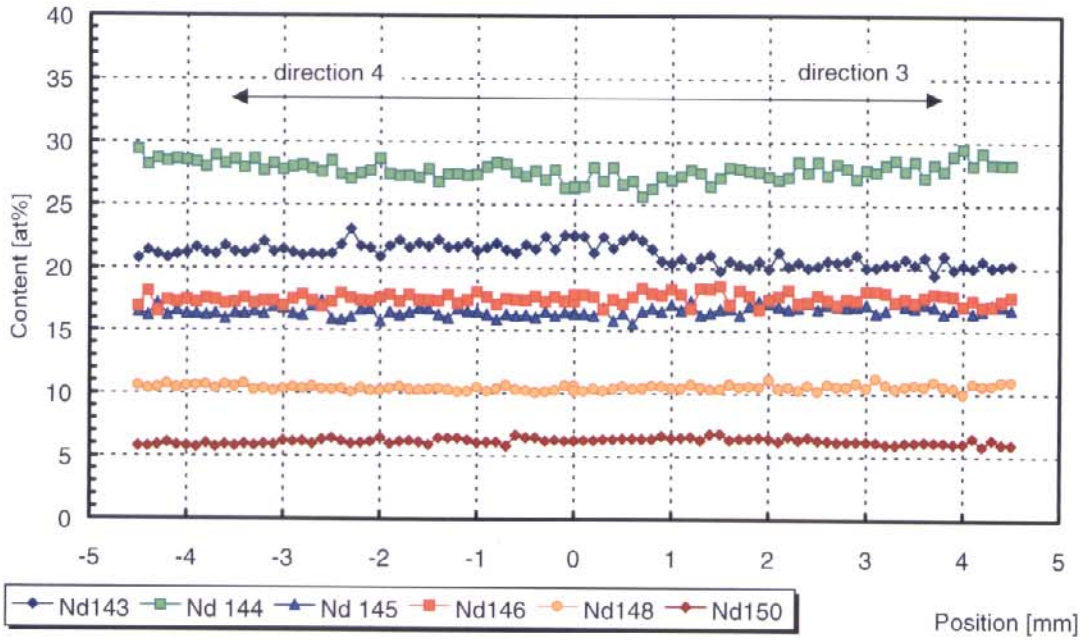


Fig. 4-10 -- Sample BM1S, local isotopic Nd composition [at%] along directions 3 and 4

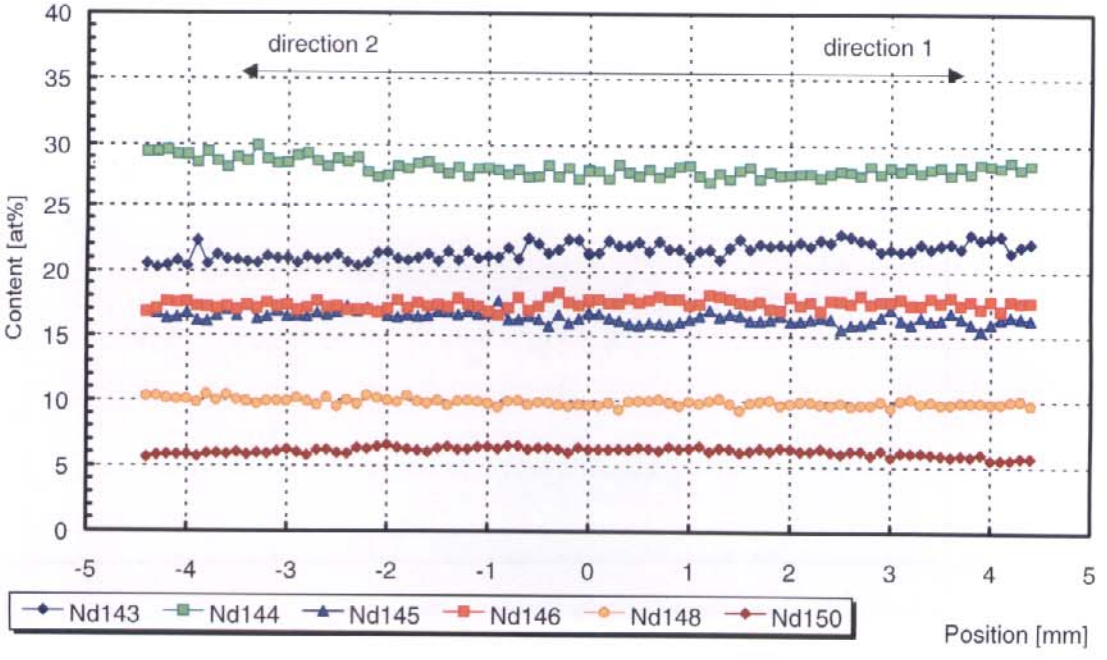


Fig. 4-11 -- Sample BM3S, local isotopic Nd composition [at%] along directions 1 and 2

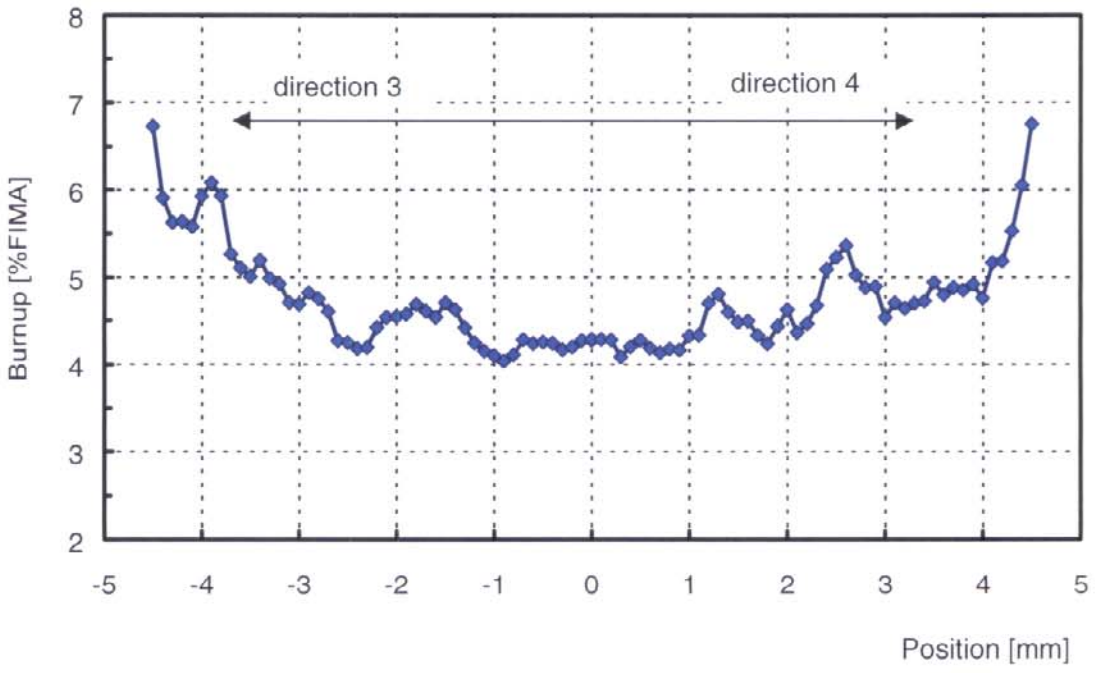


Fig. 4-12 -- Sample BM1S, burnup distribution [%FIMA] along directions 3 and 4

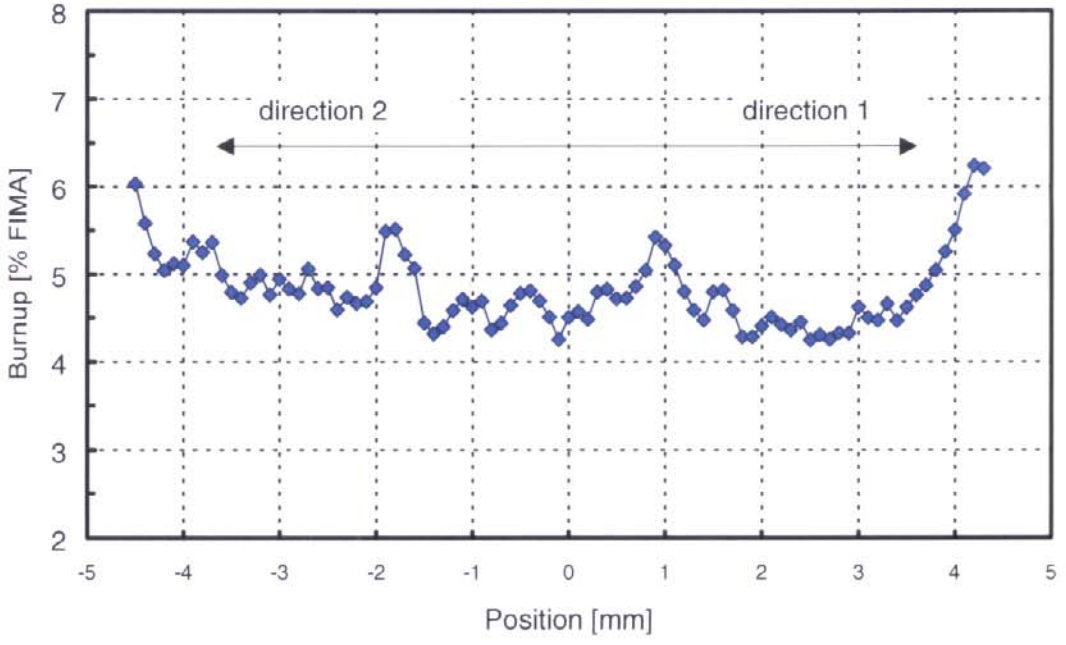


Fig. 4-13 Sample BM3S, burnup distribution [GWd/tM] along directions 1 and 2

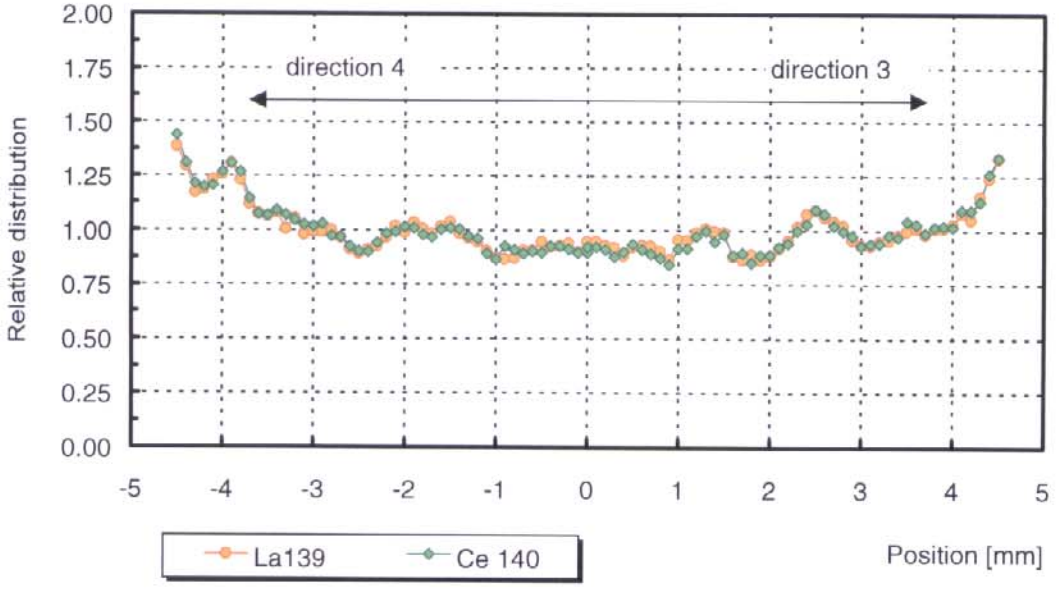


Fig. 4-14 -- Sample BM1S, relative distribution of fission products La 139 and Ce 140 normalized to an average value of 1, along directions 3 and 4

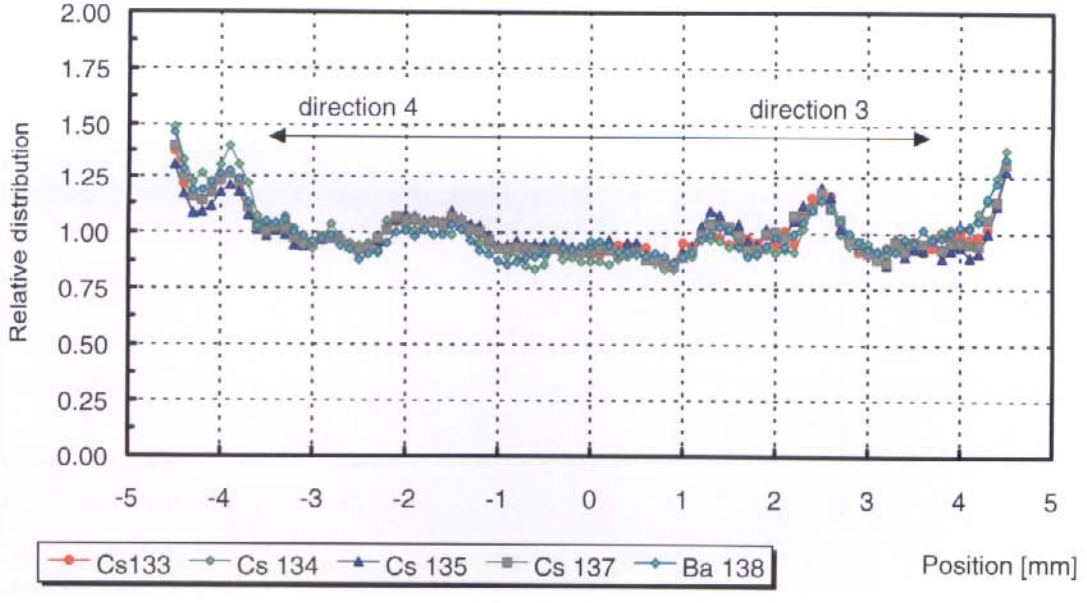


Fig. 4-15 -- Sample BM1S, relative distribution of fission products Cs 133, Cs 134, Cs 135, Cs 137 and Ba 138 normalised to an average value of 1 along directions 3 and 4

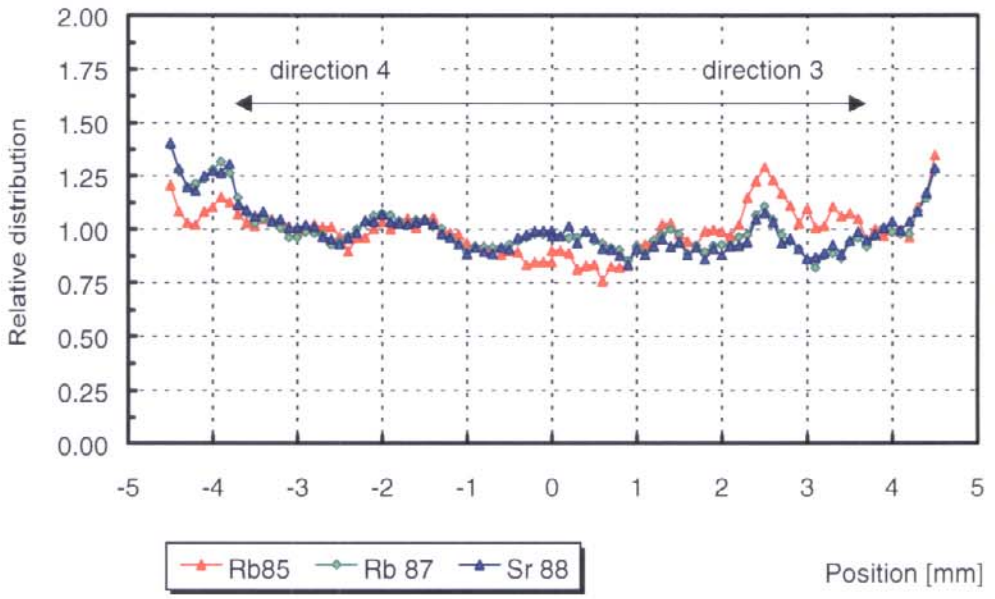


Fig. 4-16 -- Sample BM1S, relative distribution of fission products Rb 85, Rb 87 and Sr 88, normalised to an average value of 1, along directions 3 and 4

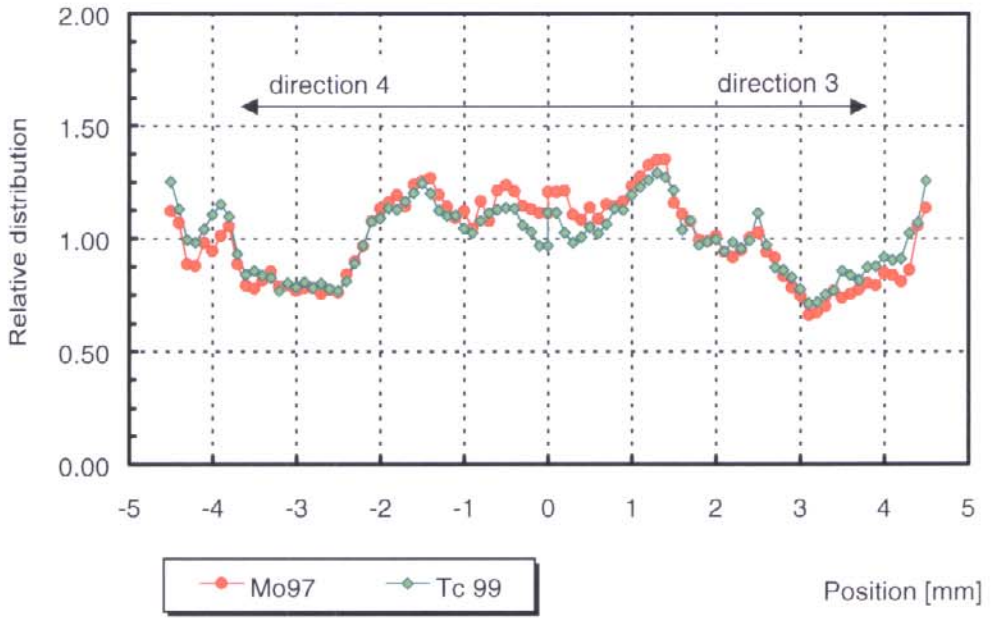
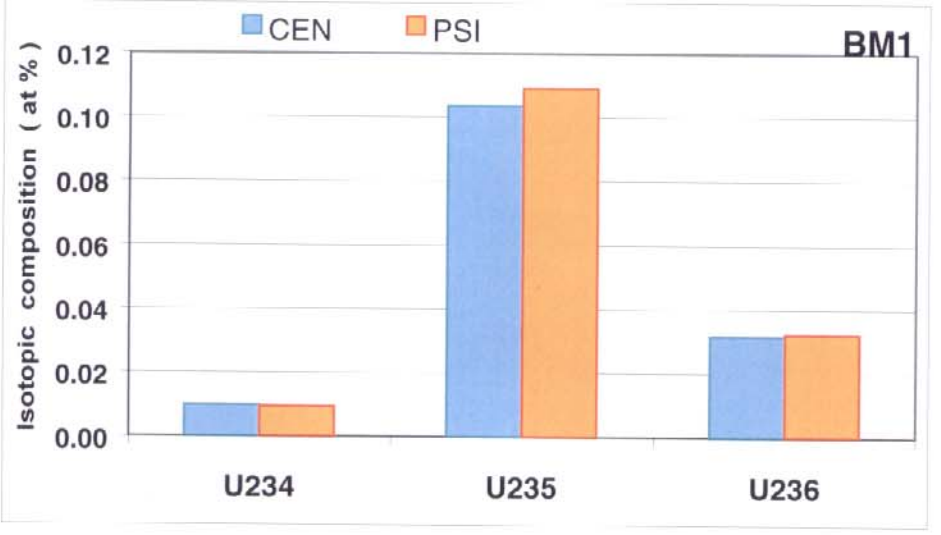
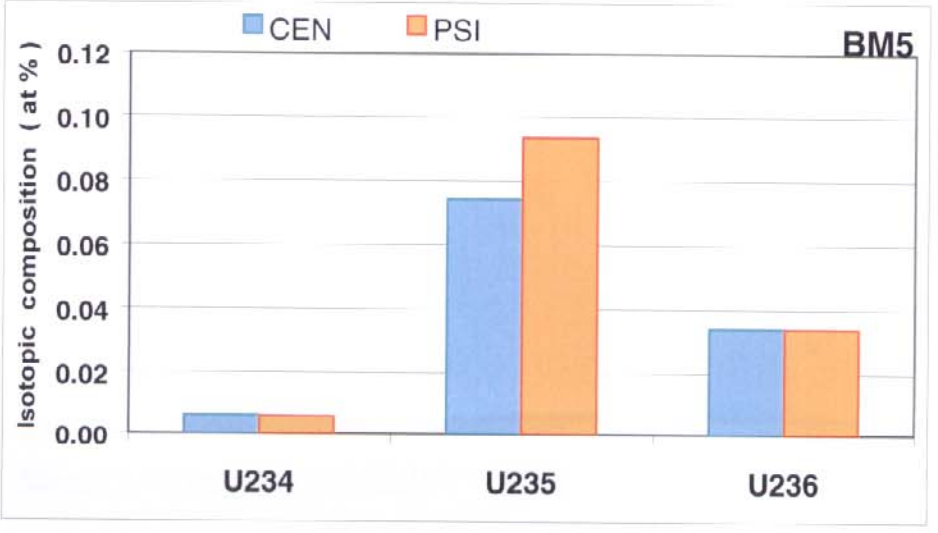


Fig. 4-17 -- Sample BM1S, relative distribution of fission products Mo 97 and Tc 99 normalised to an average value of 1 along directions 3 and 4

Figure 5.1 / 1 - Comparison of the U isotopic vectors MOX samples (at % at cross-check date)





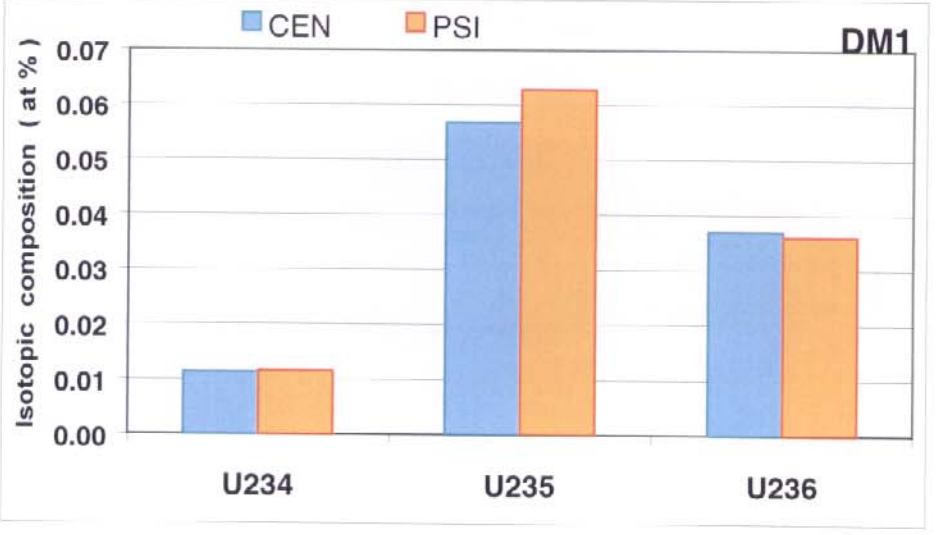
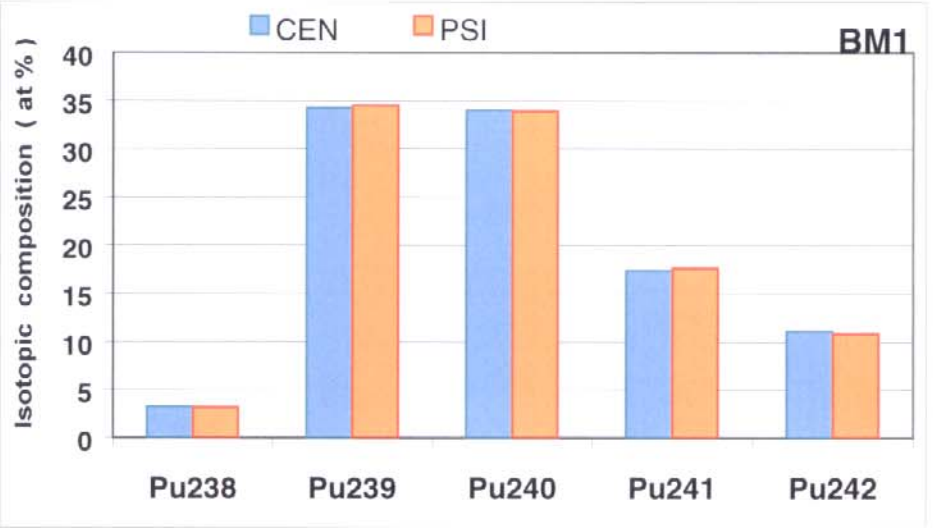
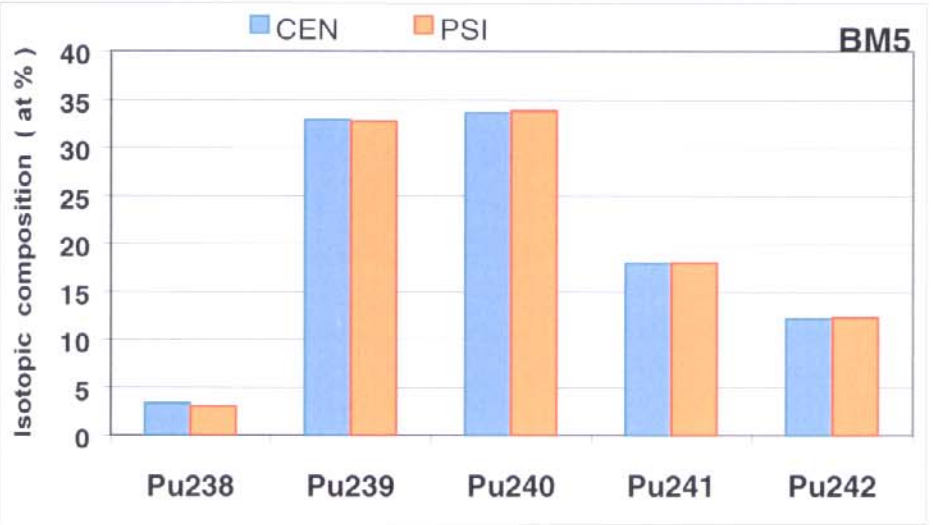


Figure 5.1 / 2 - Comparison of the Pu isotopic vectors MOX samples (at % at cross-check date)





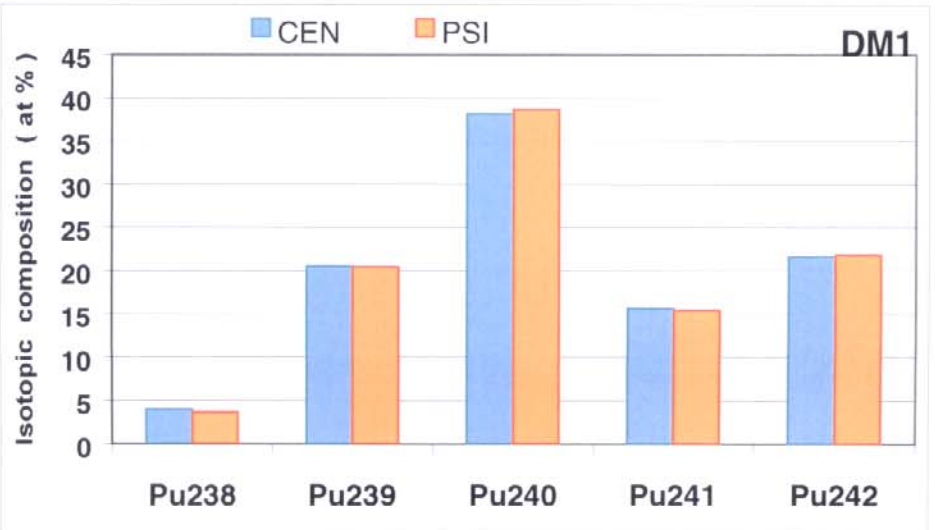
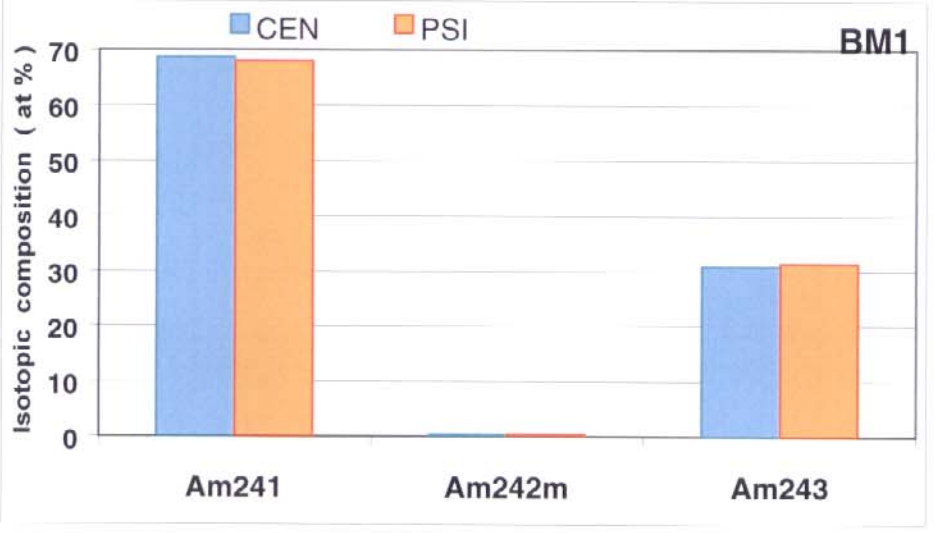
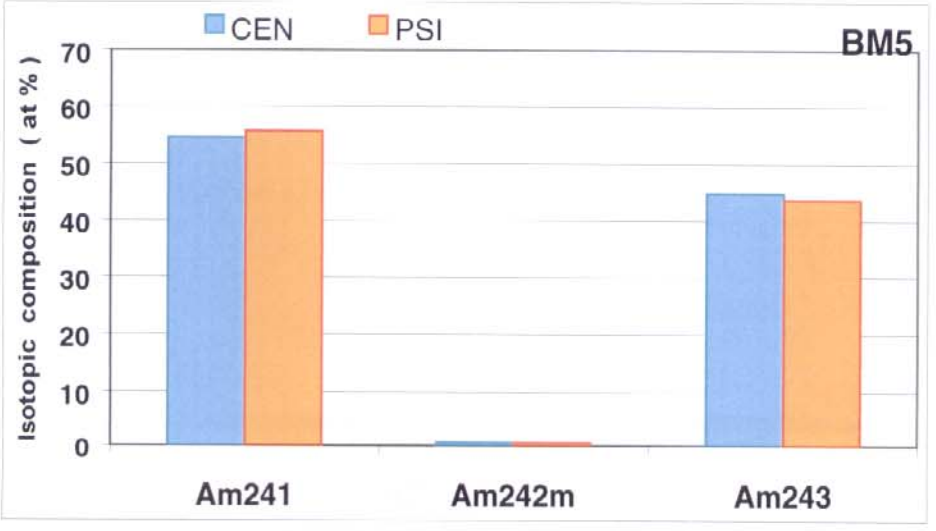


Figure 5.1 / 3 - Comparison of the Am isotopic vectors MOX samples (at % at cross-check date)





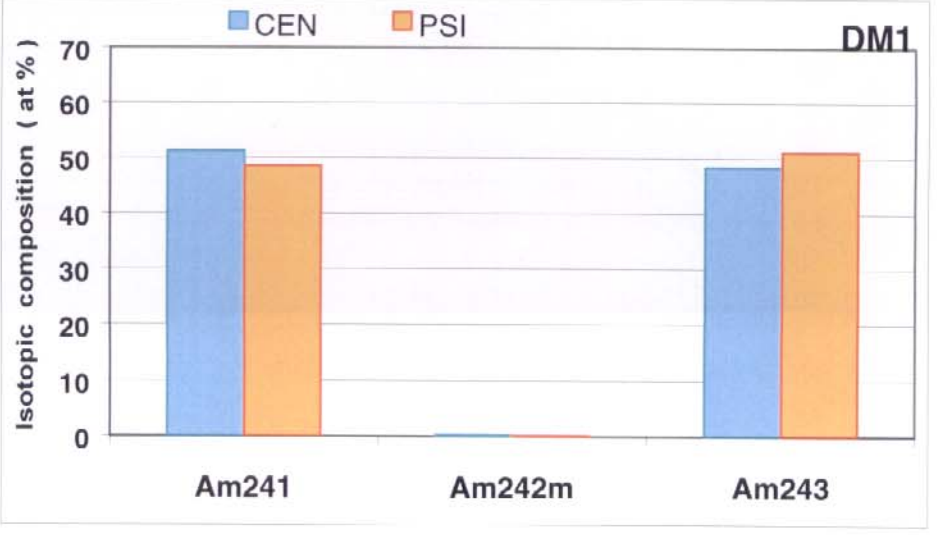
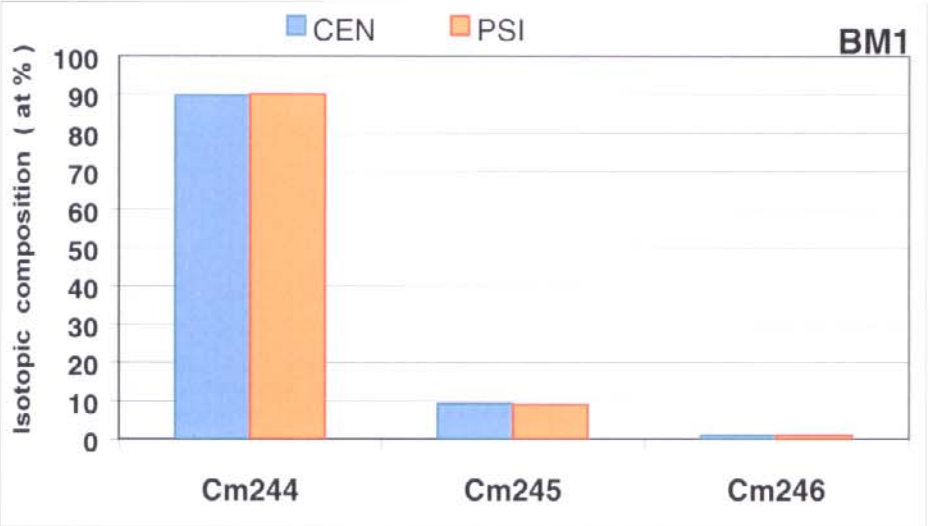
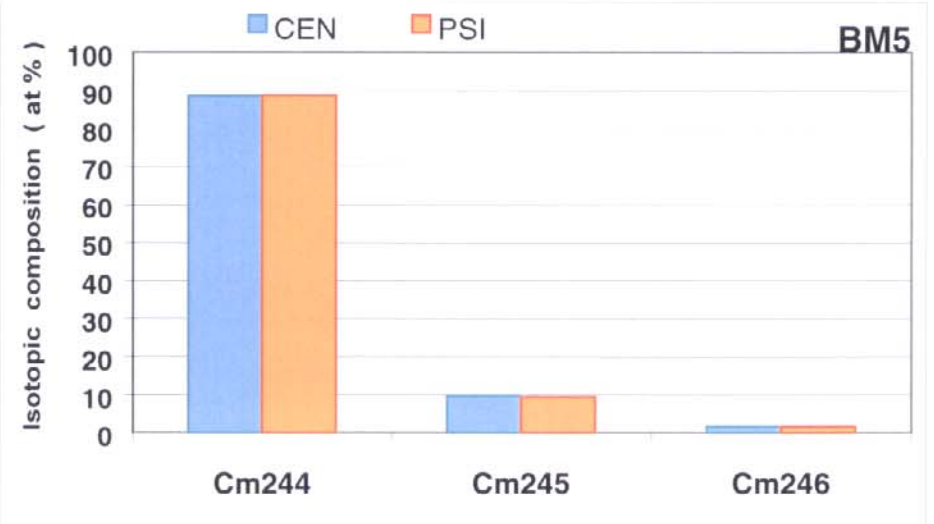


Figure 5.1 / 4 - Comparison of the Cm isotopic vectors MOX samples (at % at cross-check date)





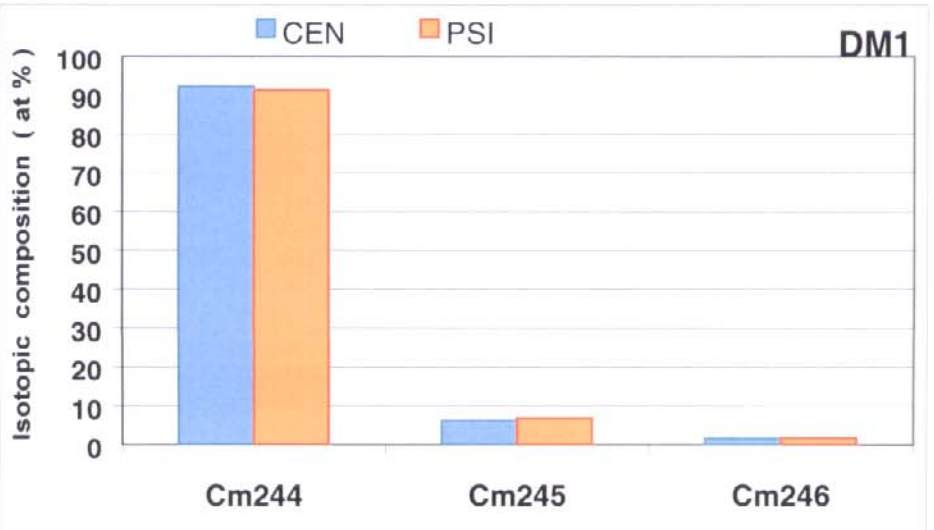
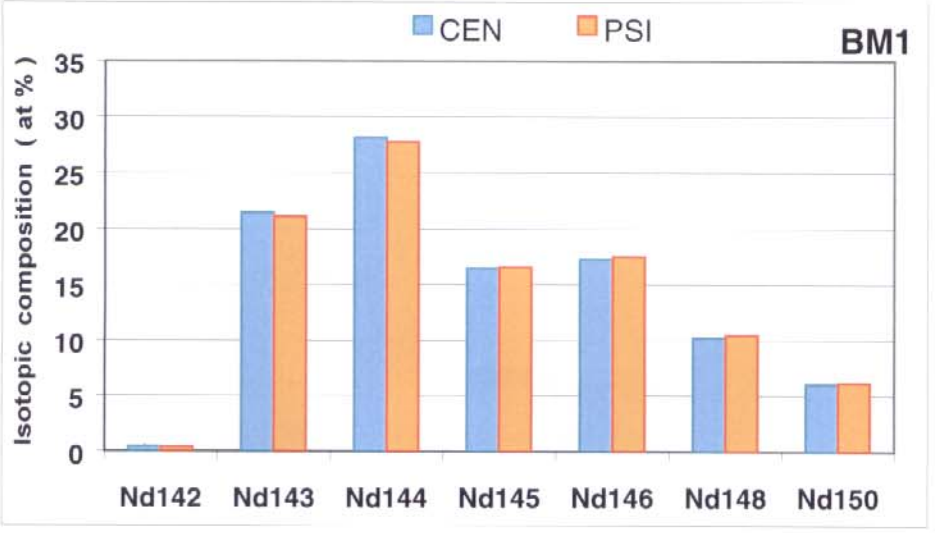
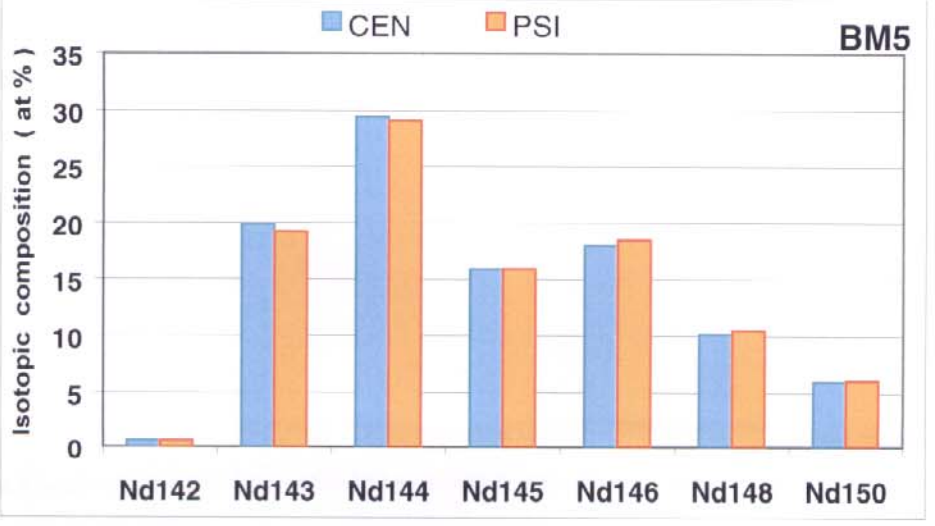


Figure 5.1 / 5 - Comparison of the Nd isotopic vectors MOX samples (at % at cross-check date)





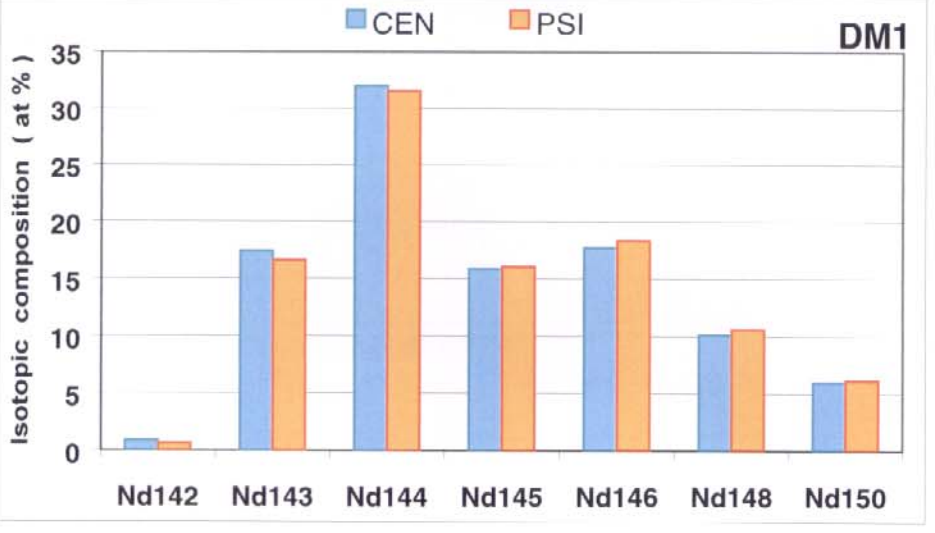
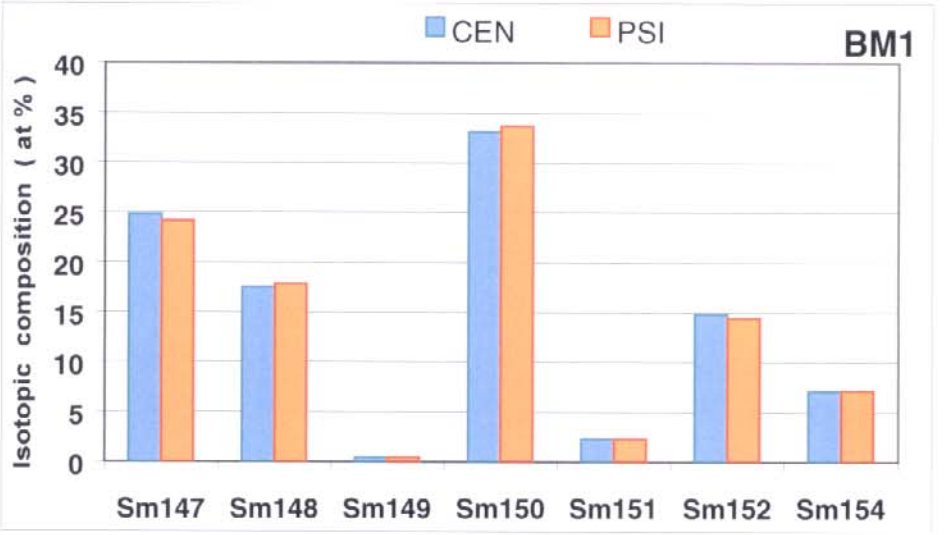
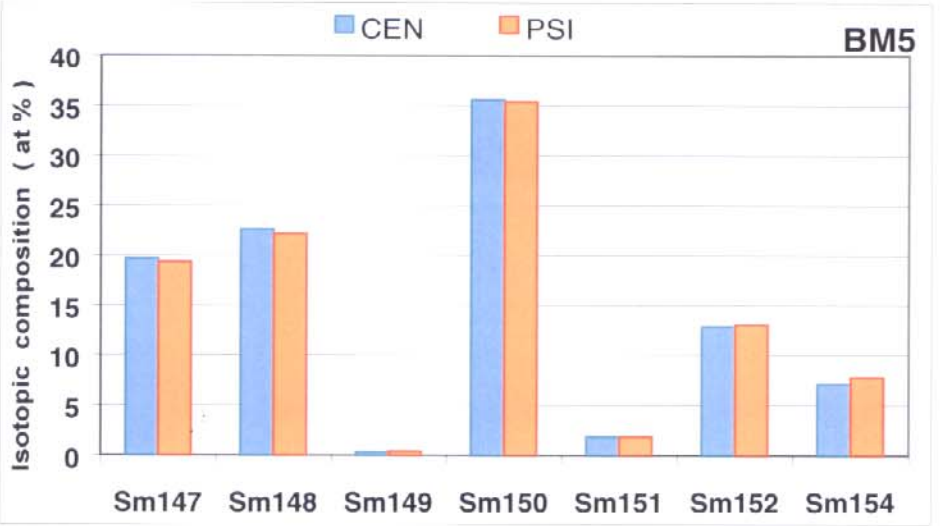
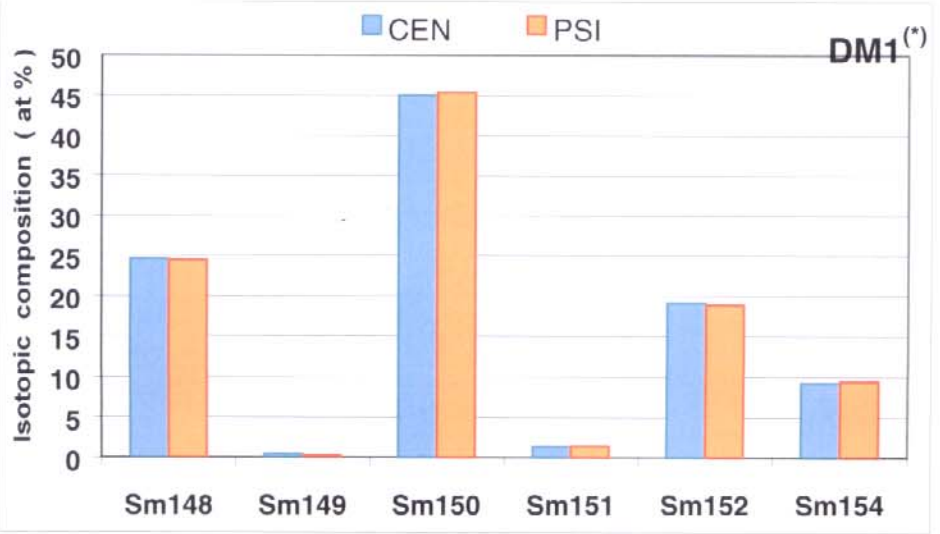


Figure 5.1 / 6 - Comparison of the Sm isotopic vectors MOX samples (at % at cross-check date)

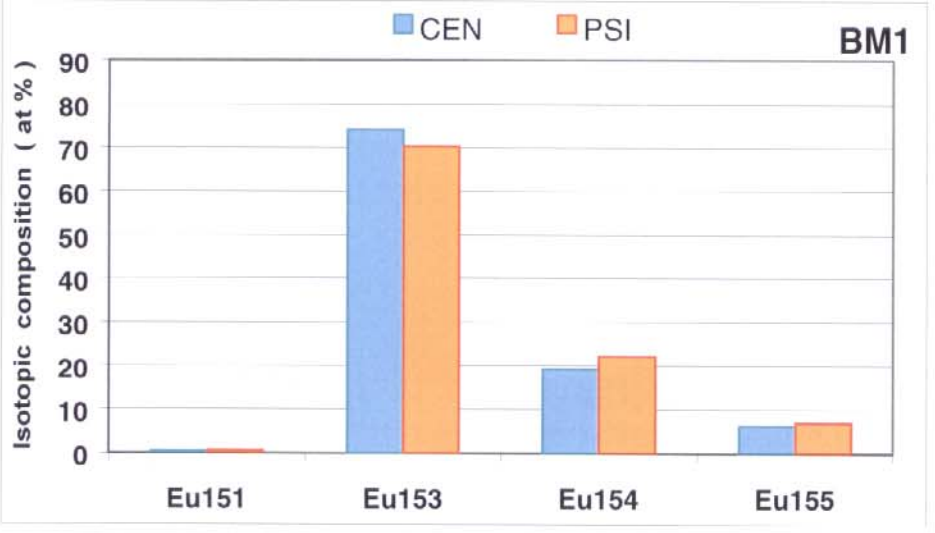


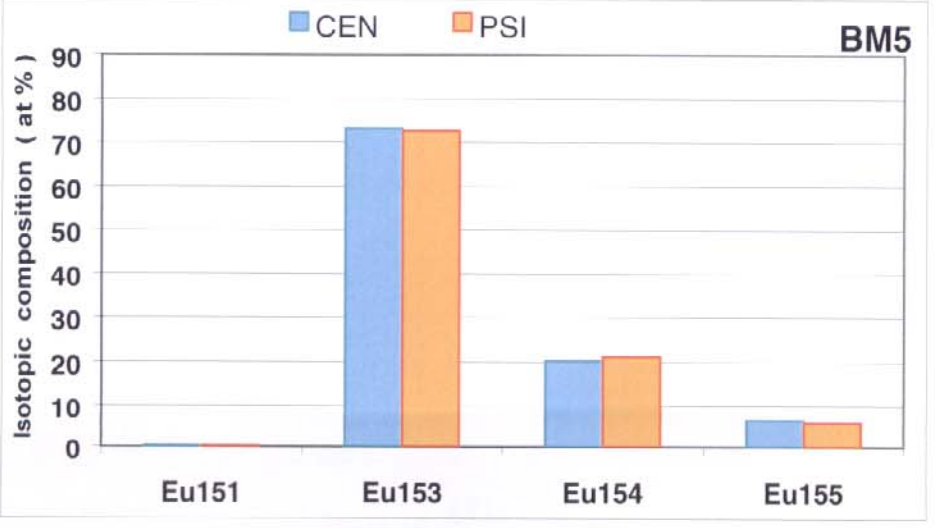




(*) no possible cross-check of Sm147 for sample DM1

Figure 5.1 / 7 - Comparison of the Eu isotopic vectors MOX samples (at % at cross-check date)





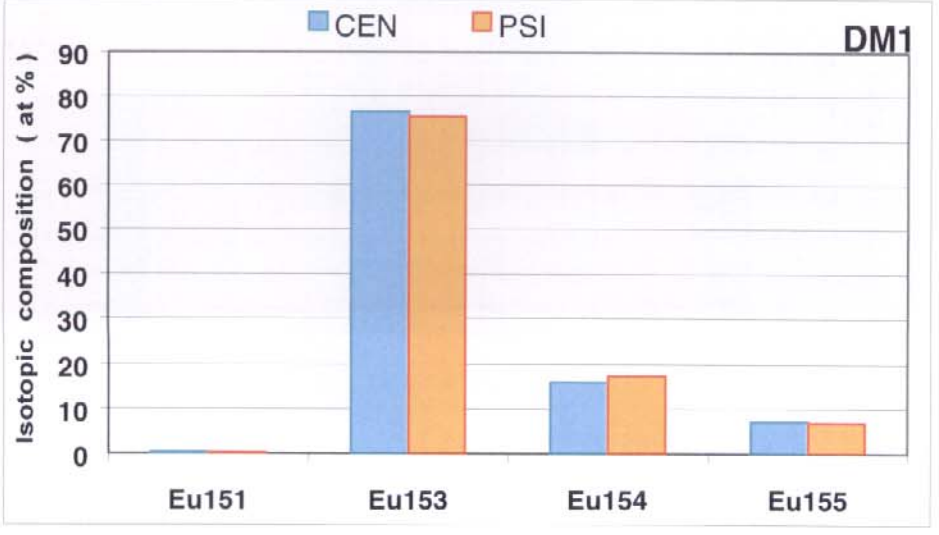
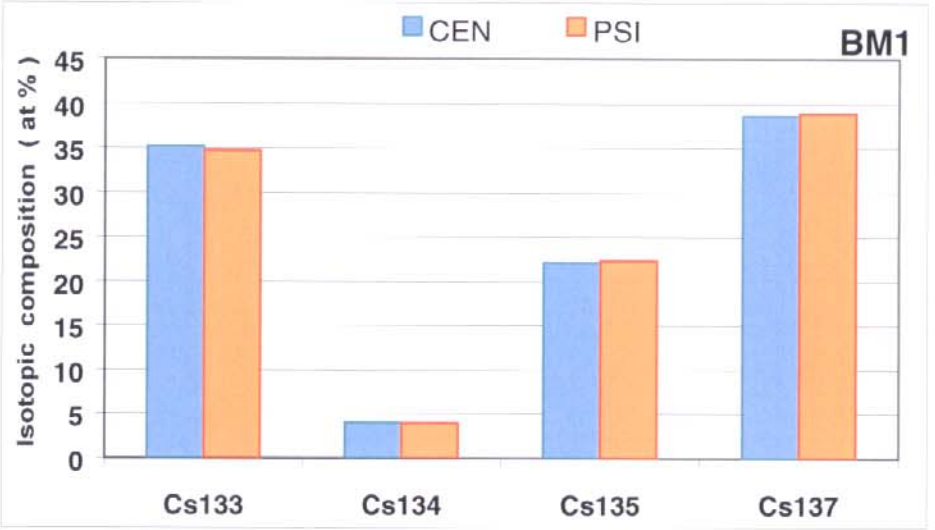
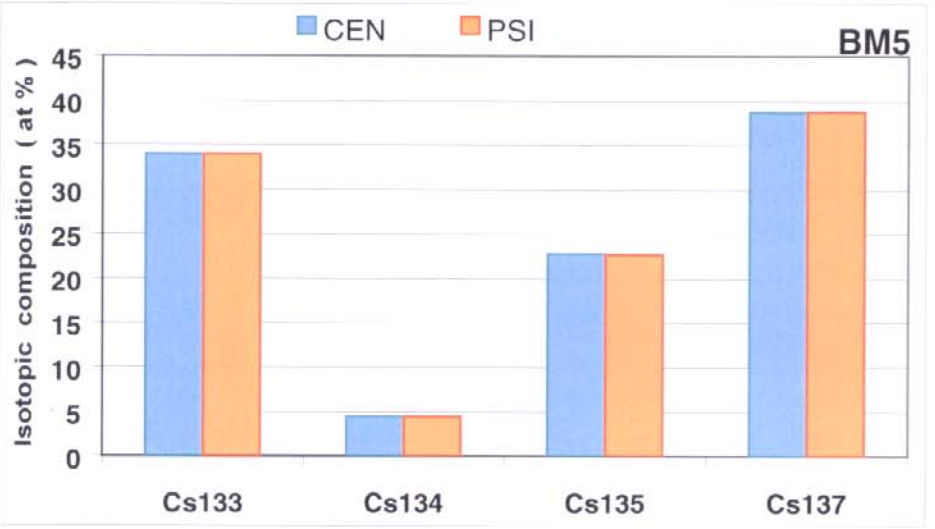


Figure 5.1 / 8 - Comparison of the Cs isotopic vectors MOX samples (at % at cross-check date)





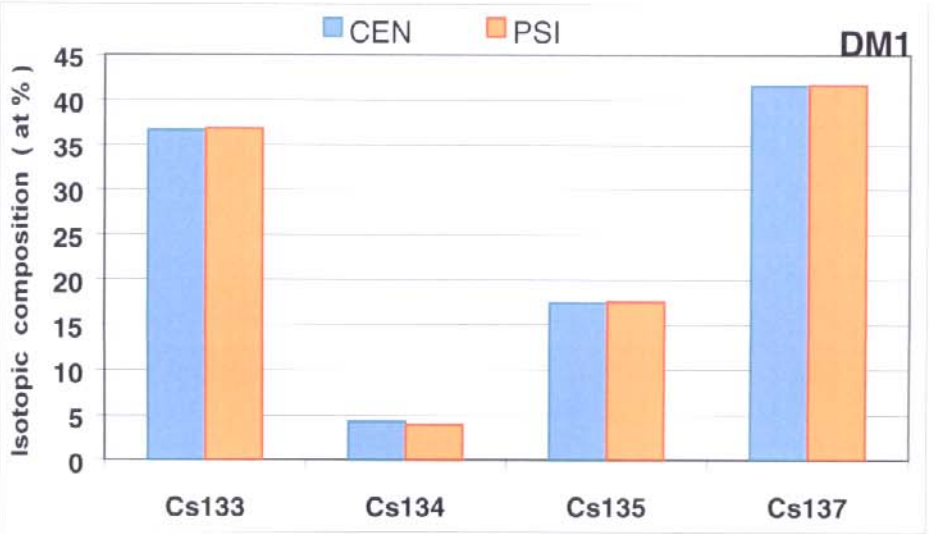
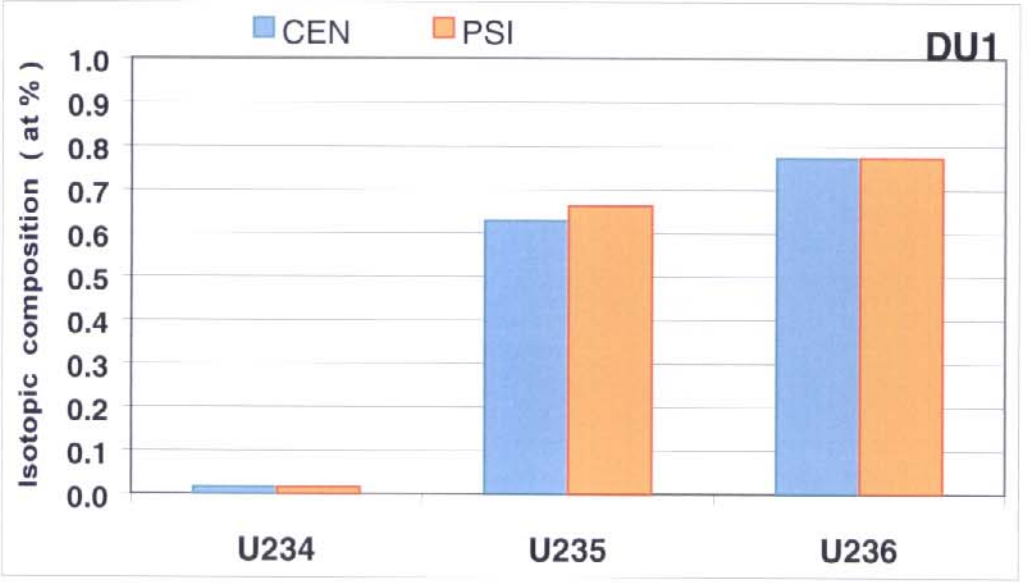


Figure 5.2 / 1 - Comparison of the U isotopic vectors UO_2 samples (at % at cross-check date)



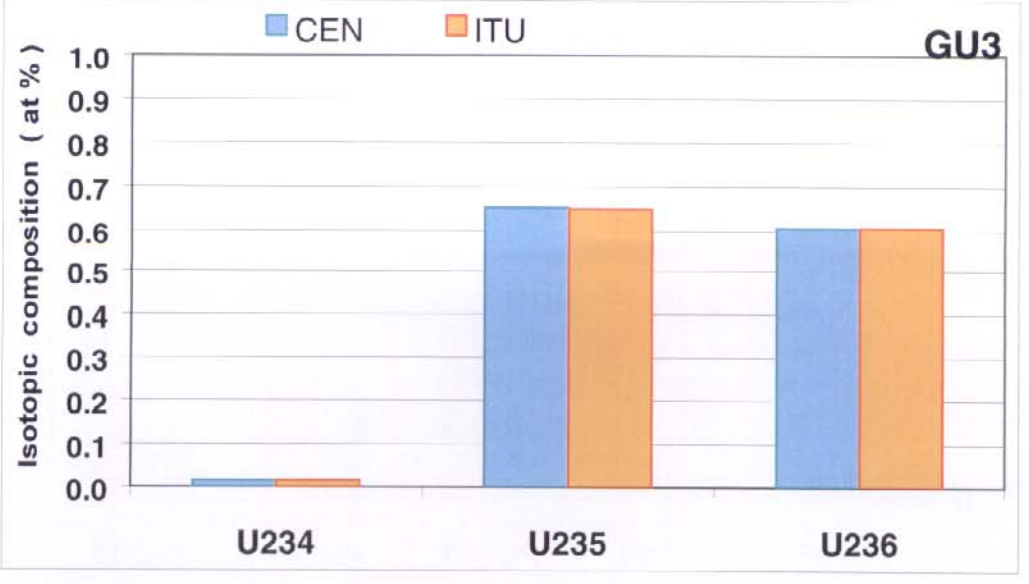
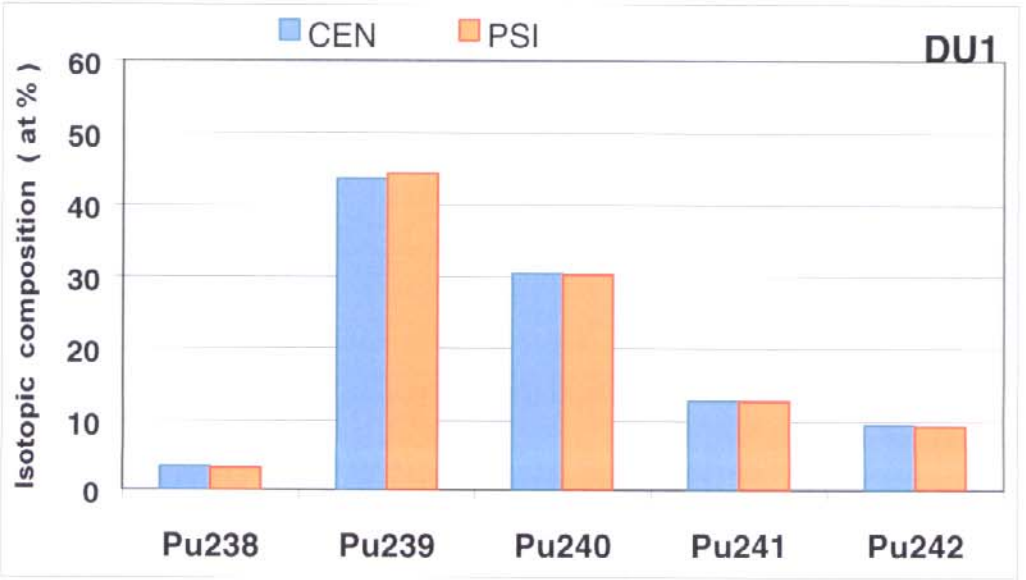


Figure 5.2 / 2 - Comparison of the Pu isotopic vectors UO_2 samples (at % at cross-check date)



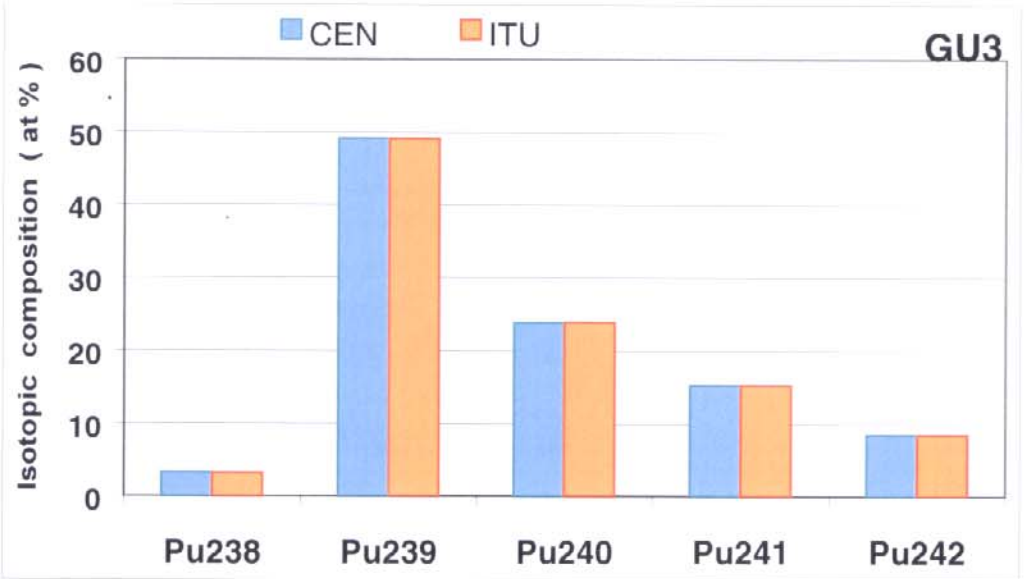
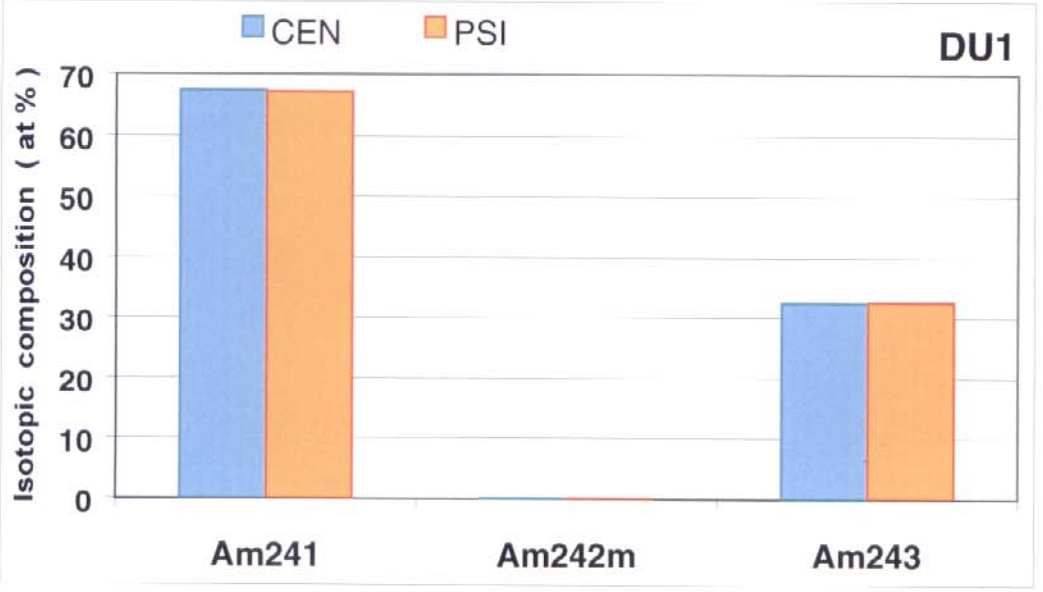
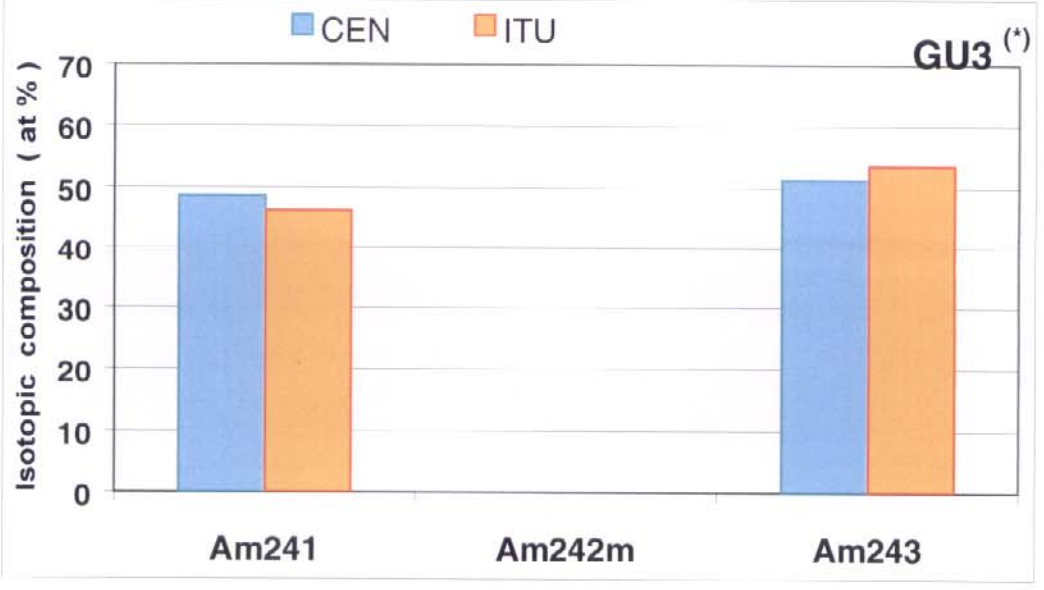


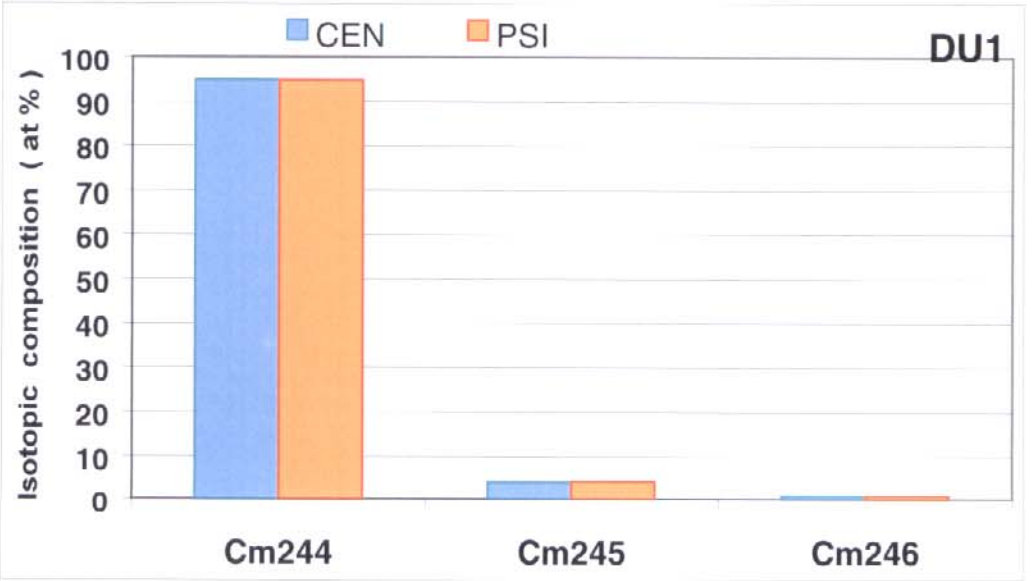
Figure 5.2 / 3 - Comparison of the Am isotopic vectors UO_2 samples (at % at cross-check date)

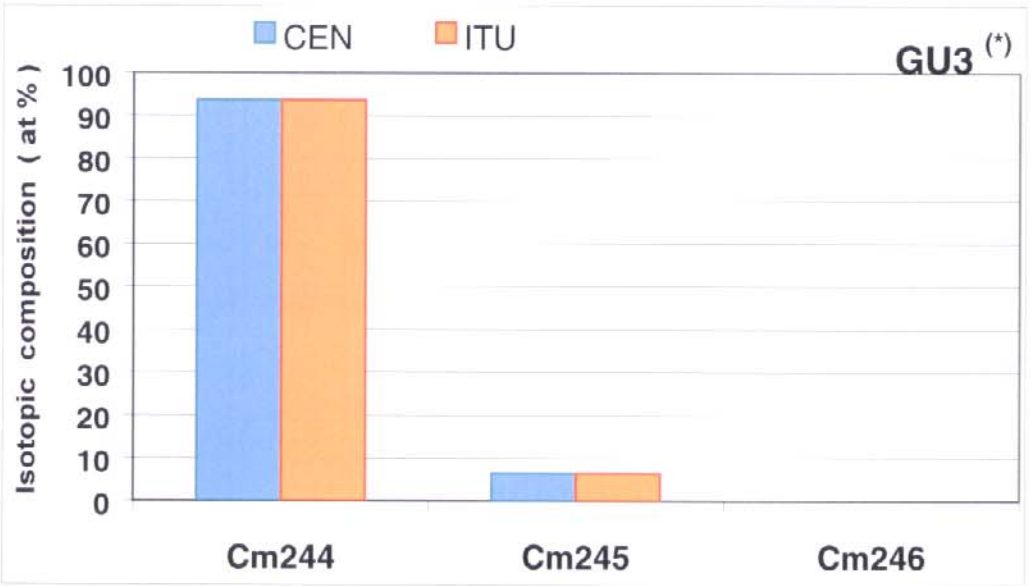




(*) no possible cross-check of Am242m for sample GU3

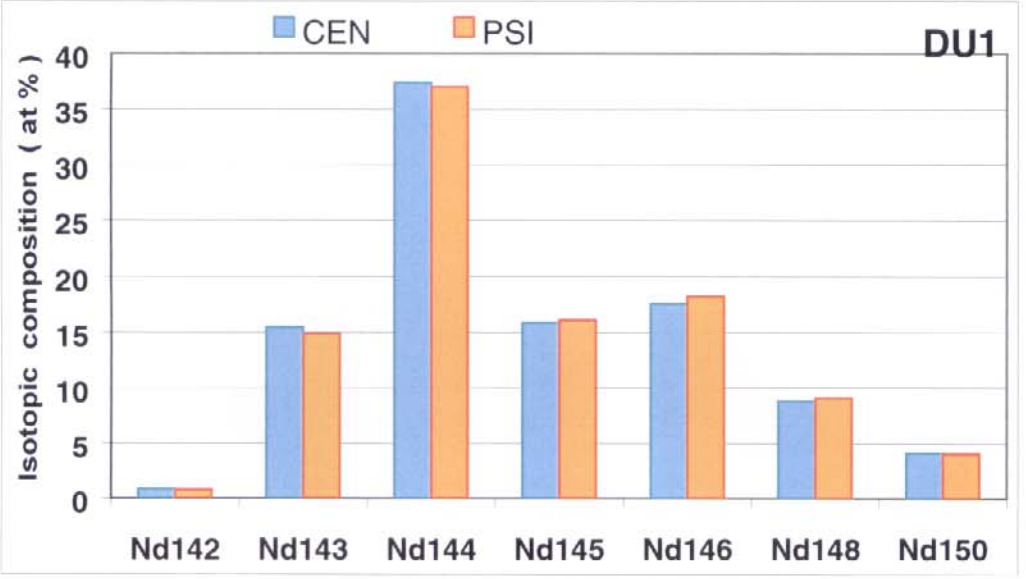
Figure 5.2 / 4 - Comparison of the Cm isotopic vectors UO_2 samples (at % at cross-check date)





(*) no possible cross-check of Cm246 for sample GU3

Figure 5.2 / 5 - Comparison of the Nd isotopic vectors UO_2 samples (at % at cross-check date)



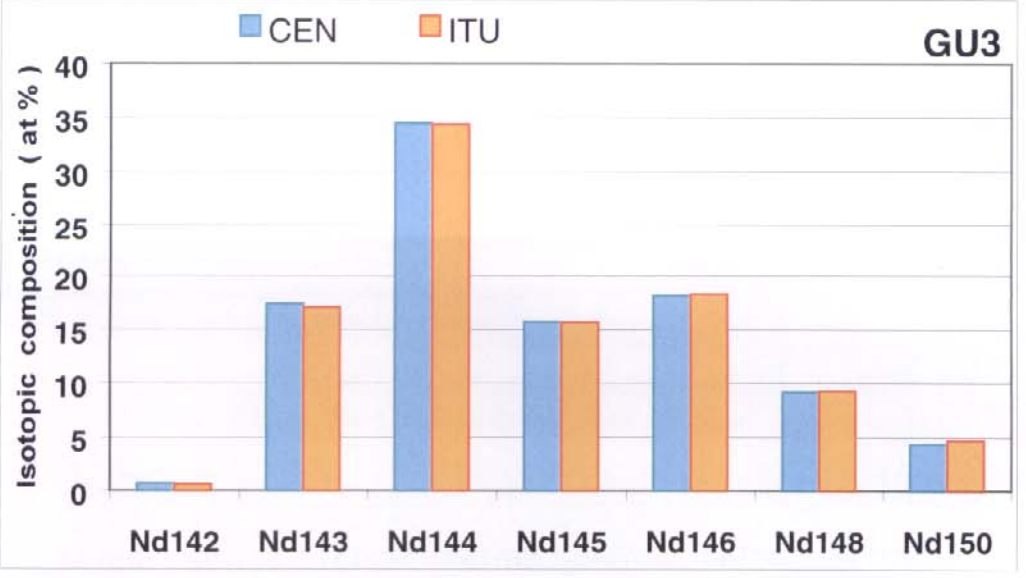
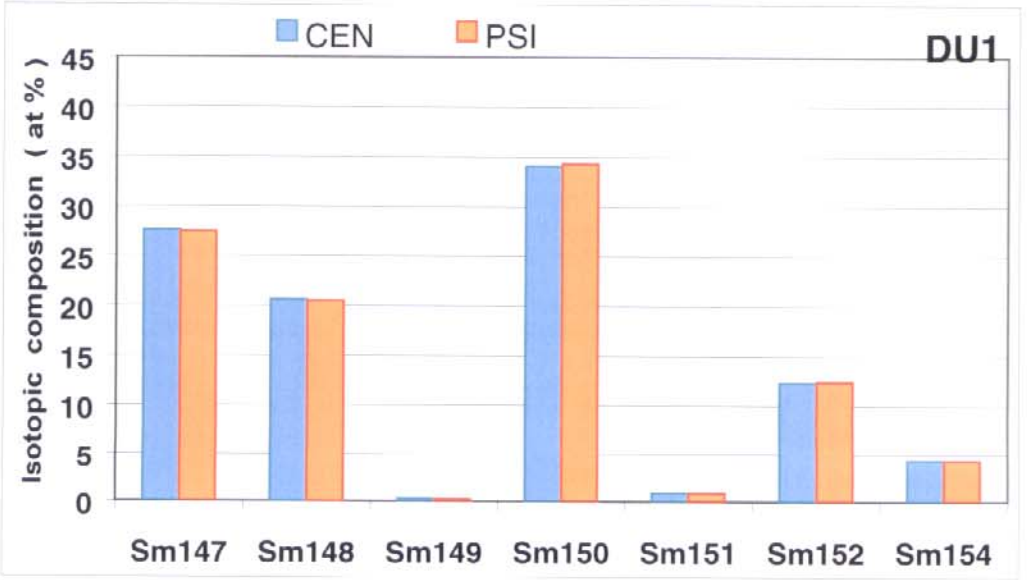


Figure 5.2 / 6 - Comparison of the Sm isotopic vectors UO_2 samples (at % at cross-check date)



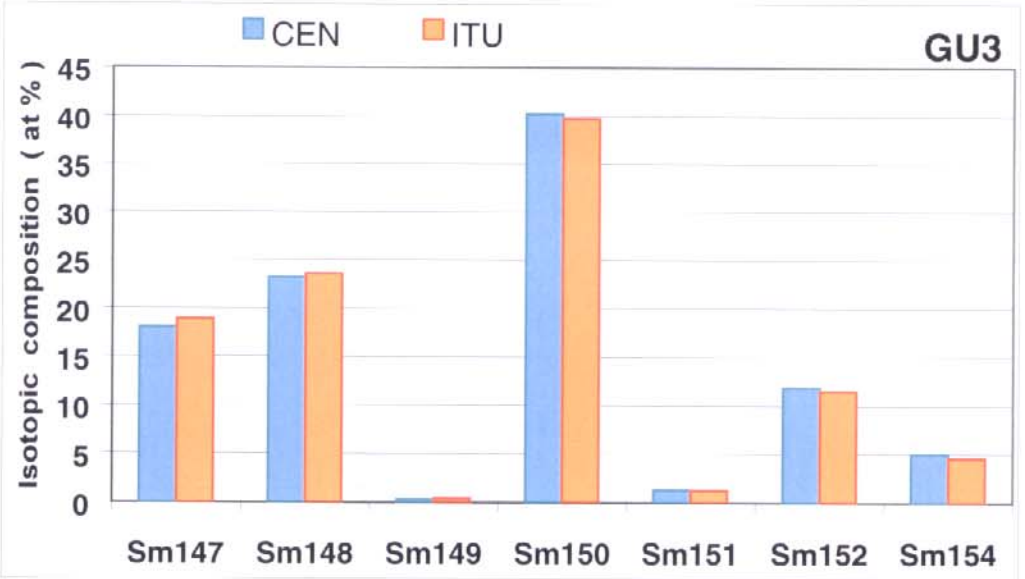
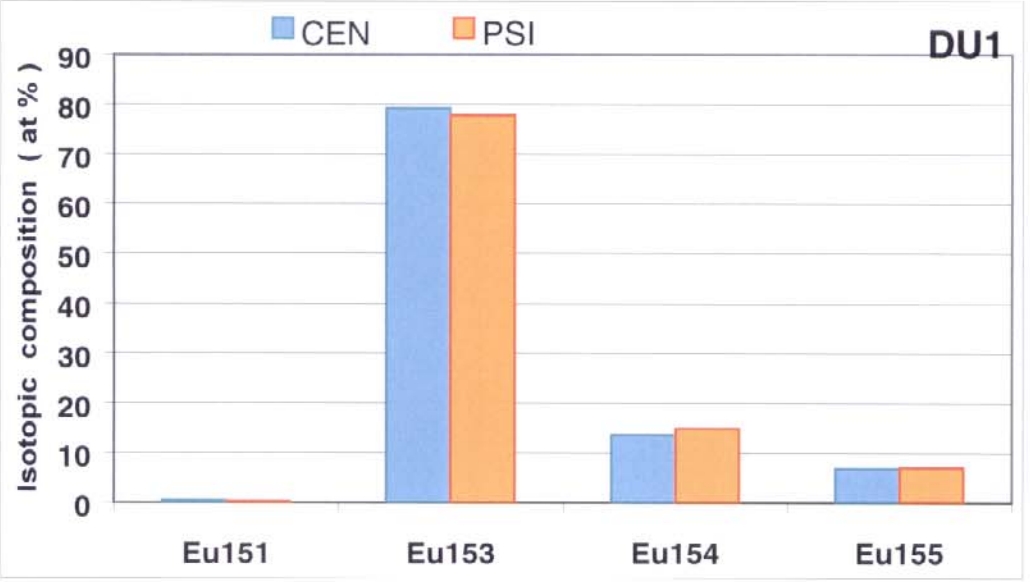
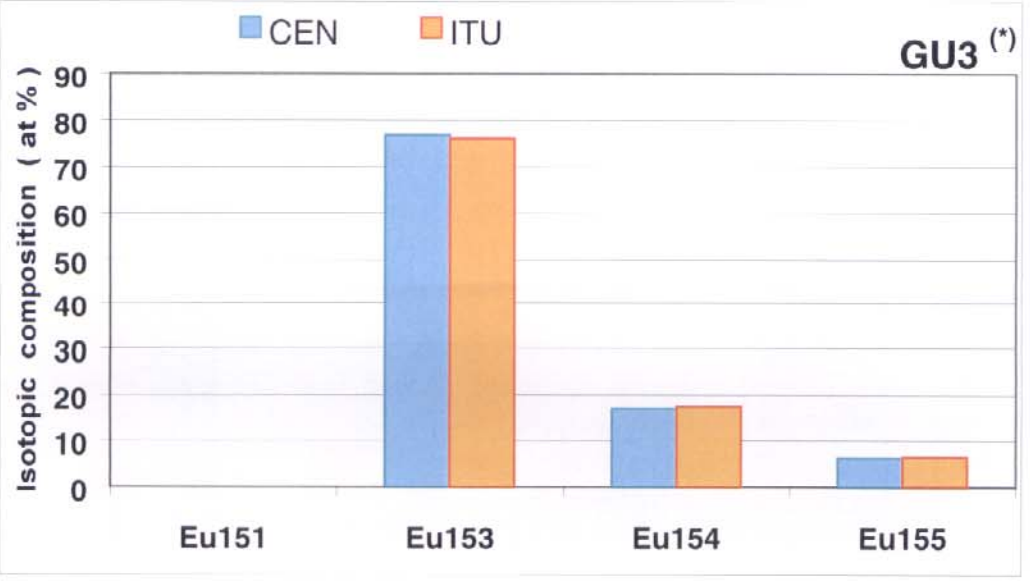


Figure 5.2 / 7 - Comparison of the Eu isotopic vectors UO_2 samples (at % at cross-check date)





(*) no possible cross-check of Eu151 for sample GU3

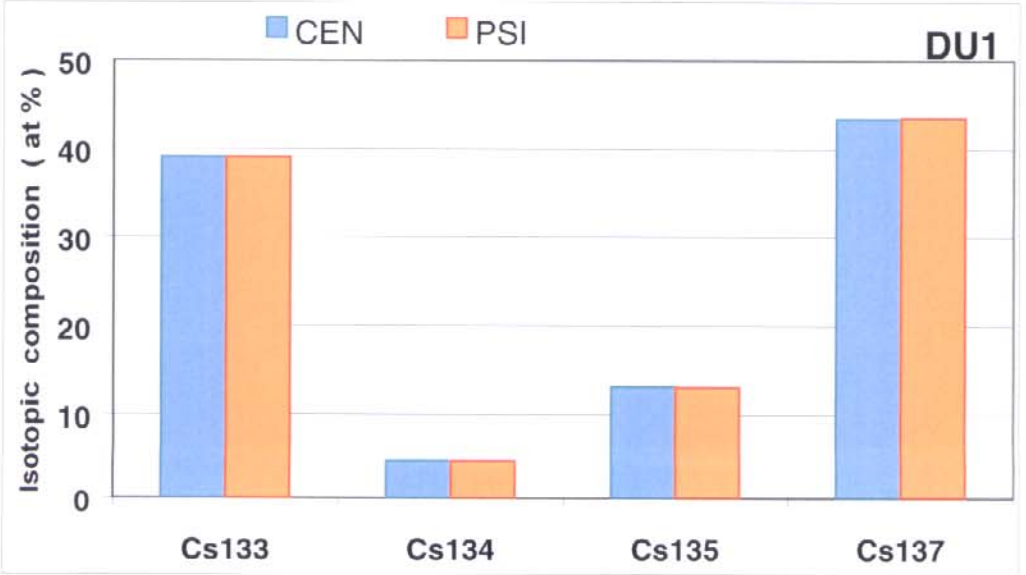
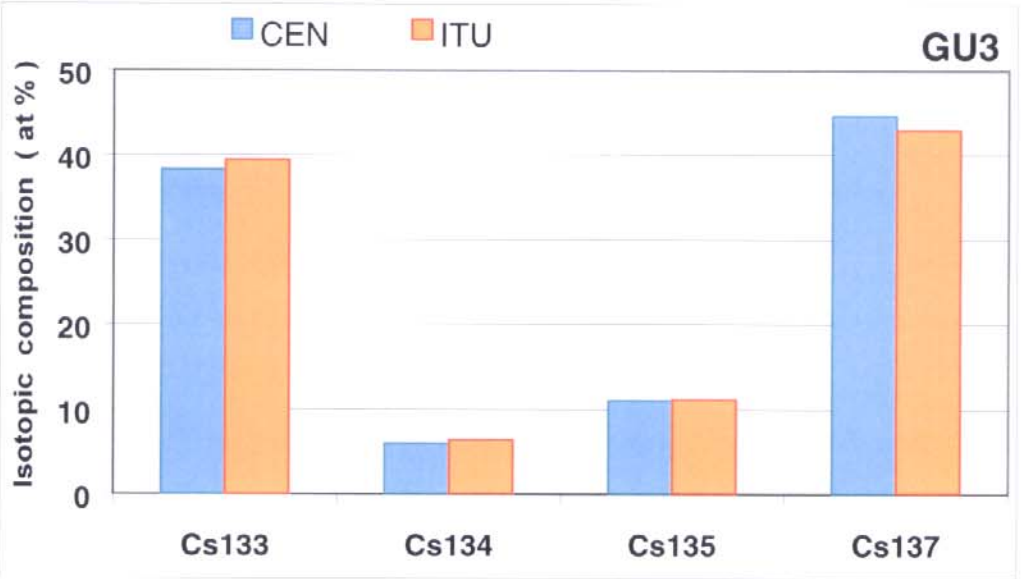



Figure 5.2 / 8 - Comparison of the Cs isotopic vectors UO_2 samples (at % at cross-check date)